GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY (SOUTH RIDING), IRELAND.

BY

Margaret M. Keegan B.Sc. (Hons)

MASTER OF SCIENCE

Institution:

Sligo Regional Technical College.

Supervisors:

Dr. Richard Thorn, Sligo RTC.

Mr. Eugene Daly, Geological Survey of Ireland.

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DECLARATION

I declare that this is entirely my own work except where otherwise stated. I agree to allow the Library to lend or copy this thesis on request.

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ABSTRACT

The aim of the project was to determine the extent and quality of the groundwater in Tipperary South Riding with a view to developing a groundwater protection plan which would allow the Local Authority to manage, protect and develop the groundwater as efficiently as possible.

The geology of the area varies with topography. The low-lying areas of the county comprise mainly Carboniferous limestones while the elevated regions consist of sandstones and shales of Upper Carboniferous, Devonian and Silurian ages. Deformation of these rocks decreases in magnitude moving northwards over the area; the Southern Synclines having suffered the effects of the Hercynian orogeny and the northern region exhibiting Caledonian orogenic trends. Quaternary (subsoil) deposits are found throughout the area and are of variable thickness and permeability. Till is the most widespread deposit with discontinuous pockets of sand and gravel in various proportions, and some marl, alluvium and peat in places.

The principal aquifers of the area are the Kiltorcan sandstone formation and various limestone units within the Carboniferous succession. 50 % of south Tipperary constitutes either regionally or locally important aquifers. Secondary permeabilities created by structural deformation, dolomitisation, karstification and weathering processes create high transmissivities and often have large well yields. Specific baseflow analysis highlighted the complexity of the aquifers and proved that the lower part of the Suir river system is a major groundwater resource region.

The hydrochemistry and water quality of the local authority groundwater sources was examined briefly. The majority of south Tipperary is underlain by limestone or Quaternary deposits derived from limestone and, consequently, calcium/magnesium bicarbonate waters predominate. The quality of the groundwater in south Tipperary demonstrates that the main concern originates from the presence of *E.coli*, and Total coliforms. The primary sources of contamination are from farmyard wastes and septic tanks.

The vulnerability of groundwater to diffuse and point sources of pollution has been found to be dependent on the overlying soil, subsoil and the thickness of the unsaturated zone. A conceptual rather than quantitative approach is used and it is found that approximately 60% of south Tipperary is designated as being extremely or highly vulnerable.

The groundwater protection plan was devised subsequent to an understanding of the aquifer systems, an assessment of the vulnerability, and a review of the Irish planning system and environmental law. It is recommended that the plan be integrated into the county development plan for legislative purposes. A series of acceptability matrices were devised to restrict potentially polluting activities in vulnerable areas while maintaining a balance between protection of the groundwater resource and the need to site essential developments.

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ABSTRACT

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CHAPTER 1 - INTRODUCTION

1.1 LOCATION

South Tipperary is situated in the southern Midlands of Ireland (Fig. 1.1). It encompasses an area of 2258 sq. km and is bisected by the River Suir. The central part of the county, comprising the valleys of the Suir and its tributaries, the rivers Multeen, Ara, Aherlow, Anner and Tar, has generally an elevation between 60 m and 122 m above sea level (asl). This central plateau is fringed by the Old Red Sandstone ranges of the Comeraghs and Knockmealdowns in the south, the Galtees in the west, Slieve Phelim and Slievenamon in the east, with the Westphalian Slieveardagh Hills in the northeast.

Over half the population of approximately 77,000 is located in the urban areas. South Tipperary has five administrative authorities, the largest one being Tipperary South Riding County Council and the others being Clonmel Corporation, Tipperary, Carrick-on-Suir and Cashel Urban District Councils.

Agriculture is the most important industry in this area, with more than 80 % of the area comprising farming land, the vast majority with a wide use range. The other 20% of the land area is mountainous and is predominantly devoted to forestry. The two most important enterprises are cattle production and dairying. Pig production has increased slightly and has become specialised in recent years. Large integrated pig units have developed. Less than one tenth of the area is devoted to tillage; barley and wheat are the most important crops.

1.2 PRINCIPAL CRITERIA FOR THE DEVELOPMENT OF THE GROUNDWATER PROTECTION PLAN

South Tipperary contains Silurian and Devonian shales and sandstones and Carboniferous limestones, sandstones and shales. The limestones are generally more productive aquifers in this area with the Kiltorcan Sandstone unit also yielding large amounts of water. The structure of the area plays an important role in the hydrogeology.

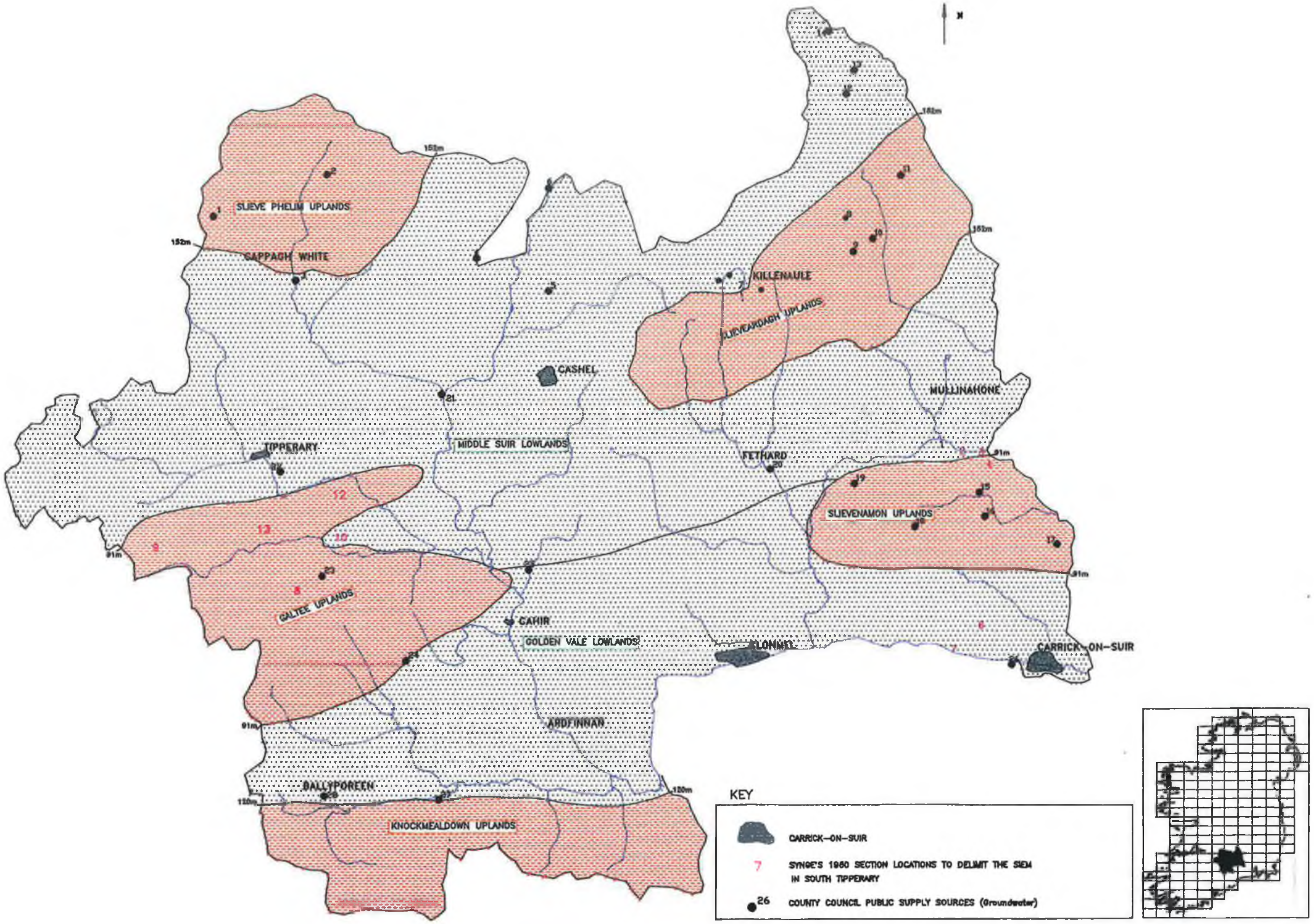


Fig. 1.1 Location Map of Tipperary (South Riding) with Physiographic Regions.

Groundwater has been used widely in south Tipperary over the last number of years. The numerous large springs and large baseflow in the rivers indicates that this is a major groundwater resource region which requires a high degree of protection.

Tipperary South Riding County Council commissioned this study to develop a Groundwater Protection Plan. This provides a reasonably objective method of ensuring that due account is taken of the 'groundwater interest' in planning decisions. Due to increased development in agriculture and industry over the last few years, the risk of groundwater pollution has escalated. The groundwater protection plan takes both interests into account. A review of other groundwater plans is dealt with in Chapter 7.

Demand for groundwater is continuing and is likely to be increasingly developed to augment existing river supplies as the urban population increases.

1.3 SCOPE AND OBJECTIVES OF THIS INVESTIGATION

1.3.1 Scope

This study outlines the geology, hydrogeology and the general groundwater quality of south Tipperary. This basic information is used to prepare interpretative maps which will facilitate planning and resource development in the form of a Groundwater Protection Plan and associated Code of Practice. The purpose of the plan is to provide a first stage screening for potential polluting activities. The effectiveness of the plan is reliant to a large degree on its integration into the present County Development Plan. The quality of the data are such that the plan can neither be pollutant nor site specific. However, it does reduce the number of areas to be studied in detail by identifying those with the greatest or least limitations. The idea of this "strategic planning" is welcome as it allows modification of the plan as further relevant information becomes available.

1.3.2 Objectives

The objectives of this study are:

a) An evaluation of the extent and status of the groundwater resource in the study area.

b) A review of the literature dealing with the establishment of groundwater management/protection plans.

c) Protection of the groundwater in south Tipperary (South Riding) by the formulation of a Groundwater Protection Plan and associated Code of Practice.

d) An examination of the legislation relating to groundwater protection in Ireland and in the light of this, establishment of the best way to fit the protection plan into existing statutory and regulatory land management plans, i.e., the County Development Plan.

e) Implications of the Groundwater Protection Plan for the County Development Plan.

f) A detailed examination of the vulnerability of a limited number of groundwater sources.

1.4 THE USE OF GROUNDWATER IN THE DEVELOPMENT OF WATER SUPPLIES

The majority of the regional water schemes in south Tipperary are from river intakes. This is due to the presence of mountains, situated at the periphery of the county, having high surface runoff. During high rainfall the colouring of the surface water becomes problematic. Groundwater supplies for water schemes are usually derived from large springs in the area, such as Mullenbawn (S 222 134), Springmount (S 201 139) and Kedrah (S 207 128).

There are some natural constraints to groundwater development in the south Tipperary area. The consolidated formations are very old and indurated as a consequence of several tectonic and metamorphic phases. The unconsolidated Quaternary deposits are complex and consist of numerous lithologies of various thickness (Daly, E.P., 1985). In both types of formations the transmissivity is likely to be variable. The complex geological history infers that the aquifers in this country are likely to be limited in extent (Daly, E.P., 1992).

1.5 LIKELY DEVELOPMENT IN THE FUTURE

Groundwater is a very suitable source of supply in south Tipperary. Groundwater, like the population, is well distributed throughout the area and can be developed in stages with low capital costs. Although groundwater quality is generally good there are numerous instances of local contamination of low yielding wells. The replacement of wells and groundwater protection will therefore be to the fore for the remainder of the 1990's. In the future, with the limited financial resources that are likely to be available, groundwater will frequently be an economically attractive unpolluted source of water for all but the very largest of schemes.

1.6 PHYSICAL CHARACTERISTICS

The county of Tipperary (South Riding) consists of an area of land lying towards the south east of the country with a maximum dimension east to west of 64 km and north to south of about 53 km. It is bisected by the River Suir which runs in a southerly direction from Holycross (S 209 154) in the north to Newcastle (S 212 114) in the south before turning northwards towards Clonmel (S 220 123) and then eastwards to Carrick-on-Suir (S 140 122).

There are seven physiographic regions and their principal features are summarised in Table 1.1. The five upland areas (Fig 1.1) are similar and are characterised by impermeable and rolling ground dissected by numerous small streams. Runoff is very rapid as the gradient of the mountains is very steep, so that river flows tend to be very 'flashy'. The land is predominantly poorly drained and has a limited use range.

The lowlands are part of the Golden Vale, which is a limestone plain. The Suir lowlands are partially underlain by a major aquifer. The lower Suir river and its tributaries provide the main source of drainage in the area. The soils are well drained, medium textured and have good moisture holding capacities. The water table is usually less than ten metres from the surface. The streams and rivers receive large amounts of baseflow. This is confirmed in that the Suir has one of the highest baseflows in the country. The surface drainage of the lower Suir basin (south Tipperary) is shown in Fig. 3.1 and is divided into sub-catchment basins.

1.7 SOILS AND LAND USE

The nature of the parent material is one of the principal factors in determining the differences in soil properties and hence, soil types. There is a wide range of bedrock and subsoils and hence, soil types in this area .

The lowlands are covered by well drained soils which are deep, medium textured and are good tillage soils. The parent materials are limestone tills, sand and gravels. The upland areas are usually characterised by poorly drained soils and therefore their uses are limited (Table 1.2). The most relevant soil property from a hydrogeological standpoint is the drainage character.

The level of vulnerability of aquifers to diffuse pollution is determined to a large extent by the attenuating capacity of the overlying soils. In south Tipperary the soils have not been mapped in any detail so the usefulness of the soil association data, in terms of vulnerability, is limited. However, it does give a general indication of the land use and thus the farming intensity and therefore the pollution load.

PHYSIOGRAPHIC REGIONS	GEOLOGICAL SUCCESSION	PRINCIPAL RIVERS	NORMAL GROUND ELEVATION (m O.D.)	PEAKS AND HIGHEST GROUND (m O.D.)	AQUIFERS PRESENT	LAND USE *
SLIEVE PHELIM UPLANDS	Quaternary Devonian Silurian	Multeen River	122 - 274 m	Knockastanna (447m) Knockalough (428m) Ring Hill (426m)	Cappaghwhite Sandstone - Major Old Red Sandstone - Minor	Mountain sheep grazing, Amenity, Forestry.
MIDDLE SUIR LOWLANDS	Quaternary Carboniferous	Suir River Multeen River	61 - 122 m	Kilough Hill (236m) Mount O'Meara (207m)	Ballyadams/Lismalin - Major Waulsortian - Major Crosspatrick - Minor	Tillage, Grassland.
SLIEVEARDAGH UPLANDS	Quaternary Carboniferous	Kings River Munster River Clashawley River	122 - 274 m	Renaghmore (344m) Boggan (335m)	Westphalian sandstone-Minor	Unsuitable for tillage, Limited Potential for grassland, Forestry.
SLIEVENAMON UPLANDS	Quaternary Devonian Silurian	Lingaun River Anner River	122 - 457 m	722m Carrickabrock (567m) Knockahunna (504m)	Kiltorcan Sandstone - Major Old Red Sandstone - Minor	Forestry, Sheep grazing.
GOLDEN VALE LOWLANDS	Quaternary Carboniferous Devonian	Suir River Aherlow River Tar River Anner River Moyle River	31 - 91 m	Bennets (183m)	Waulsortian/Silverspring - Major Rathronan/Ballyglasheen - Major Killee/Kilsheelan - Minor Croane - Minor	Tillage, Grassland.
KNOCKMEALDOWN UPLANDS	Quaternary Devonian	Duag River Tar River	122 - 396 m	Knockshanahulion (656m) Farbreaga (520m)	Kiltorcan Sandstone - Major Old Red Sandstone - Minor Knockmealdown/Ballytrasna - Minor	Forestry, Sheep grazing.
GALTEE UPLANDS	Quaternary Carboniferous Devonian Silurian	Aherlow River Behanagh River Attychraan River	122 - 640 m	Dawson's Table (920m) Greenane (803m) Sturraken (520m)	Kiltorcan Sandstone - Major Waulsortian Limestone - Major Old Red Sandstone - Minor	Thin soils, Forestry.

Table 1.1 Summary of Physiographic Regions in Tipperary South Riding.

(* Land Use information derived from Gardnier, M.J. and Radford, T., 1980)

PHYSIOGRAPHIC REGIONS	PRINCIPLE SOILS	ASSOCIATED SOILS	PRIMARY SOIL DESCRIPTION	SUITABILITY
SLIEVE PHELIM UPLANDS	Podzolised Gley 75% Gleys 60%	Peaty Gleys 25% Brown Earths 20% Peaty Gley 20%	Formed from glacial till of mixed sandstone, shale and limestone composition. Poorly drained of sandy loam texture.	Limited use range - poorly drained, this drainage problem seems to consist mainly of seepage associated with stratification of the underlying bedrock. They are best suited to grassland.
SUIR LOWLANDS	Minimal Grey Brown Podzolics 70% Minimal Grey Brown Podzolics 80%	Gleys 20% and Brown Earths 10% Gleys 10%, Brown Earths 5% and Basin Peat 5%	Carboniferous limestone till derived. They are deep, free draining, medium textured and have a good moisture holding capacity. The Brown Earths are found throughout the area on kames and knolls.	Wide use range - first class grassland soils, also good tillage soils and are suitable for cereals and root crops.
SLIEVEARDAGH UPLANDS	Acid Brown Earth 70% Gleys 60%	Gleys 15% and Peaty Gleys 15% Brown Earths 20% and Peaty Gleys 20%	Connected with the Upper Carboniferous sandstones and shales. Well drained but the associated soils are poorly drained and heavy textured.	Limited use range - due to their heavy texture, tillage or extensive grazing are difficult. The climatic factor is responsible for a restricted growing season.
SLIEVENAMON UPLANDS	Peaty Podzols 75% Brown Podzolics 80% Podzols 70%	Lithosols 15% , Blanket Peats 10% Gleys 15% and Podzols 5% Gleys 15% and Peaty Gleys 15%	Outcropping rock common, peaty layer overlying coarse textured, moderately well to poorly drained soil.	Limited soil use - due to the high elevation, inaccessability, peaty surface and low nutrient status. Confined to sheep grazing, amenity and forestry.
GOLDEN VALE LOWLANDS	Same as the Suir Lowlands above.	As for the Suir lowlands above.	As for the Suir lowlands above.	As for the Suir Lowlands above.
KNOCKMEALDOWN UPLANDS	Gleys 75% Peaty Podzols 75% Lithosols & Outcropping Rock 70%	Peaty Gleys 25% Lithosols 15% & Blanket Peat 10% Blanket Peat 25% and Peaty Podzols 5%	Formed from glacial till and sandstone outcrop. The predominant soil is poorly drained.	Limited use range - because of the poor drainage. It is best used for grassland.
GALTEE UPLANDS	Peaty Podzols 75% High Level Blanket Peats	Lithosols 15%, Blanket Peats 10%	Coarse textured, outcropping rock, moderately to imperfectly drained.	Limited use range - not suitable for tillage or intensive grassland, but are confined mainly to mountain sheep grazing, amenity and some forestry.

Table 1.2 Summary of Soil Types and their Uses.

(Derived from Gardiner, M.J. and Radford, T. (1980))

CHAPTER 2 - GEOLOGICAL SETTING

2.1 INTRODUCTION

The geology of south Tipperary is varied and complex. The geological sequence extends from the Silurian to the Carboniferous with later deposits from the Tertiary at Ballymacadam and the subsoil cover of the Quaternary. The uplands are underlain by Lower Palaeozoic, Devonian and Upper Carboniferous strata while the lowlands are underlain by Carboniferous limestone and a cover of Quaternary. Greater attention has been placed on the aquifer formations than on the rest of the succession as the strata type is significant in the understanding of the hydrogeology. The subsoil information is sparse so an interpretative map has been prepared using all available information. These deposits are a very important part of a groundwater protection plan and therefore are described with the vulnerability aspect in mind.

The geological structure varies across the area; an arbitrary divide has been used to assist in the understanding of the hydrogeology, by dividing the bedrock geology map into two regions. The southern part of the county (Southern Synclines) has been affected by the Hercynian orogeny. It was subjected to intense folding of an east-west trend and faulting with a north-south trend. The magnitude of the deformation decreases gradually northwards. In the northern region the structural trend changes from Hercynian (east-west) to Caledonian (northeast-southwest) and is less intense.

The geology is shown on two maps, bedrock (Map 2) and the other being subsoils (Map 3).

2.1.1 Source and Quality of Geological Information

The Geological Survey of Ireland (GSI) is the main source of information for the geology maps. The sources for the two maps are dealt with below;

i) Bedrock

The bedrock geology map is derived from the following sources:

Geology PhD theses (Carruthers 1985, Shearley 1988, Keeley 1980, Doran 1971 and Colthurst, 1977) were obtained from TCD for the researching of this section of the project. The following areas in the southern part of the study area, Galtee mountains, around Mitchelstown (R 181 113) and Carrick-on-Suir (S 140 122) and an area to the north around Hollyford (R 154 192) and the area of Slievenamon, were mapped at a 1:25,000 scale which allowed detailed maps to be produced by the respective authors. The information derived from these PhD theses was transferred to AutoCAD and used in the production of smaller scaled maps of the county.

A facies map of the midlands of Ireland was made available from Chevron Mineral Corporation of Ireland (Hitzman, M. 1993). This is a detailed map but it does not include separate geological formations. The facies map links together formations with the same depositional environments.

The GSI holds the relevant information on the geology of the area. This includes a complete series of 1:10,560 geological maps, compiled in the early 19^{th} century and covering the whole country. The information on these sheets deals with the description of rock outcropping at the surface and some subsoil information. In some cases geological formation divisions are crude but the outcrop descriptions assist in the continuation of the more recently derived geological boundaries.

A Limerick Basin geology map has been published by the GSI (Stanley, G., 1988) and this covers the mid-western region of the study area. The geology of the Nore Basin was provided by E P Daly, GSI.

The Mineral Resources Division (MRD) of the GSI allowed access to Open File Reports of prospect licence areas submitted by exploration companies. This information is often restricted to very small areas and only a brief geological description is given in the reports, but these reports are necessary to correlate the more detailed maps across the county. They also contain borehole data which provides depth to bedrock information for the production of this map (Map 7).

The quality of the bedrock data varies. The old GSI maps and the MRD reports contain generalised geological information whereas the PhD theses and the other geological reports include detailed maps which divide the different lithologies into formations. The Chevron map, although it is a facies map, is still very useful as it combines lithologies that behave hydrogeologically in a similar manner.

ii) Subsoil

The Quaternary geological information for south Tipperary is poor. All available relevant data have been taken into account. There are different levels of confidence in the information available depending on the source.

The 1840's GSI 1:10,560 series of maps provides most of the information. The geologists at this time were mainly interested in bedrock outcrop and so subsoils were mentioned in passing only. Simple descriptive terms such as drift (limestone and sandstone), limestone gravel, peat (bog), marl, alluvium were used.

Information from the gas pipeline which runs through the southern half of the county has been digitised from the 1:25,000 sheets. The confidence in this information is quite high as it is based on trenches dug in the mid 1980's.

Well and mineral exploration borehole data are also included when information on the subsoil has been recorded. There are not many records with this type of information recorded. Vertical sections from boreholes have been logged (some examples in Appendix A.1).

The "no drift" areas are areas with less than one metre (<1m) of subsoil and are taken from the 1:63,360 GSI geology sheets. These are represented as white on the map (Map 3).

Some field mapping was undertaken at five sites. These sources have been taken as being representative of the different environmental settings in south Tipperary. The fieldwork was carried out at a 1:10,560 scale. Present day field cuttings, river sections and gravel pits were mapped.

2.1.2 Methodology

The geological and geomorphological information from all the above sources was transferred by hand to 1:25,000 overlays. Twenty three of these sheets were needed to cover the study area.

The bedrock geology map was produced in consultation with A. Sleeman (Bedrock Section) GSI which allowed the correct nomenclature to be adopted for the final sheets. Each of the final sheets was then analyzed to ensure consistency across the sheet boundaries. In certain cases the source of information changed across these boundaries and therefore consultational editing was required.

The subsoil map was derived from all the information described above. The positions of the descriptive terms used have been transferred to 1:25,000 sheets and then digitised using a coloured letter code to show the distribution of the deposits. This process has also been used to record the information from the gas pipeline investigations (Dublin-Cork and Cork-Waterford). Some limits for the peat, marl and alluvium areas have been outlined by the early workers. Interpretation of the type and spatial location of the deposits was then undertaken and the resultant map is therefore not intended to be site specific.

When the final bedrock geology, subsoil and 1:25,000 overlay sheets (23 each case) were completed, the digitising process commenced. AutoCAD versions 9 to 12 were used in the digitising process. Producing secondary maps, which are derived from two or more primary maps, is made uncomplicated with this package.

2.2 GEOLOGICAL HISTORY

The Devonian and Carboniferous of the Upper Palaeozoic differ considerably from the Lower Palaeozoic sediments. There was considerable erosion between the two eras. Much of the Old Red Sandstone (ORS) was deposited under terrestrial desert conditions and outcrops as rims around much of the Lower Palaeozoic in the hills and low mountains.

By contrast, the lower Carboniferous was deposited in a deepening sea which slowly expanded northwards across Ireland throughout most of the Carboniferous (Clayton and Higgs 1979). In early Courceyan times, there were limestones and shales in the south, shelf limestones in the northern part of the county. By late

Courceyan times, sedimentation had changed to a wide region of Waulsortian reef mudbanks, with some limestones and shales in the north. During the Chadian, Waulsortian mudbank limestones continued to accumulate to the south and west of the study area. Further to the north there were wide areas of calcareous mudstones and cherty, argillaceous, dark biomicrites which pass into cleaner limestone at the basin margins. Somewhat similar depositional conditions continued during the Arundian, Holkerian and Asbian stages; there were regions with lime mudmounds in the Arundian, rivalling the earlier Waulsortian reefs. In the Brigantian and up into the Namurian, thin skeletal limestone sequences were deposited over the shelf area and in some places overlain by cherty limestones.

The Namurian covers less than one third of the county and Westphalian rocks have very limited outcrop in the Slieveardagh Coalfields. In Namurian times sands, silts and muds derived from northerly, westerly and south-westerly sources were deposited in subsiding troughs and basins, separated by structural highs which received much less sedimentation.

A few Tertiary deposits have been found in the caves and sinkholes of the Carboniferous in the south of the county, which was subjected to karstification during the Tertiary. Much is still unknown regarding the Tertiary topography of Ireland (Mitchell 1980). The Quaternary geology of Ireland is complex and dominated by the formation and subsequent melting of successive ice-sheets. Maximum thicknesses seldom exceed 100m and thicknesses of 5-15m are normal. The topography was moulded by solid water and subsequently reformed by liquid water, both ice-melt and precipitation. This has resulted in a complex topography presenting many drainage problems. Only two glaciations are known with certainty in Ireland. The older, Munsterian, is only exposed in Munster. Elsewhere, it is covered or was eroded by the subsequent Midlandian glaciation, which covered much of Ireland excluding Munster.

2.3 LOWER PALAEOZOIC - SILURIAN

Rocks of Silurian age crop out in the core of the Slievenamon inlier, Slieve Phelim range and the Galtees mountains as seen in Fig. 1.1, and possibly constitute the basement throughout the whole area. A summary of the succession in the three areas is given in Table 2.1.

The Silurian rock types are generally similar throughout the three upland areas and are predominantly greywackes, siltstones, mudstones and shales. The lithology of the Hollyford formation bears some similarity to the upper part of the Ballygeana formation, where sediments are finer grained and interbanded siltstones and mudstones appear. Graptolites from the Ballygeana formation indicate the presence of lower to middle Wenlock zones. Areas not directly linked by palaeontological evidence include the South Lodge formation which bears some lithological similarities to the Inchacoomb formation and allowing for a swing in strike from east-west in the Galtees to northeast-southwest in Slievenamon, these beds may be laterally equivalent (Jackson, 1978).

2.4 OLD RED SANDSTONE

In the southern half of Ireland the upper Old Red Sandstone is extensively developed. In south Tipperary it crops out around the three Lower Palaeozoic inliers; Slieve Phelim, Galtees, Slievenamon and the Knockmealdowns. The lithological descriptions of the strata are given in Table 2.2. The Devonian sediments are shallow water deposits (fluvio-lacustrine processes) and the so called " Munster Basin " into which they were deposited continued to subside as the material was being laid down. The Devonian succession thins rapidly to the north of the Munster Basin (Capewell, 1957). As can be seen in Table 2.2 the Devonian successions given for the Galtees by Carruthers (1985) and the Knockmealdowns are obviously much thicker than the successions at Slievenamon and Slieve Phelim, which are not part of the area defined as the Munster Basin. There is evidence to suggest that part of the succession in the Munster Basin is of late Middle to early Upper Devonian in age (Clayton and Graham,

		SLIEVE PHELIM UPLANDS (from Doran, 1971)	GALTEE UPLANDS (from Jackson, 1978)	SLIEVENAMON UPLANDS (from Colthurst, 1977)
SILURIAN	PRIDOLI	------ DEVONIAN - SILURIAN UNCONFORMITY ------		
	LUDLOW			
	WENLOCK Upper	HOLLYFORD Fm., >1000m Repetitive sequence of greywackes, siltstones and mudstones, referrable to the *C lundgreni* Zone of upper Wenlock.		
	WENLOCK Middle		BALLYGEANA Fm., 1275m Sequences of greywackes, presence of thick inter-bedded dark grey to black shales which are graptolitic in part. Grey argillaceous beds also occur. INCHACOOMB Fm., 1600m Upper part consisting predominantly of fine grained grey sediments. Lower part is predominantly inverted, greenish grey greywackes.	
	WENLOCK Lower			SOUTH LODGE Fm., +3000m Characterised by greenish greywackes and slates, most of the greywackes have a calcareous matrix. RATHCLARISH Fm., 340m Well developed grey turbidites. The base is usually a greywacke which is graded and passes up into sandy siltstone, siltstone and mudstone. AHENNY Fm., +1075m Grey banded slates and hard blue black slates. Characterised by the development of conglomerate horizons. The sediments have been intruded by lamprophyre sills and later by quartz porphyrys.
	LLANDOVERY			CARRICKTRISS Fm., 800m Consists of rocks of volcano-clastic origin; feldspathic crystal tuffs, fine grained green tuffs and green breccias. Sediments include siliceous convoluted siltstones and soft black slates.

Table 2.1 Silurian Nomenclature and Approximate Correlations.

		GALTEE UPLANDS Carruthers, 1985 (Munster Basin)	SLIEVENAMON UPLANDS Colthurst, 1977 (northern edge of Munster Basin)	KNOCKMEALDOWN GSI	SLIEVE PHELIM Doran, 1971 (north of Munster Basin)
D E V O N I A N	Upper	KILTORCAN Fm., 300m Consists of five main lithologies; intraformational conglomerates, coarse grained white to yellow sandstones, medium to fine grained red to yellow sandstones and red and green mudrocks.	KILTORCAN Fm., 270m It has been suggested that the formation in this area is, at least in part, Tournaisian. An idealised cycle from the Kiltorcan formation begins with intraformational conglomerate overlain by coarse yellow sandstone. This is overlain by flaggy yellow or purple sandstone followed by laminated silty mudstone and massive mudstone. The coarse grained sandstones are cross-stratified.	KILTORCAN Fm., Coarse white-yellow sandstones, mud-flake conglomerates, finer flaggy micaceous red-yellow sandstones, yellow to green silty mudstones and massive red sandstones.	CAPPAGH WHITE Fm., 300m The basal beds are usually coarse conglomerates rich in locally derived Silurian clasts. Sandstones are dominant. Black mudstones only occur near the base of the Gortdrum Fm. Detailed mapping indicates that the lithologies are repetitive.
		ARDANE Fm., 70m The base is defined by the incoming of coarse-grained sandstones and resistate pebble conglomerates. The conglomerates consist of thick-bedded units composed of a pebble to cobble-grade framework.		KNOCKMEALDOWN Fm., Fine to coarse grained pink to purply-red sandstones, often cross bedded, with intraformational siltstone conglomerates at the base of the individual sandstones. The lowermost beds are thick siltstones passing up into pebbly sandstones.	
		BALLYDAVID SANDSTONE Fm., 470m Consists of fine to medium-grained red sandstones with minor amounts of mudrocks and only rare thin resistate-conglomerate units. The grain size of the sandstones varies from fine to coarse, but medium-grained and fine-grained sandstones are by far the most common.	CARRIGMACLEA Fm., 460m The rock types present are sub-divided into three groups on the basis of grain size; conglomerates, sandstones, and mudstones. The lowest section consists of locally derived breccias interbedded with red muds, overlying these are quartz cobble conglomerates, pebbly sandstones, flaggy sandstones and laminated silty mudstones, all of which are red in colour. The upper section is dominated by well-bedded purple sandstones, but these contain beds up to 4m thick.		
	Middle	SLIEVENAMUCK Fm., 600m The base is marked by the incoming of laterally persistant resistate-conglomerates and purple coarse-grained conglomeratic sandstones. Higher in the section there is a gradual decrease in the mudrock component.		BALLYTRASNA Fm., Thick bedded 1-2 m units of purple to purply-red siltstones. Rare coarse grained sandstones occur (10-30mm) and there are some thicker coarse grained sandstones commonly greenish in colour.	
		SLIEVEREAGH Fm., 125m The section is dominated by thick-bedded purple, framework supported, lithic-conglomerates. Clast size varies from small pebbles up to small boulders.			
		LOUGH MUSKRY Fm., 328m A succession of inter-bedded purple-red siltstones with sandstones and some lithic conglomerates. It is often characterised by the presence of thick (up to 2m) purple mudrocks.			
	Lower	GALTYMORE SANDSTONE Fm., 200m Consists of predominantly thick-bedded fine to medium-grade pale red sandstones.			
		PIGEON ROCK Fm., 160m It is composed of poorly bedded, pebble to boulder grade conglomerates and breccias in beds 0.5 to 5m thick. Sandstone units occur sporadically throughout the formation but are limited to thin discontinous wedges.			

Table 2.2 Devonian Nomenclature and Approximate Correlations.

1975). Hence, some of the rocks in the Munster Basin are not represented farther north and the oldest Old Red Sandstone facies rocks represented get progressively younger northwards.

The Old Red Sandstones have been folded by the Hercynian orogeny. These sandstones are exposed at the surface when they cover entire anticlines (Galtees) and the flanks of these structures (Slievenamon) where the core of Lower Palaeozoic rocks is exposed. In the southern synclines, the Devonian sediments are overlain by thick (1,000-2,000m) Carboniferous sediments. The Cappagh White formation is taken to be equivalent to the upper 200-300m of the Old Red Sandstone, ie. Kiltorcan formation of the Slievenamuck and Galtees mountains. The marine transgression which terminated the ORS facies sedimentation moved across the area from south to north.

2.5 CARBONIFEROUS SYSTEM

2.5.1 Introduction

The Carboniferous in south Tipperary comprises two units; a lower unit, the Dinantian, and an upper unit, the Namurian and Westphalian. The Dinantian underlies the lowlands whereas the Upper Carboniferous is evident in the upland area of the Slieveardagh Hills and in localised areas of high relief. The regional divide into the Northern Region and the Southern Synclines takes into account the hydrogeological differences in the Carboniferous limestones. The Dinantian is important in terms of aquifers and so is described in detail whereas the Upper Carboniferous is not as significant.

2.5.2 Dinantian

The Dinantian consists of various types of limestones, dolomites and shales found in a number of different structural and topographic settings. The aquifers in these strata are the most extensive and productive in the region. The Dinantian comprises the most important strata hydrogeologically.

In the northern region, thick Upper Dinantian Limestones (Visean) and dolomitised limestones are considered to be aquifers. Dolomitisation is a process by which the dolomite mineral ($CaMg(CO_3)$) replaces the calcite and aragonite minerals ($CaCO_3$) which form naturally in a marine environment. The dolomitised limestones dip 5-15 degrees under the Namurian and Westphalian (upper Carboniferous) strata of the Slieveardagh Hills. The middle of the Dinantian succession in the northern area is characterised by extensive dolomitisation.

The limestones in the region defined as the southern synclines are extensively faulted and folded. The Dinantian succession according to Wright (1979) may be treated for the most part as being one aquifer as the lithology appears to be of a lesser importance than the faulting.

A significant difficulty in compiling the available material on the Dinantian strata in this region arose from the different nomenclatures used by the various workers who have mapped (different) parts of the area. A summary of the lateral equivalency of these formations is given in Table 2.3 (an explanatory note can be found in Appendix A.2). At this date there is no agreed system of nomenclature so two systems have been adopted by this author for each geological setting (Table 2.4).

The structural and stratigraphic differences between the northern region and the southern synclines provides a good basis for the partition. The southern synclines region has been affected by more intensive faulting and folding than the northern region. The succession is thicker in the south and gets progressively shallower northwards. The Waulsortian mudbanks begin to 'die out' northwards as the strata become thinner. There is also a stratigraphic change from east to west in the southern synclines.

The lithological descriptions of the Dinantian limestones in the northern and southern syncline regions are summarised in Table 2.4. The Courceyan succession is almost identical in both regions, whereas the rest of the succession has been divided in two because secondary features have been superimposed on the lithology.

NAMURIAN	Keeley (1980)	Daly (1986)	Sleeman (1990 pers. comm.)	Jones (1977)	Carruthers (1985)	Chevron (1993)	Doran (1970)	Shearley (1988)
	Giantsgrave Fm.	**Namurian**			**Shrough Fm.**	**Coal Measures W**		
BRIGANTIAN		**Cullahill Fm.**	**Clogrennan Fm.**	**Lismalin Fm.**	**Farranacliffe Fm.** **Lackanetedane Fm.**	**SHU** / **Namurian N** **CPU**		**Carrigataha Fm.**
ASBIAN	**Croane Fm.** **Rathronan Fm.** **Ballyglasheen Fm.**		**Ballyadams Fm.**	**Ballykeefe Fm.**	**Hore Abbey Fm.** **Lagganstown Fm.**			**Killee Fm.** **Killavenoge Fm.**
HOLKERIAN	**Kilsheelan Fm.**							**Garrane Fm.**
ARUNDIAN		**Calp Fm.**	**Agmacart Fm.**	**Cloneen Fm.**	**Suir Fm.**	**SHL** / **CPL**		
CHADIAN	**Silverspring Fm.**	**Crosspatrick Fm.**	**Crosspatrick Fm.**	**Poulacapple Dolomite**	**Athassel Fm.** **Knockordan Fm.** **Waulsortian Fm.**	**AW**	**Kilfeacle Fm.**	**JRM/Mag.. Fm.**
COURCEYAN	**Waulsortian Fm.** **Hook Head Fm.** **Porter's Gate Fm.**	**Waulsortian Fm.** **Sub Reef Lmstn. Fm. (Lisduff oolite)** **Porter's Gate Fm.**	***dolomitised* Waulsortian Fm. *undolomitised*** **Ballysteen Fm. Lisduff member** **Ballymartin Fm.** **Ringmoylan Fm.** **Mellon House Fm.**	**Waulsortian Fm.** **Upper Ballysteen Fm. Middle Ballysteen Fm. Lower Ballysteen Fm.** **Porter's Gate Fm.**	**Ballysteen Fm.** **Ballymartin Fm.** **Ringmoylan Fm.** **Mellon House Fm.**	**Waulsortian Fm.** **ABL**	**Solohodbeg Fm.** **Gortdrum Fm.**	**Waulsortian Fm.** **Ballysteen Fm.** **Ballyvergin Shale** **Ringmoylan Fm.** **Ballyderowen Fm.**
DEVONIAN	**Kiltorcan Fm.**	**Kiltorcan Fm.**	**Kiltorcan Fm.**	**Kiltorcan Fm.**	**Kiltorcan Fm.**	**Old Red Sandstone**	**Cappaghwhite Fm.**	**Kiltorcan Fm.**

Table 2.3 Previous Carboniferous Nomenclature and Approximate Correlations for the study area.

	NORTHERN REGION	SOUTHERN SYNCLINES
BRIGANTIAN	Lismalin Fm. (? m) Thin to meduim bedded argillaceous biomicrites with shales and cherts.	
ASBIAN	Ballyadams Fm. (*c.* 90 - 300 m) The formation comprises medium grey to dark grey thick bedded to massive crinoidal calcarentic wackestones and packstones. The limestones are periodically separated by clay way-boards.	Croane Fm. (*c.* 300m) Thin bedded dark micritic limestones, shales and cherts. Rathronan Fm. (*c.* 300m) Massive pale-grey clean micritic limestones and crinoidal wackestones limestones with thin-bedded cherts. Ballyglasheen Fm. (*c.* 300 m) Trough cross-bedded pale-grey winnowed oolitic grainstone limestones. Kilee Fm. (*c.* 100 m) Thinly -bedded algal rich cherty micritic limestones or wackestones.
HOLKERIAN		Kilsheelan Fm. (*c.* 600 m) Clean to slightly argillaceous wackestone, packstone and grainstone limestones with occassional chert nodules.
ARUNDIAN	Aghmacart Fm. (*c.* 140 m) Comprises fossiliferous calcilutites and calcisiltites with some calcarenite, all characteristically dark grey.	
CHADIAN	Crosspatrick Fm. (*c.* 70 m) Pale grey, cherty bioclastic limestones which are dolomitised in places.	Silverspring Fm. (*c.* >10 m) Pale grey bedded cherts and dark grey siliceous biomicritic limestones.
COURCEYAN	Waulsortian Fm. (c. 170 - 200 m) Massive wackestones and packstone calcilutite limestones with spar and lime mud filled cavities. Bryozoan and crinoid rich. Ballysteen Fm. (*c.* 200 m) Dark-grey argillaceous and fossiliferous wackestone / packstone calcarenitic limestones. Ballymartin Fm. (*c.* 50 m) Dark-grey very argillaceous fossiliferous calcarenites and interbedded shales. Porter's Gate Fm. (*c.* 50 m) Grey flaser-bedded sandstones, calcareous or dolomitic sandstones, grey mudstones and interbedded thin limestones.	Waulsortian Fm. (*c.* 170 - 400 m) Massive wackestone and packstone calcilutite limestones with spar and lime mud filled cavities. Bryozoan and crinoid rich. Ballysteen Fm (*c.* 500 m) Dark-grey argillaceous and fossiliferous wackestone / packstone calcarenitic limestones Ringmoylan Fm. (*c.* 10 m) Interbedded thin fossiliferous limestones and dark grey to black thick calcareous mudrocks.

Table 2.4 Dinantian Nomenclature of Strata used in this thesis, approximate relationships and geological descriptions.

2.5.2.1 Courceyan

Across the North Munster Shelf, the sand dominated 'transitional' beds of the Mellon House sequence are overlain by a sequence of thinly bedded, argillaceous limestones and dark shales; the Ringmoylan formation. These strata reflects a change from barrier/beach environment to open, shallow water and eventually deeper water, marine conditions.

A sequence of diagnostically argillaceous limestones occurs between the Ballyvergin formation and the overlying cleaner limestones of the Ballysteen formation. These limestones form a distinctive, mappable unit termed the Ballymartin formation. The rocks consist of thinly bedded, nodular, pale grey, argillaceous bioclastic limestones, alternating with dark, calcareous shales in approximately equal proportions (Shearley, 1988). The Ballymartin formation and the upper part of the Ballysteen formation are generally thin bedded and contain a substantial amount of argillaceous material.

Throughout southern Ireland, a sequence of medium to dark, argillaceous, bioclastic limestones forms a distinct unit, the Ballysteen formation, between the underlying Ballymartin formation and the overlying Waulsortian formation. Characteristically it consists of a lower and an upper shaley part (Shearley, 1988). Chert is present throughout the succession, as irregular nodules and thick and thin nodular interbeds.

The Courceyan-Chadian boundary is spanned by the Waulsortian formation which is a widely recognisable unit found continuously in previous work. This formation thins out as it moved into progressively shallow water and as it gets younger to the north. These limestones are interpreted as deposits of a fairly deep water environment and represent the culmination of the marine transgression. In the southern synclines region they appear sheet-like in their topography, probably through a coalescing of bank forms whereas, in the northern region, they pinch out as the water shallows.

The Crosspatrick formation of the northern region consists of cherty limestones which are dolomitised in places. This formation fills in hollows in the top of the Waulsortian and passes up into the Aghmacart formation. The Silverspring formation of the southern synclines, is laterally equivalent to the above Crosspatrick formation.

The Waulsortian in the southern synclines is continuous and so the Silverspring formation is uniform overlying it. The Silverspring formation is a mappable unit which is included within the Waulsortian with respect to its hydrogeology.

The Aghmacart formation is conformable on the Crosspatrick formation in the northern region and passes up gradationally to the Ballyadams formation. It comprises fine grained limestones. This formation is thought to be laterally equivalent to the lower Kilsheelan formation in the northern region. The Kilsheelan is a very thick formation up to 600 m.

The Ballyadams formation of the northern region rests conformably on the Aghmacart formation and is overlain by the Lismalin formation. The Ballyadams formation comprises thick bedded to massive wackestones and packstones. The upper part of the formation may contain clay-wayboards. This upper part is equivalent to the Croane formation of the southern synclines. The Ballyglasheen and Rathronan formations are taken to be equivalent to the middle units, while the Killee and upper Kilsheelan formations are equivalent to the lower Ballyadams formation. The middle of the formation comprises clean bedded limestones and the lower part contains a number of thin argillaceous beds. In places in the northern region, especially in the upper part of the formation, the limestones have been dolomitised. The dolomitisation is frequently associated with joints and fractures (Daly, E.P 1993a). The total thickness of the Ballyadams formation is approximately 300 m, whereas the combined thickness of the equivalent formations in the southern synclines is approximately 1000 m. The Ballyglasheen and Rathronan formations consists of clean oolitic grainstones and micritic limestones respectively. The Croane formation contains dark micrites with some cherts and shales at the top.

The Lismalin formation of the northern region contains thin argillaceous limestones with shales and chert. The upper part of the Lismalin formation and the Croane formation both contain some clay wayboards. The succession in the southern synclines is not complete and the Namurian Giant's Grave formation unconformably overlies the Croane formation.

2.5.3 Upper Carboniferous

These strata unconformably overlie the Dinantian limestones. In the Slieveardagh Uplands (Northern Region) the complete Namurian succession is present whereas in the Southern Synclines only the lower section of it is found over small areas. The Slieveardagh Uplands were formerly one of the most important coal mining areas in the country.

2.5.3.1 Namurian

These strata consist mainly of shales, mudstones and siltstones with occasional sandstone units. The sandstones are more common towards the middle and top of the Namurian. A few sandstones units are sufficiently thick to have been mapped over an area. The succession commences with a sequence of grey shales and sandy shales (Nevill 1957) overlain by the Bregaun Flagstone Fm. and the Fleck Rock, all of which are Namurian in age.

For the purpose of this study the Namurian formations of the northern region have not been subdivided. In the Southern Synclines these strata have been called the Giant's Grave formation and have been described by Keeley (1980) as consisting of dark mudstones with siltstones and sandstones with an approximate thickness of 300m.

2.5.3.2 Westphalian

The Westphalian strata are located in the Slieveardagh Hills where they conformably overlie Namurian rocks. The lowest sandstone formation is the Glengoole Sandstone formation, a coarse grey feldspathic sandstone, thickest (30m) in the centre of the Slieveardagh Coalfield and decreasing towards the edges. It is discontinuous in the south-east, and in the south-west is replaced by another sandstone. The uppermost formation, the Main Rock Sandstone formation, is a grey-green, friable, micaceous sandstone, normally between 8 and 10m in thickness although there is considerable variations.

The Glengoole Sandstone comes to the surface at the perimeter and in the centre of the coalfield whereas the Main Rock Sandstone formation crops out regularly throughout the area.

2.6 TERTIARY

The Tertiary period is generally thought to be an era of erosion which included the solution of the limestones and subsequent formation of extensive karstic surfaces. Tectonic activity also may have been prevalent much of the time (Howes, 1990). Tertiary deposits are not extensive and are not generally exposed at the surface and have been encountered in several boreholes at various locations throughout the county. One such deposit is found at Ballymacadam (S 206 123) where a roughly circular hollow in Carboniferous limestone has been infilled with Tertiary material. The deposit consists of white or bluish-white pipeclay, a very fine clay with some small silica crystals. 'Lignite' occurs above the pipeclay, apparently not as a continuous stratum but as local lenticular masses. A thin deposit of drift overlies the hollow and the surrounding limestone (Watts, 1957).

Deposits similar to that at Ballymacadam occur again at Loughlohery (S 207 125) and Knockgraffon (S 204 130). Pipeclay predominates and lignite is not as well represented as at Ballymacadam, although the Loughlohery deposits are larger and deeper. The four deposits are similar in general character, and all occur at about 76 m level. It seems reasonably to assume that they are contemporaneous (Watts, 1957).

2.7 QUATERNARY (SUBSOILS)

2.7.1 Introduction

This section deals with Quaternary deposits or subsoils which are the materials between the soil and the bedrock. They consist of Pleistocene glacial (till) and glacio-fluvial (outwash) deposits, bog and alluvial deposits of Holocene age. These deposits were laid down during the Quaternary Period. The term 'Quaternary deposits' is used by geologists to describe these sediments but the more user friendly term 'subsoil' will be used synonymously with it throughout this study.

The subsoils are an important part of the hydrogeological regime in Ireland as they form the uppermost geologic layer and cover very large areas of the country. Owing to their extensive nature, the subsoils also affect groundwater movement and chemistry in the rock aquifers that they overlie. These deposits consist of numerous lithologies of variable thickness and are found in many different topographic settings.

The importance of these subsoil deposits will be further expanded upon in Chapter 5.3. It suffices to say at this stage that there are two main points of concern. Firstly, the subsoils provide natural protection to groundwater, and in general offer most opportunity for attenuation of contaminants. Secondly, they exhibit a wide range of permeabilities. Thick (>10m) extensive deposits of permeable material (i.e. sands and gravels) which provide protection for underlying bedrock aquifers may also act as aquifers often yielding large quantities of groundwater. These subsoil aquifers also need to be protected.

The glacial depositional history of south Tipperary is open to debate. Since the type of deposit depends on the mode of deposition and the stratigraphic / glacial history it will be necessary to deal briefly with the stratigraphy and glacial history of the area.

A subsoil map (Map 3) has been produced from available information taking into account the quality of the data and its intended use with regard to vulnerability.

2.7.2 Depositional History

Subsoil deposits are very variable and the information in many areas is not as detailed as one would like. Therefore, to assist in the interpretation of the types of deposit present, the depositional environment has been studied.

In Ireland, extensive ice sheets covered almost the entire country and the resulting sediments were deposited either directly from the ice or from streams flowing beneath, through, along the sides, or off the front of the ice. These sediments form geomorphological features which in turn assist in the interpretation of the type of deposit and therefore provide an insight into the material present. The sediments deposited directly by the ice (moraines etc.) are generally mixtures of boulders, pebbles and fine clays, while those deposited by streams (outwash, valley train, etc.) are usually better sorted sands and sands / gravels. Often the two types are intermixed with pockets of sand and gravel in otherwise extensive till sheets and vice versa (Howes, 1990). The till consists of unsorted and unstratified clay, silt, sand and gravel, including boulders. Outwash, deposited by meltwater streams beyond active glacier ice, consists largely of sand and gravel with some cobbles, boulders and silt which is better sorted and stratified.

Most of the subsoil deposits which cover large areas of Ireland were laid down by a number of ice sheets which advanced over the island and then retreated in a series of halt stages. The deposits achieve their maximum thickness at the various halt stages of these ice sheets which are usually marked by an end-moraine.

In this country, the glacial deposits are all generally regarded as belonging to the last two cold stages of the Quaternary period. They consist of an older series of drifts which are broadly equivalent to those of the Saale glaciation of northern Europe, here termed Munsterian and a younger series, which is correlated with the Weichsel, known here as the Midlandian. The older and more extensive of these glaciations engulfed the whole of Ireland, with the possible exception of some mountain summits in the south and south-west. In contrast, the younger glaciation was represented by an ice sheet that covered the northern and central parts of Ireland, but failed to inundate the southern third of the island. South Tipperary has been covered by both these ice sheets. The absolute extent of the Midlandian ice sheet is the subject of some debate. Early work by Charlesworth (1928), shows a limit through Ballylanders (R 176 128) onto Cahir (S 205 128) and then north to Slieveardagh, which he calls the South Ireland End Moraine. Later work by Synge (1970) and Finch (1971) has placed the limit further south and east, based on the extent of the preservation of the limestone clasts in the soils and underlying till (Fig. 2.1).

It is now generally felt that the South Ireland End Moraine Limit does go through south Tipperary where it manifests itself as thick deposits of glacial material

Modified after Finch, 1971.

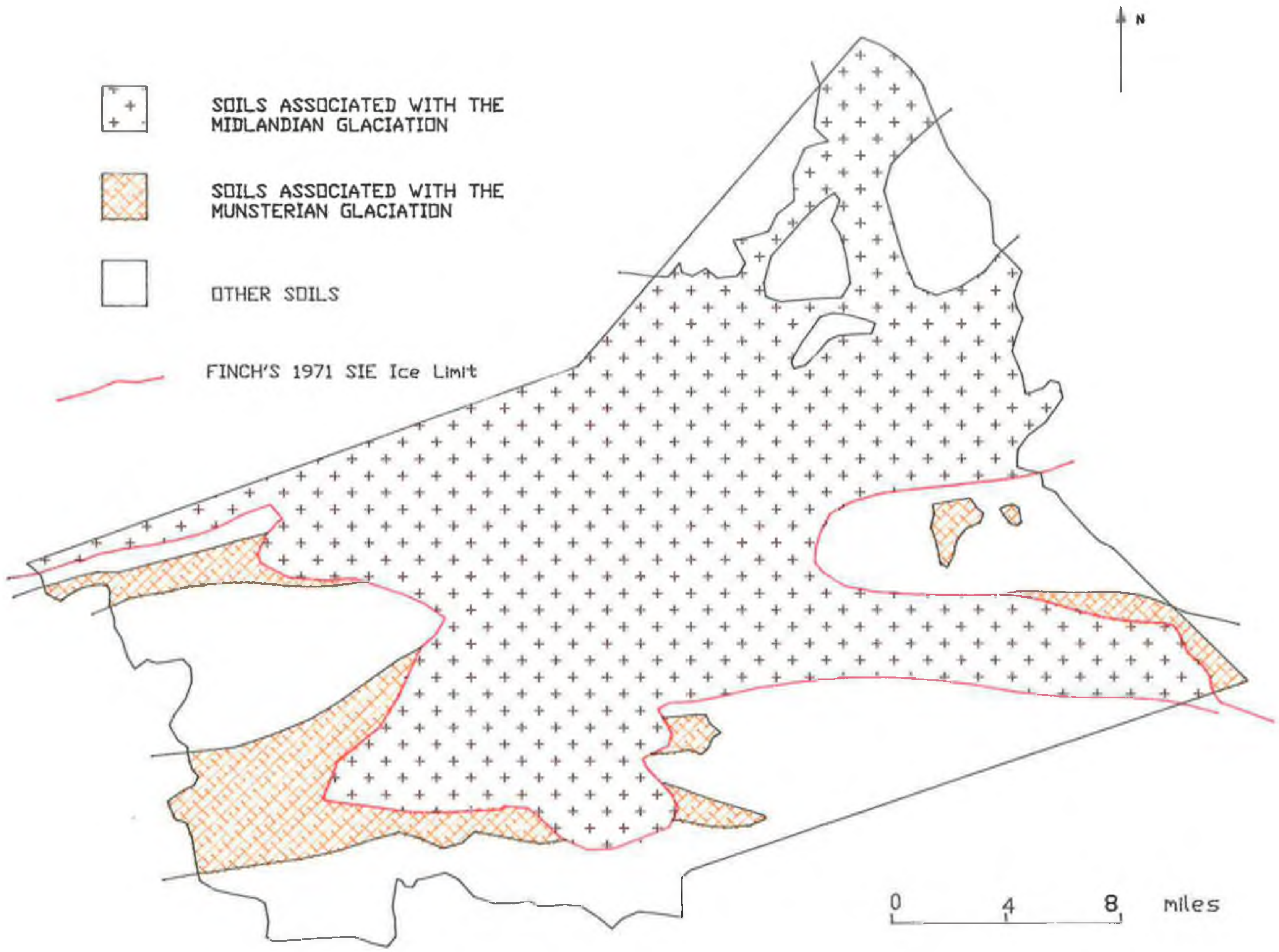


Fig. 2.1 Soils of South Tipperary and Finch's 1971 SIE Ice Limit.

(see Map 7). Finch (1971) redefined the limits of the Midlandian glaciation on the basis of differences in soil characteristics. The ice sheet and its moraine stretched from the Galtees in a large tongue south as far as the Knockmealdown foothills and eastwards along the Suir Valley to Piltown (S 245 122). The ice margin then passed around the west face of Slievenamon and along the northern face of this mountain to the Kilkenny county boundary. The ice moved over the Slieveardagh Hills and covered the lowlands to the south (Finch, 1971).

2.7.3 Description of Deposits

2.7.3.1 Introduction

Terms such as drift (limestone and sandstone), limestone gravel, peat (bog), marl, alluvium were used on the early maps of the Geological Survey of Ireland. The bog, marl and alluvium areas were easy to delimit and so there is confidence in these areas shown on the maps. The term drift refers to any glacial cover material. More recently this term has been replaced by till. Areas shown on the one inch geology sheets (GSI), as having no drift cover represent areas of rock close to surface ie. < 1m.

The subsoils map (Map 3) illustrates the planar view whereas the vertical cross-section (Fig. 2.2) provides an insight into the vertical variation. The depth to bedrock contours (Map 7) highlight the areas of significantly thick deposits. The three-dimensional picture is difficult to construct but an attempt has been made for the Gortdrum area and is shown in Fig. 2.3 and in the cross sections to clarify it. It demonstrates an increase in sand and gravel deposits to the north-east and also in the south east of the area. There are not a lot of detailed vertical logs through these deposits. The vertical thickness and type of deposit tends to vary rapidly over short distances as is seen in Fig. 2.2 The cross section is taken from the Ballypatrick area (S 231 125). It shows that there is a rapid change in lithology over a short distance (500m).

LEGEND

Mainly Sand and Gravel

Interbedded Clay's Silt's, Sands (with cobbles)

Limestone Bedrock

From: K.T.Cullen, Consultant Report for Proposed Landfill, 1990.
(Restricted Access)

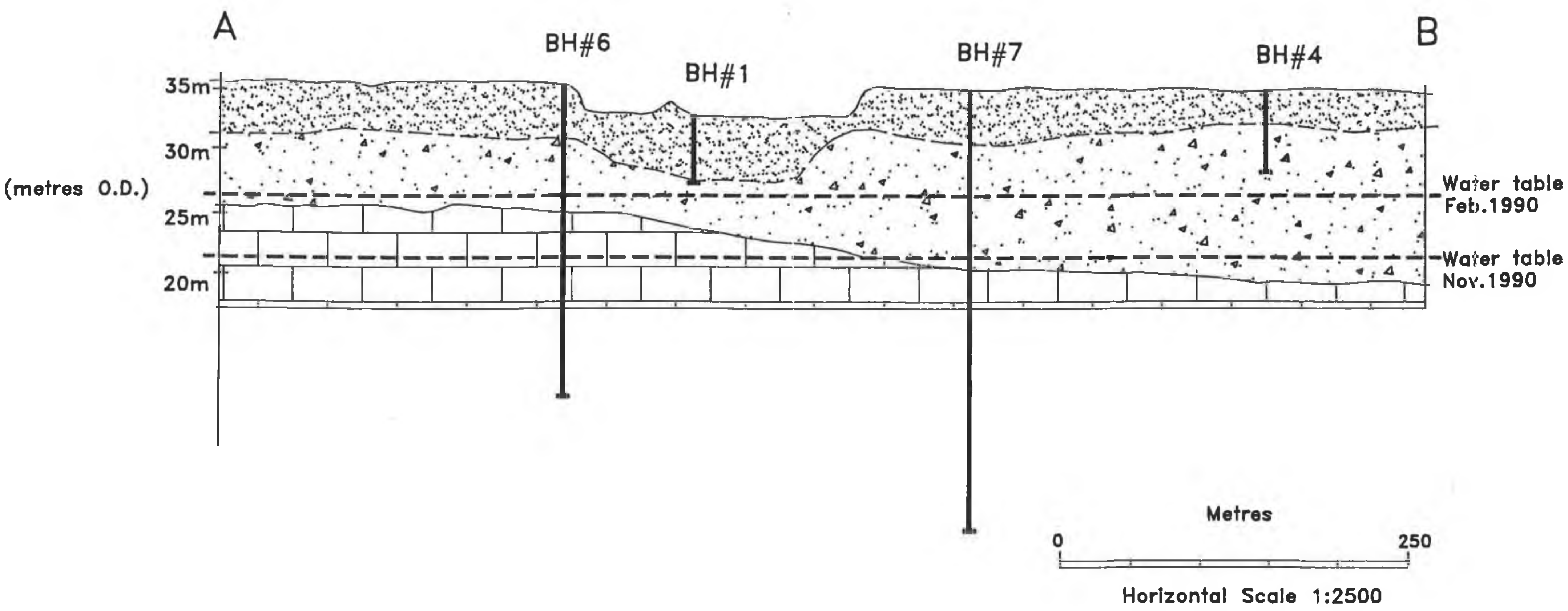


Fig. 2.2 Vertical Cross-section at Ballypatrick.

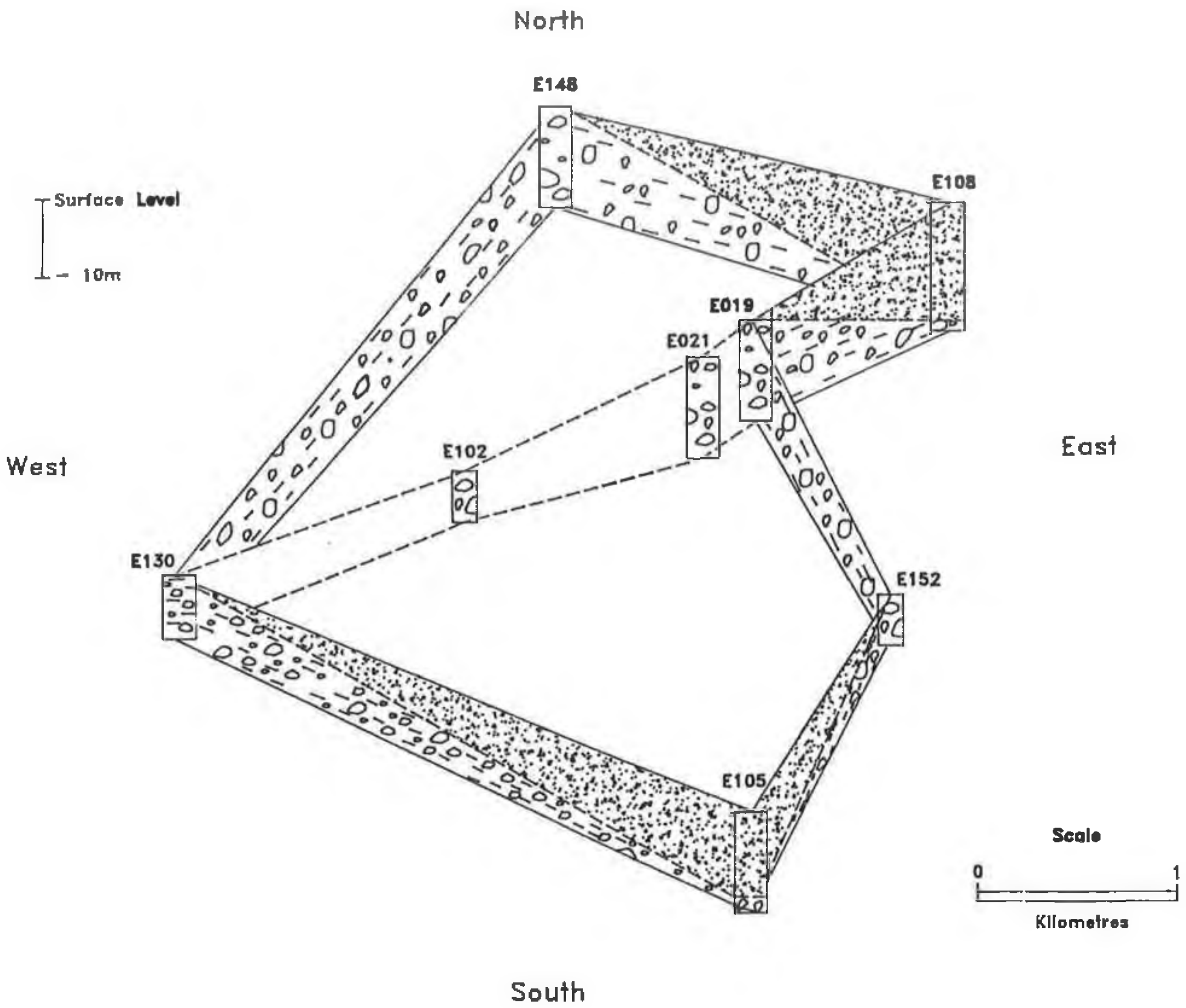


Fig. 2.3 3–D Fence Diagram of Gortdrum Area.

Based on borehole records from mineral exploration companies in the Gortdrum Mine Area.

2.7.3.2 Till

Till (often referred to as boulder clay) is the most widespread and diverse deposit laid down by ice. In south Tipperary, the till can be divided into predominantly limestone or sandstone till based on the dominant clast lithology. These deposits can further be subdivided into clayey, silty, sandy, gravelly and stony till where detailed mapping and analysis are carried out. However, this has not been possible in the study area as little detailed mapping and sample analysis has been carried out. Therefore, the deposits have been described in general terms only. The till characteristics depend on a number of factors such type of parent material, method of deposition, environment of deposition etc. Till is more variable than any other sediment known by a single name. As a result there are a number of ways in which it may be classified.

i) Limestone Till

The dominant till type, in south Tipperary, is limestone till, which is found throughout the lowlands. The limestone clasts have been weathered out in places, particularly in the older deposits of the Munsterian glaciation. These tills are undifferentiated in terms of matrix composition.

ii) Sandstone Till

It is found in the upland areas, associated with the underlying Old Red Sandstone and it is typically red in colour. These are also undifferentiated in terms of matrix, although this may be more sandy than in the limestone till.

iii) Namurian Till

This is not indicated on the subsoils map, as it was not delineated by the 19th Century workers. However, the Slieveardagh Hills are predominantly Namurian shales and sandstones and based on information from a similar type area in Limerick, it can be assumed that these sediments are a mainly clayey, shale rich deposit with more fine material than the other tills.

iv) Till with gravel

This term is used to describe the deposits in the centre of the county, which account for about 40% of the total cover. These deposits are a combination of till which may be clayey, sandy, gravelly, stony or a mixture of all these with some limestone gravel. These deposits are chaotic mixtures of permeable material. There are pockets or lenses of sandy or gravelly material as well as some till, but the exact boundaries have not been mapped out. It is probable that detailed mapping would not radically alter the overall distribution pattern as described. The deposits are thought to be kame and kettle as described by Synge (1970).

Weathering can play an important role in determining the permeability in limestone dominated glacial deposits. The limestone in the till has been shown to weather out to depths greater than seven metres, leaving behind 'ghost' limestones (Warren, 1991) with a consequent likely increase in porosity. However the impact on the permeability is more complex. The overall permeabilities of till are varied and extremely difficult to predict as they are complex and diverse and variations both laterally and vertically can be quite dramatic.

2.7.3.3 Sands and Gravels

The central region of south Tipperary contains discontinuous pockets of sand and gravel. Deposition of sand and gravel takes place mainly during recessional phases while glaciers melt. There are a few environments in which sand and gravels are deposited: kame and kettle are formed from 'dead ice'; eskers are deposited from subglacial meltwater streams; and sandy/gravelly tills which were deposited directly by the ice, have been reworked or 'cleaned out'. The subsoils deposited in these environments are primarily well rounded gravels with sand and with the finer fractions of clay and silt washed out.

The depth to bedrock contours indicate areas with depths greater than ten metres and these may be considered as potential aquifers (see Chapter 3.3). The permeability depends on the grain size, sorting etc. An outwash deposit would be cleaner and therefore more permeable than the kame deposits.

2.7.3.4 Marl

Marl is a whitish calcareous clay often containing freshwater shells and consisting of at least 90% $CaCO_3$. It was originally deposited in lakes and its frequent presence beneath bogs, marshes, and the low-lying areas, indicate that the lakes were much more extensive. Marl is a fine grained, compressible material; therefore the permeability is low.

2.7.3.5 Alluvium

Alluvium is a sedimentary deposit resulting from the erosive action of rivers, followed by deposition along the river bed and floodplain. Alluvium is composed of unconsolidated fragmented material from the coarsest sand and gravel, to the finest clay and silt particles. As this deposit has a variable particle size, its permeability is also variable and depends on the grain size, sorting and the percentage of fine material present. Most of the coarse alluvial deposits are not sufficiently extensive horizontally and vertically to be considered as aquifers in their own right. These deposits generally consist of material reworked from older fluvio-glacial deposits and therefore are considered with them.

2.7.3.6 Peat (Bog)

Peat is an unconsolidated brown to black organic material comprising a mixture of decomposed and undecomposed plant matter which has accumulated in a water logged environment. Blanket bog is found in the higher hill and mountain areas where rainfall is very high. Permeabilities in peat are generally quite low and this varies with the degree of humification; the more humified the peat, the less permeable it is. This low permeability coupled with the high attenuation afforded by the organic material ensures a high degree of protection for aquifers when sufficiently thick.

2.7.4 Distribution of Deposits

South Tipperary is largely covered by a thin layer of till which is predominantly less than five metres thick. There are pockets of thicker till and sand

/gravel of variable thickness scattered throughout the area. The predominantly limestone gravel areas in the centre of the county have till deposits surrounding them. The deposition in the central area of the county was chaotic, and mixtures of sand, gravel and limestone till were deposited as the ice melted. The deposits surrounding the sand and gravel areas are referred to as till-with-gravel deposits. Post glacial alluvium is predominantly found along river channels and floodplains. The deposits vary from very coarse to fine grade particles along the Suir. The marl deposits at Ballagh (S 201 149) and Masterstown (S 204 133) are remnants of glacial lakes. Peat development is in the form of raised and blanket bogs. Peat is found in the north-eastern part of the area, from Killough Hill (S 211 151) to Urlingford (S 228 163).

The distribution of deposits in the seven physiographic regions is outlined below;

i) Slieve Phelim Uplands

The dominant deposit in these uplands is shallow Old Red Sandstone till. Smaller amounts of fluvio-glacial sand and gravel are found in the area of Ironmills. Slieve Phelim has a thin covering which is assumed to be blanket bog.

ii) Middle Suir Lowlands

The central lowlands (Fig. 1.1), are dominated by discontinuous sands and gravel, till-with-gravel and limestone till deposits. This area is located behind the South Ireland End moraine. The low hummocky topography suggests a kame and kettle type environment of deposition. These types of deposits are formed by 'dead ice', which deposits till with some reworked meltwater gravels. At Ballagh, there is a marl deposit plus a small amount of peat and alluvium in the lowlands previously described. An extensive deposit of peat is found along the county boundary at Holycross (S 208 155). It is assumed that the peat is generally less than 10m deep.

Synge in 1970, traced the South Ireland End Moraine through the southern part of these lowlands. Some of his observations are marked in red by points in Fig. 1.1 in this and succeeding sections (ii) to (vii). In the eastern part of this region, detailed descriptions have been noted. West of Gurteen House (1) the succession contains grey gravelly till with fresh limestone clasts indicative of the Midlandian. South of this area (2), there is a low morainic ridge composed of fine and coarse bedded sands and gravels. Around Nine-mile-house (3) there is a large morainic ridge with some fresh limestone clasts at surface.

iii) Slieveardagh Uplands

The predominant deposit in this area is till. These Namurian tills are clayey and shale dominated. The subsoil in this area is usually shallow with a lot of bedrock at or near the surface.

iv) Slievenamon Uplands

Less than 30% of this region is covered by shallow Old Red Sandstone till with almost two thirds of the cover being limestone dominated till. A small amount of gravel deposits are found at the eastern side. Heavy till as described by Synge and Stephens, (1960), is leached and weathered to 2 - 2.5m, is located south of Nine-mile-house (4). Fresh limestone clasts are only found at depth (Munsterian). This site description was used to define the Southern Ireland End (SIE) ice limit.

v) Golden Vale Lowlands

This region includes the lowland area extending from Mitchelstown (R 128 144) to Carrick-on-Suir. The SIE ice limit of Synge and Finch runs along south of the river Suir across to Piltown, Co. Kilkenny and then back around the outline of Slievenamon. The predominant deposit is limestone till with a small area of till with gravel deposits and scattered shallow gravel deposits.

In the Ballypatrick (S 231 127) area (6) there are esker-like deposits, with rounded limestone gravels. A gravel ridge is found at Kilsheelan (S 228 123) (7). The exposed deposits are typically morainic, contorted sands, gravels and boulder clay. The latter is grey and gravelly and full of limestone.

There is a significantly thick limestone till deposit in the area of Poulnamucky (S 211 127). Not much data have been obtained on this type of deposit, but there is no evidence of any gravels being present. Similarly at Knocklofty (S 214 121) there is a thick deposit (up to 20m) of limestone till. Clonmel and Loughcuteen have similar deposits. In the area east of Clogheen (S 201 114), there is a significant till deposit, possibly greater than twenty metres in thickness. In general till dominates these thick sequences so the natural protection is great.

Most of the area has depth to bedrock values of less than five metres. The rivers Suir, Tar, Shanbally and Burncourt have alluvial deposits along their banks and the Suir river valley is marked out by alluvium deposits. Around the Carrick and Kilsheelan areas, the alluvial deposits are gravelly.

vi) Knockmealdown Uplands

These uplands have shallow subsoil deposits of less than one metre thickness. There is no information regarding the type of deposit but it is assumed to be Old Red Sandstone till as these uplands are predominantly of this rock type.

vii) Galtees Uplands

This area is bounded to the north by the Slievenamuck range and includes the Galtees range. The predominant subsoil deposit is till, which consists mainly of Old Red Sandstone clasts on the Galtees. The Glen of Aherlow is covered by till with gravel, sand and gravel deposits and some Old Red Sandstone till deposits. This area is of interest in the light of the Southern Ireland End Ice Limit (SIE). Various significant geomorphological features have been observed at different points (8),(9),(10),(12),(13) by Lewis et al. 1977 (Fig. 1.1). Local corrie glaciers developed in the mountains, producing deep cirques and a prominent series of moraines, piled up on top of each other. A good example are those at Glencoshnabinnia (8). At Galty Lodge (9), a broad saddle crosses the Slievenamuck ridge and this feature has been named the Corderry delta. A loop of terminal moraine (Midlandian age) plugs the east end of the Glen of Aherlow, observable at Castle Mary (10). Bansha Wood (R 194 133) has examples of large subglacial meltwater channels that trend across the end of the Slievenamuck sandstone ridge and are partly buried by an end-moraine belt of Midlandian age.

There are some significantly thick gravel deposits in the Glen of Aherlow, possibly from the melt-water channels to the north of it. These deposits are assumed to be fairly well rounded and clean and therefore of a high permeability.

The majority of the Galtees are covered by areas of rock close to the surface and therefore the overlying deposits are not described. It is assumed that they are Old

Red Sandstone derived tills with substantial amount of rock outcropping.

2.8 GEOLOGICAL STRUCTURE

South Tipperary has been affected by the Caledonian and the Hercynian orogenies. The Caledonian deformation occurred during the late Silurian - early Devonian Period. The regional strike in the study area is a west-south-west orientation. Within the southern part of the Slieve Phelim inlier, Doran (1971) has demonstrated local variations in strike of bedding and cleavage through 90^0 from north-south to east-west. The main deformation is compressional, forming the major F1 folds. The Leinster granite probably rose along a major anticline which runs to the north-east of the study area. The same anticline is traceable along the Suir Valley underneath the Carboniferous strata and lying between the Slievenamon and Lower Palaeozoic inlier of the Comeraghs. Another major fold belt (synclinal) can be traced through the Wenlock inliers of the Slieve Bloom and Slieve Phelim. The effects of the Caledonian deformation in the Leinster zone decrease to the south-west where, conversely, the Hercynian effects are seen to increase in importance (Phillips and Holland, 1985). In the Devonian strata, faulting is mostly north-south. Three groups of joints have been recognised in these sandstones, with north-south, east-west, north northeast-south southwest trends.

At the end of the Carboniferous another phase of deformation ensued, known as the Hercynian orogeny. The major Hercynian folds have amplitudes and wavelengths of several kilometres. Many of them can be traced for tens of kilometres along strike, the axes of which trend east-north-east to east-west (Sevastopulo, 1985). There are tension joints running along the crests of anticlines and the troughs of synclines. In general those on the anticlinal compression axes will be more open than those on the synclinal compression axes. The north-south shear joints have opened and they are suspected of influencing the direction of groundwater movement. This north-south jointing is probably the most important structural control on groundwater movement in south Tipperary. The faults tend to be planar and are often vertical or sub-vertical. The rock in the vicinity of such faults is likely to be shattered and probably provides privileged paths for groundwater circulation (Burdon, 1978). The intensity of deformation decreases gradually northwards and is assumed to extend as far north as Cahir.

2.9 HYDROGEOLOGICAL IMPLICATIONS

2.9.1 Introduction

The rock strata in south Tipperary, as elsewhere in Ireland, are old and have a complex geological history. Many of the original depositional features have been altered to a considerable degree and therefore the hydrogeological properties have also been altered. Thus, most of the permeability we observe in these rocks today is secondary and generally of the fractured/fissure type. A number of geological factors are important in understanding the hydrogeological characteristics of particular strata.

These are:

- Lithology - grain size, degree of sorting, the proportion of muddy to clean material and the number of impermeable layers.

- Geological history of the particular strata - the degree of consolidation, metamorphic history, weathering/erosion since deposition, the amount of structural deformation and the structural setting.

- The present location of the particular strata both topographically and relative to other strata and also their position relative to groundwater circulation.

- The possibility for active groundwater circulation in both the present and in the past.

There is a very obvious distinction between the structural setting north and south of an east-west line drawn through Cahir. The area defined as the southern synclines has been affected by the Hercynian deformation and the north-south and minor east-west trending faults and folds are a by-product of this deformation. The northern region has a Caledonian northeast-southwest trending geological structure.

Faulting has a number of effects on groundwater flow, which are as follows;

- The break up of the strata making them more jointed.
- The faults themselves can act as conduit paths for flow.
- They can cut off partially or completely the flow of one part of an aquifer from another.
- They may also connect different aquifers or they may cut off the recharge area.
- Faulting may lower a formation to a depth at which it is not practical to develop it.

The major geological units are discussed below with the effect geological processes have on the hydrogeology being considered.

2.9.2 Lower Palaeozoic

The Lower Palaeozoic rocks in this region are mainly dominated by muds, and have all been subjected to low grade regional metamorphism (deep burial) and extensive folding. These rocks will therefore have low permeability and groundwater circulation will normally be restricted to the near surface zone. However, they generally occur on elevated ground where groundwater flow does not concentrate.
There are a number of geological units of restricted extent that are likely to be more permeable than the rest of the Lower Palaeozoic. These are the Brownstown member of the Ahenny formation which includes lamprophyre sills, quartz porphyrys and some feldspathic tuffs of the Carricktriss formation. These are principally clean and competent rocks which will fracture more readily and have a higher permeability than the surrounding rocks.

2.9.3 Old Red Sandstone

The lower of the two formations of this period, the Carrigmaclea formation, generally occurs as relatively high ground indicating a resistance to weathering. It also contains a substantial amount of fine grained material (mudstone/siltstone) in the succession which is repeated regularly due to the highly sinuous braided nature of these deposits. Hence, it has a low permeability except in areas of localised intense faulting.

The Kiltorcan formation is more productive as an aquifer than the Carrigmaclea formation because there is a higher proportion of fine grained material in the latter and it is laterally consistent and persistent units. The Kiltorcan formation is dominated by coarse grained or flaggy sandstones particularly at the top of the formation where fine grade material forms only a small proportion of the succession. The strata in the Kiltorcan formation and the overlying Porter's Gate formation are considered to be a major aquifer in this area. The Kiltorcan formation is close to the base of the main sedimentary sequence, and therefore is the formation in which deepest groundwater flow is likely to occur. It is important for this aspect alone (Daly, E.P., 1992).

The thickness and transmissivity of the formation both in outcrop and at depth reduces to the east. Analysis of the numerous logs of boreholes in the adjoining Nore River Basin that penetrate this formation show that in the top two thirds of the sequence most of the sandstone units are quite thick in contrast to most of the mudstone units, so that the transmissivity of the upper part of the formation will be much greater and thereby more productive as an aquifer.

A number of features in these rocks make them more susceptible to weathering and they tend to break up and decompose relatively easily;

- ☐ They are dolomitised in places.
- ☐ Frequently they have a dolomitic or calcareous cement.
- ☐ They contain easily weathered feldspars.

Where these features are common, the rocks will be more porous near the surface, and this in turn will give them some intergranular permeability.

2.9.4 Carboniferous

The intensity of the folding and faulting creates a secondary permeability which allows some circulation along fault and joint zones. The intensity of the structural deformation is very much decreased in the northern region. Where present it provides some secondary permeability along fractured fault zones.

2.9.4.1 Dinantian

The Porter's Gate Formation marks the onset of marine conditions and contains thinly interbedded units of coarse and fine material, limiting the development of transmissivity. The lower part of the formation normally contains more permeable material than the upper part which is considered to be an aquitard. The Porter's Gate formation is taken to be part of the Kiltorcan Sandstone aquifer and the fine grained material at the top of the formation confines this aquifer and protects it from contamination (Daly, E.P., 1992).

The Ballymartin and Ballysteen formations are discussed together. The former and the upper part of the Ballysteen formation are generally thin bedded and contain a substantial amount of argillaceous material. There are some cleaner, coarser units which would be more susceptible to solution and karstification but this is unlikely to be significant at depth. In contrast the lower Ballysteen formation is cleaner, with thicker units.

The Waulsortian mudbank limestone is a massive unbedded clean limestone, that has been dolomitised in places. Dolomitisation is the dominant factor in the northern region whereas the intensity of structural deformation in the southern synclines, as well as the dolomitisation, is responsible for secondary porosity and permeability. The limestones in the northern area have been dolomitised in places. The features associated with dolomitisation are jointing, shrinkage cracks, sand filled cavities, vugs and extensive weathering. Although apparently scattered randomly throughout the formation, they appear to be more concentrated at the top and along fault zones (Daly, E.P., 1993a). The undolomitised limestone in the north is very tight and so has a low permeability. In the southern synclines the predominant feature is intense faulting, so that even where the there is no dolomitisation there is a good secondary permeability.

The Crosspatrick formation in the northern region mainly consists of clean, generally thick bedded limestones which are dolomitised in places, especially in the east. The presence of some argillaceous and shale units may restrict circulation. The Silverspring formation of the southern synclines, is taken to be laterally equivalent to the above formation. This formation comprises pale grey bedded cherts and dark grey siliceous biomicritic limestones.

The Aghmacart formation includes fossiliferous calcilutites and calcisiltites with some calcarenite. This formation has a very low permeability since it is fine grained, thin bedded and compact. The Kilsheelan formation of the southern synclines is laterally equivalent to the Aghmacart formation. The only permeability that the Kilsheelan formation possess is secondary. The upper unit is equivalent to the Killavanogue member, which contains the Mitchelstown caves. The structural deformation in this region enhances the development of karst in the upper unit of this formation but unfortunately it has not been mapped for any distance. The majority of this formation restricts groundwater circulation.

The Ballyadams formation is equivalent to the Ballyglasheen and Rathronan formations. The upper part of the Ballyadams formation contains clay wayboards and it outcrops on sloping ground which limits the amount of area exposed to the surface. This will restrict the groundwater circulation, and therefore the vertical development of permeability, to fairly small areas. Secondary permeability within the limestones has developed in the horizontal direction due to the presence of the clay way-boards. The extent of this horizontal development varies in length from 10-30m. The lower part of the formation is quite thick and a wide section of the aquifer is open to the surface and available for recharge. The processes of solution and karstification are unhindered and relatively large groundwater circulation systems can develop. This results in relatively high permeability zones being formed (Daly, E.P., 1992). The Rathronan and Ballyglasheen formations are considered as one unit. The lithology and structural deformation creates preferential pathways for flow and hence, solution and karstification follow. The Ballyglasheen formation consists of cross bedded, pale grey, winnowed oolitic, grainstone limestones which are likely to be susceptible to karstification.

The base of the Lismalin formation has been suggested to be laterally equivalent to the Croane formation of the southern synclines. The upper part of this formation is argillaceous and shaley, therefore limiting the extent of karstification. This may be a reason why the swallow holes at the edge of the Namurian are such a distance away. The lower part has the potential to become intensely karstified. Preferential karstification occurs along the fault zones (Daly, E.P., 1992).

2.9.4.2 Upper Carboniferous

The lower part of the Namurian consists mainly of shales which restrict the amount of groundwater movement throughout the whole succession by their impermeability. There are some sandstones present in the middle and upper part of the successions which are extensive enough to have minor resource potential.

The two main sandstone units in the Westphalian, although indurated and very hard with no primary permeability, have developed a little secondary permeability as a result of the widespread folding and faulting and associated jointing.

2.9.5 Subsoils

The effect of the subsoils on groundwater movement is largely a function of their permeability and to a lesser extent, their thickness and area. Subsoils of a low permeability such as clays, silts, till and peat restrict the amount of recharge water getting down to the underlying aquifers. Where these deposits are sufficiently thick and/or fine-grained, they will cut off infiltration almost completely thereby confining the underlying aquifer and in certain circumstances, artesian conditions may result. A positive effect of the low permeability is that the movement of contaminants into an aquifer may be prevented or the concentration sharply reduced by physical, chemical, and biological processes active in the underlying Quaternary strata.

Where high permeability deposits are sufficiently thick, extensive, saturated and clean, they are considered to be aquifers in their own right and have potential for development. Where these deposits are not sufficiently extensive, or perhaps unsaturated, they are still important as they will allow a high proportion of recharge water to enter an underlying rock aquifer with which they are in hydraulic continuity (Daly, E.P., 1985).

CHAPTER 3 - GROUNDWATER / HYDROGEOLOGY

3.1 INTRODUCTION

The complex geological environment in South Tipperary has a large impact on the groundwater flow regime. Two conceptual models have been developed to describe the hydrogeology of the two regions into which the area has been divided, the Northern Region and the Southern Synclines. The boundary (approx.) is located north of the Galtees in the west and north of Slievenamon in the east, and is shown in Map 2.

The basis for the conceptual models comes from work undertaken in the South Munster Synclines (Wright, G., 1979) and in the Nore River basin (Daly, E.P., 1992). Specific work and examples from the study area will be used to confirm that these concepts are relevant to the situation in south Tipperary. Baseflow analysis, hydrogeological features, well yields and specific capacities are used in determining the properties of the aquifers. Five groundwater sources were examined in detail from a groundwater vulnerability point of view. Their capture zones are defined using different methods.

Approximately 50% of the area of south Tipperary is considered to consist of either regionally or locally important aquifers. The available resources are estimated and their future development explored in this chapter.

3.2 HYDROLOGY

3.2.1 Climate, Rainfall, Evapotranspiration

The Irish climate is a cool, temperate, oceanic and is predominantly mild, moist, windy and changeable. Major factors in shaping the climate are the westerly atmospheric circulations of middle latitudes and the Atlantic ocean which lies to the north, west and south of Ireland. These factors give Ireland a markedly maritime character but the influence decreases with inland distance (Wright and Aldwell, 1988).

The prevailing winds are from the west and most of the rainfall originates from fronts associated with easterly moving Atlantic depressions (Daly, E.P., 1992).

The most consistent feature of the Irish climate is its unpredictability! The change from winter to spring or from summer to autumn is gradual and the general trend is subject to reversals which may last for a week or more (Rohan, 1986). An important feature of Irish rainfall is its even distribution throughout the year, with only a slight tendency to a drier season in the spring. In most of Ireland at least 1 mm of rainfall is recorded on more than half the days in the year (Wright and Aldwell, 1988). In south Tipperary the local topography has superimposed itself on the overall rainfall pattern in Ireland which consists of a general reduction from west to east. The upland areas which form the western, southern and eastern perimeters have rainfall levels which vary from 1000mm/year in the east to 1800mm/year in the west and south. The lowlands have values less than 1000mm per annum. A mean annual rainfall map (Map 4) has been prepared. The rainfall figures were taken from the 1951-1980 year average provided from the Meterological Service.

The actual evapotranspiration at the synoptic weather station at Kilkenny has a range of values of 400-460mm/year. The range for the south Tipperary region is taken to be slightly higher as it is less influenced by the sea, this range is 425-480mm/year. Therefore the effective rainfall in the lowlands is less than 535-575mm/year whereas the uplands range in value from 525-1325mm/year.

3.2.2 Surface Drainage / Run off (Flow Measurements)

3.2.2.1 Dry weather flow / Baseflow analysis

Flows in the large rivers are generally at their lowest in late August and early September, reflecting groundwater baseflow. Baseflow is the component of discharge of a stream which is derived from groundwater seeping into the river. In most rivers the baseflow is almost equal to the total flow during the summer as the surface runoff component is very low. The baseflow at this time is also at its lowest, and is not masked by the large amounts of surface water which are characteristic of winter discharge. Baseflow is derived from the groundwater in the strata and areas where baseflow is large indicates the presence of important aquifers. The lower part of the Suir river system has one of the largest baseflows in the country, which implies that this region contains major groundwater resources (Wright, 1979).

Low flow measurements were made by current meter by the Office of Public Works (OPW) and An Foras Forbartha (AFF) on the Suir river system in late August-early September 1976. These measurements were taken after a long dry summer where the total rainfall value recorded at Drangan (S 264 144) for the period 21 July to 09 September 1976 was 6.1mm. Hence, these measurements are considered to be extreme low flow values. There was a negligible surface water component, so that all the strata contributed to some degree to the baseflow.

An analysis of the baseflow inputs into the river system was achieved using the previously mentioned low flow measurements carried out by the OPW and AFF. There are twenty three river gauging stations located on the Suir river (Fig. 3.1). A preliminary analysis showed major groundwater contributions to baseflow in the Suir river system (Fig. 3.1).

The total flow was given for each gauging station and an incremental flow at each station can be calculated by subtracting the total flow of all the sub-catchments up gradient from it. This gives the actual flow for each sub-catchment area. The specific baseflow, which is the total flow per unit area ($l/s/km^2$), is calculated by dividing the incremental total flow by the sub-catchment area.

The upland catchments have a number of different river drainage characteristics, including higher rainfall, little subsoil cover and it is difficult to get accurate flows. The lithologies of these uplands are such that they are considered to be locally important/poor aquifers. Therefore they are not included for further analysis.

The lowlying Dinantian limestones owing to their lithology were considered for more detailed analysis. Each lowlying sub-catchment area was examined with respect to its aquifer potential. The aquifer and aquitard areas were determined by lithology and from earlier research in similar areas. There were some formations that could not decisively be placed into either grouping and were then termed 'white' areas. A planimeter was used to calculate the respective areas in each of the sub-catchments (Table 3.1).

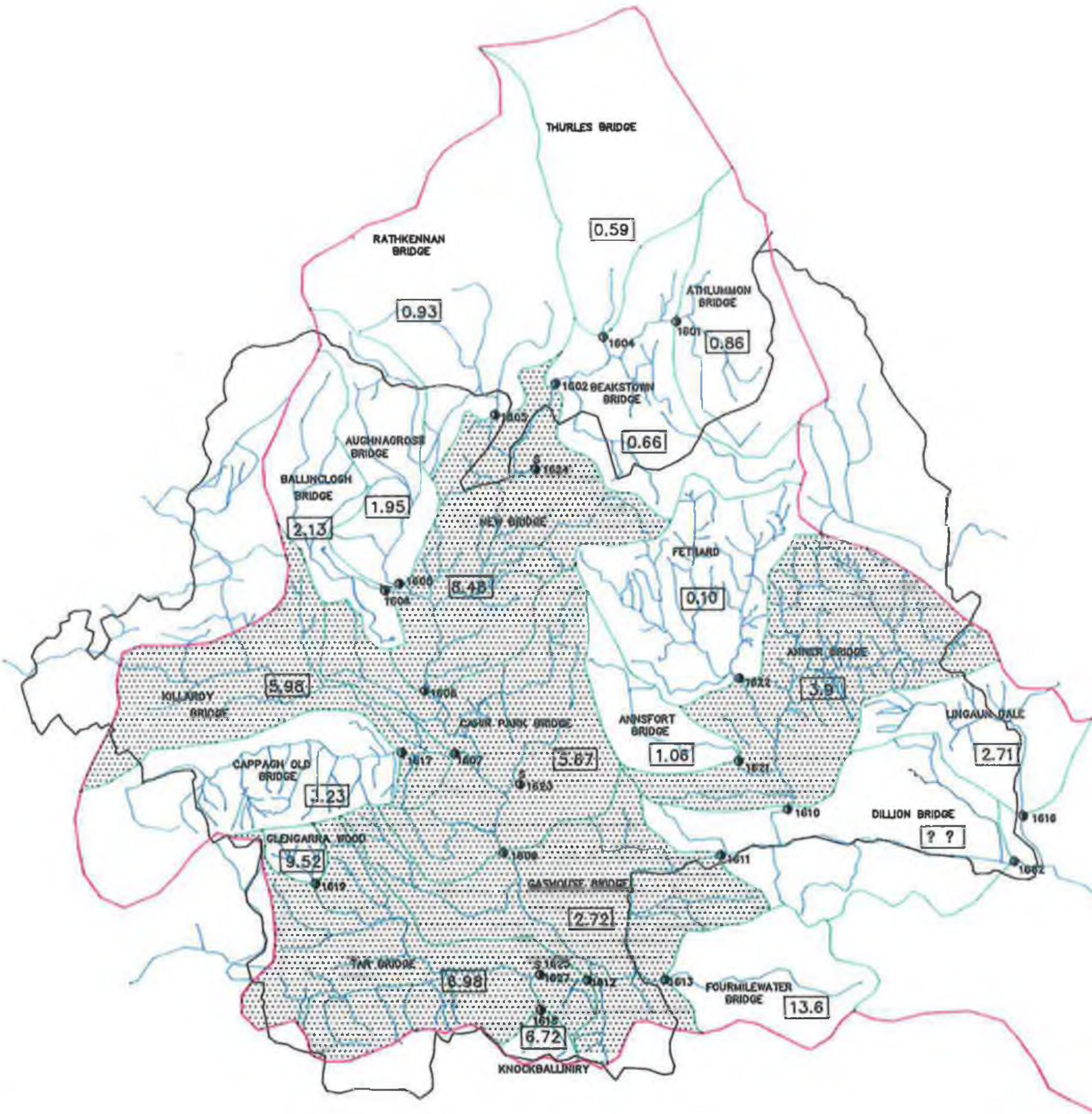


Fig 3.1 Suir Catchment Baseflow Map

THURLES BRIDGE

0.59 SPECIFIC BASEFLOW (l/s/km2) AT THURLES BRIDGE GAUGE STATION

S GAUGING STATION (S INDICATES A SPRING OUTFLOW)

AREAS OF HIGH BASEFLOW VALUES

COUNTY BOUNDARY

SUIR RIVER SUB-CATCMENT BOUNDARY

SUIR RIVER CATCMENT BOUNDARY

SUIR RIVER SYSTEM FOR THE SOUTH TIPPERARY AREA

Gauging Station	River	Actual Baseflow L/s	Specific Baseflow L/s/km^2	Area of Aquifer km^2	Area of Aquitard km^2	Area of 'White' km^2	Specific Aquifer Baseflow L/s/km^2
1601 Athlummon Bridge	Drish	120	0.86	61.37	55.14	16.58	1.137
1602 Beakstown Bridge	Suir	90	0.66	38.44	74.6	36.0	0.327
1607 Killardry Bridge	Aherlow	581	5.98	8.35	83.5	60.92	* 57.47
1609 Cahir Park	Suir	1170	5.67	20.89	101.54	87.24	* 49.68
1610 Anner Bridge	Anner	855	3.9	54.89	127.96	42.47	13.94
1611 Gashouse Bridge	Suir	880	2.72	16.38	95.8	75.12	* 46.42
1612 Tar Bridge	Tar	1417	6.98	24.59	105.5	77.23	* 52.42
1617 Cappagh Old Bridge	Aherlow	579	3.23	18.59	140.85	9.25	25.49
1621 Annsfort Bridge	Moyle	59	1.06	14.15	13.07	30.74	2.00

Table 3.1 Specific Aquifer Baseflow Values for selected lowlying Gauging Stations.

* High Specific aquifer baseflows sub-catchment areas.

A specific baseflow value of 0.7 l/s/km^2 was taken to represent the aquitard areas (similar to values found in Nore (Daly, E.P. 1993) for aquitard areas). The unknown ('white') areas were assumed to have the same characteristics as the aquitards and therefore a flow of 0.7 l/s/km^2 was used for this analysis. The specific baseflow of these two areas is determined by adding their areas together and then multiplying by 0.7 L/s/km^2. This specific baseflow when subtracted from the total specific baseflow for the sub-catchment gives the specific aquifer baseflow (Table 3.1).

Some sub-catchment areas (indicated by * in Table 3.1) have quite high specific aquifer baseflow values relative to those found in the Nore (E.P. Daly pers. comm.). Two reasons put forward to try and understand these values are that

(1) There are different hydrometric characteristics between the Suir and the Nore, potential recharge approx. 650mm and 470mm respectively.

(2) The undefined 'white' areas may be locally important aquifers with specific baseflow values greater than 0.7 L/s/km^2 and therefore the specific baseflow for the total aquifer area would be reduced. The specific baseflow value for the aquitard area is also likely to be higher in the Southern Synclines due to the extreme Hercynoid faulting and folding. Reasons for promoting these observations are that the deformation of the strata have an effect on the hydrogeology. This concept has already been dealt with in Chapter 2.9.

The baseflow analysis highlights the complexity of the aquifers in south Tipperary. The geological implications must be understood and taken into account when investigating the aquifers.

3.3 HYDROGEOLOGY

3.3.1 Introduction

The geological situation is a controlling factor of the hydrogeologic regime. The hydrogeology is therefore complex in the study area. Work elsewhere in similar situations suggests that the hydrogeological regimes in the Northern Region and

Southern Synclines are different. This suggestion was examined and found to be acceptable and therefore conceptual models were developed with this in mind. This requires assumptions to be made. The basis for these assumptions is derived from studies in Cork (South Munster Synclines) by Wright (1979) and more recently detailed work carried out by E.P. Daly, (1992) in the Nore River Basin. These studies have both been examined and where relevant, applied to south Tipperary. The basic assumption is that the geologic situation in the South Munster Synclines in Cork is the same as in the Southern Synclines and similarly the Nore River Basin is comparable to the northern region of this report.

The flow regime is different in the two areas. The primary reason for this is structure, which is clearly seen from the intensity of folding and faulting in the Southern Synclines.

The two hydrogeological concepts to be described are based on previous literature which provides a good understanding of the two systems. A number of areas that are typical of the major aquifers are looked at in detail in Chapter 3.11 The concepts refer particularly to the Carboniferous limestones as they are greatly affected by the deformational processes. A bedrock geology map (Map 2) has been prepared for this study with a detailed stratigraphy. This assists in discerning the hydrogeology in south Tipperary.

There are some hydrogeological features which are common to most limestones in south Tipperary. These are: secondary porosity and permeability due to faulting, dolomitisation and karstification. These characteristics are normally most developed in the highest 10-20m of rock, owing to the effects of weathering, geologic conditions and water movement.

The hydraulic conditions are predominantly unconfined in the main rock aquifers as the water table is generally less than 10m from the surface, with an annual fluctuation of less than 5m. The bulk of groundwater occurs in the unconfined areas, at shallow depths; it moves relatively rapidly along short flow paths and discharges in the effluent streams which cross the aquifers (Daly, E.P. 1992). Rainfall has a range of 1000 mm/year to 18000 mm/year approximately and is well distributed throughout the year. Recharge to the rock aquifers often takes place through the Quaternary deposits (Daly, E.P., 1993b).

The definition of aquifers adopted in this study is that used by the Geological Survey of Ireland. Bedrock aquifers (i.e. fissure flow aquifers) are divided into three main categories Regionally Important, Locally Important, Poor Aquifer/Aquitard. The two latter categories are further divided into two sub-divisions (refer to Appendix B.2). These categories and subdivisions are applied to the two hydrogeological environments.

3.4 CONCEPTUAL MODELS

3.4.1 Southern Synclines Conceptual Model

3.4.1.1 Introduction

The southern synclines is an area south of an arbitrary line drawn north of Cahir. The geological sequence in the lowlands predominantly comprises of Dinantian limestone with a few high relief Namurian areas. The uplands area consists of older Devonian and Silurian sandstones and shales. This area is considered to be a major groundwater resource area.

3.4.1.2 General Development of Permeability

The limestones in the south of the county were intensely folded by the Hercynian (E-W) orogeny. Today their outcrop is largely restricted to a series of synclinal valleys, flanked by anticlinal ridges of Devonian and Silurian clastic rocks. This region is part of the south Munster synclines. Its northern limit not clearly defined, since the intensity of folding decreases gradually. An arbitrary line drawn north of Cahir has been taken to define it (Map 2).

The key to the aquifer characteristics seems to lie in the geological structure, since this region is a distinct structural province. Wright (1979) concluded that insofar as preliminary conclusions could be drawn, the entire limestone succession (or at least the major part of it) could be regarded as one aquifer. This is due to continuity between the limestone aquifer units *via* faulting. This is not to say that the lithology of the various limestones is of no importance; some lithologies may be more permeable than others. But it does seem that the lithology is of less importance here, than in, for instance, the limestones of the Midlands (Wright, 1979).

Within all the limestones in the southern synclines the intense faulting and folding has created a secondary permeability. There is also some evidence of karstification. The extensive joints, faults, etc., make the strata susceptible to karstification by providing potential pathways for groundwater movement and resulting in enlargement by solution. The natural evidence for this secondary permeability is found in the general absence of surface water where the limestone is close to the surface, sinking streams, springs directly from rock, numerous cave systems, and collapse features such as swallow holes. The depth and extent of karstification of the principle limestones aquifers has largely been determined by older drainage systems and the length of time of deep groundwater circulation, could have operated below the base level of the present system. The most significant period was probably that in the late Tertiary (Drew, 1991). Another period when the conditions for active karstification were optimum probably occurred during the two glacial periods (Daly, E.P pers. comm.)

The structural deformation is expressed in the form of faulting, jointing and bedding planes. Some of the strata are indurated and so fracture easily. The compiled geology for the southern synclines shows that the anticlines and synclines are cut by series of shear faults, trending approximately north-south and a series of thrust faults with a general east-west trend. The major north-south shear faults are paralleled by a very well developed system of vertical or near vertical north-south joints.

3.4.2 Northern Region Conceptual Model

3.4.2.1 Introduction

The lowlands of this region comprise Dinantian limestones of which 50% are considered to be poor aquifers. The area contains the complete Carboniferous succession including the Namurian and Westphalian. The upland area of the Galtees, Slievenamon, and the Knockmealdowns is composed of Devonian and Silurian strata. These strata are not affected as much by the secondary deformational processes as in the southern synclines.

3.4.2.2 General Development of Permeability

The regionally important limestone aquifers in this region are divided into two hydrogeological formational units, due to the post depositional processes that have affected them. These processes include faulting which is less intense than in the southern synclines, followed by dolomitisation and karstification. The lithology of the strata govern which of the processes takes place. In general clean thick bedded limestone units that are open to the surface are susceptible to karstification. The faulting provides pathways for enlargement by solution. The limestones that have been dolomitised have lost their original bedding and formational contacts are obliterated. These processes all tend to open up the rock. The more intensely dolomitised the rock the greater the number of features that add to the permeability and storage. From a hydrogeological point of view the most important feature of dolomitisation is that it results in an increase in the porosity and permeability of a sediment as the crystal lattice of dolomite occupies about 13% less space than that of calcite (Freeze and Cherry, 1979).

In the south eastern part of Ireland there has been extensive dolomitisation of the limestones particularly those strata in the middle of the Dinantian succession i.e. Upper Ballysteen, Waulsortian, Crosspatrick and Aghmacart Formations. The intensity of dolomitisation generally appears to be greatest in the originally cleaner (Waulsortian and Crosspatrick formations) strata and along faults. Dolomitisation is not a near surface phenomenon and hence permeability can be anticipated to occur at depth. Permeability and weathering have been shown to exist at depths of over 100m at Killamery (south east Tipperary) (Hitzman and others, 1992).

3.5 APPLICATION OF THE CONCEPTUAL MODELS TO SOUTH TIPPERARY

3.5.1 Southern Synclines

The concept for the southern synclines has been adopted and specific cases studied. The lithology is considered in the understanding of the flow systems but the overriding feature is the structure.

The aquitard formations are similar in both regions and so are dealt with first. These strata are different from the aquifers in that they have relatively low permeability and storage. Much of the potential recharge is rejected and the throughput is relatively low. In these strata groundwater flow is generally restricted to the upper weathered zone, more permeable beds of limited extent and fault or fracture zones. Circulation is restricted to these types of areas with shallow flow and short flow cells, with very little continuity between them (Daly, E.P., 1992). The Silurian and Old Red Sandstone unconformity is a likely zone of higher permeability in these rocks. The Ballysteen and Ballymartin formations and the Aghmacart formation are the poor aquifers in the Dinantian. The Namurian shales and sandstones are hard and siliceous. Even though the shales are extensively broken near the surface they exhibit a very low permeability.

The Kiltorcan formation is a regionally important aquifer. In this formation the intensity of fracturing may vary over relatively short distances. It has been established that the positive fractures extend to depths of over 100m.

Limestones such as the Rathronan formation, Ballyglasheen formation, Silverspring formation, Waulsortian Mudbank formation, are considered to be regionally important aquifers due to their secondary permeability which is a result of the faulting, karstification and some dolomitisation. The Old Red Sandstones and Dinantian limestones, (Croane formation, Killee formation, Kilsheelan formation) even though their lithological descriptions imply that they should be considered to be poor aquifers, are classified as locally important aquifers due to their secondary permeability. The faulting creates local permeable zones.

Due to investigations carried out at Kedrah (Jones and Fitzsimons, 1992) it has been found that the alteration of the original strata has been complex and resulted from a number of geological processes that were sequential but also partially overlapping.

The fault systems have been mapped in the south Tipperary synclines and the mapped spacing of the north-south faults is typically about one every two and half kilometres.

Evidence of deep karstification is found by the presence of caves and is documented by speleologists. The Mitchelstown caves are the most well known caves in south Tipperary and work carried out there and in Mullinahone by Gunn (1984) also supports the influence of north-south jointing. These investigations leave no doubt that solution of the limestones in this region is widespread.

The presence of very large springs such as Poulalee, Poulatar, Mullenbawn, Roaring Well (Kiltinan), Kedrah and Roaring Water, indicates high throughput in the major limestone aquifers, i.e. Waulsortian, Rathronan and Silverspring formations, in the southern synclines. Karst features, like cave, swallow holes, sinking streams and springs aid in the delineation of the extent of the karstification (Map 5).

3.5.1.1 Aquifer Characteristics

Although there are few data on the properties of the limestone aquifers, they do appear to have transmissivities in the 200-2000 m^2/day range. Wright (1979) used groundwater hydrographs to gain a broader view of the potential of the southern synclines. The annual watertable fluctuation at Cloyne-Aghada (east Cork) is about 2.5 - 3 metres, though up to 6 -7 metres would be typical of the aquifer. The hydrographs also show that in such areas summer recharge can and does take place after heavy rain. The limestones i east Cork are overlain by permeable sands and gravels and they are in hydraulic continuity with the aquifer. These subsoils provide extra storage to the limestone as the water table of the limestones is in the sands and gravels. The available annual recharge is around 500mm and the watertable fluctuations imply a storativity of several percent (Wright, 1979). A similar situation is suggested for areas of limestone overlain by sands and gravel in south Tipperary.

The well yields (Appendix B.3) recorded prior to this study represent minimum yields as no detailed pumping tests were carried out, so that there are very few drawdown values and specific capacities have not been calculated. There is great variability in well yield as the permeability is dependent on the secondary processes.

3.5.2 Northern Region

The northern region is comparable with the Nore River Basin and hydrogeologic inferences are made from this comparison. The uplands are predominantly poor aquifers except for the Kiltorcan formation which is a regionally important aquifer and has been described earlier. The formation thickness decreases northwards, as does the permeability. The Old Red Sandstones are considered to be locally important. The lowlands are predominantly limestone and in which approximately half of the area is considered to be a poor aquifer.

In south Tipperary the extent of the dolomitisation within the Dinantian limestones is quite variable although there does seem to be a general decrease from east to west (pers. obs). Delineating the boundaries of aquifer units is difficult owing to the variability of the intensity of dolomitisation and the fact that the dolomitisation crosses lithological boundaries and often obliterates them.

The lithological characteristics of the Waulsortian and the Ballyadams formations are different. They are both considered to be regionally important. The lithology in conjunction with structural deformation creates environments where processes such as dolomitisation and karstification can develop and enhance permeability. The Crosspatrick formation is a locally important aquifer which has been subjected to similar secondary processes.

The Waulsortian and Crosspatrick formations units are considered to be aquifers only where they are dolomitised. The Waulsortian limestone formation is clean and it has been subjected to dolomitisation. Similarly, in the eastern area the Crosspatrick formation is also dolomitised and the contact with the Waulsortian formation is obscured.

The overlying Ballyadams formation is a very clean, massive bedded limestone with a middle unit which contains some clay wayboards. The secondary permeability of these strata results from the development of fissures through enlargement of joints and bedding planes by solution (Daly, E.P., 1992). However, only that part of the Ballyadams formation that crops out at the surface and lies above the lowest drainage water level is considered to be a major aquifer. Its lithology is conducive to the development of karst. The process of karstification is accentuated along structural features such as fold axes and faults which can result in very high permeability and throughput in relatively narrow zones. In the lower part of the upper unit and the lower unit of this formation there is preferential karstification. As mentioned previously the middle unit contains clay wayboards, which restrict groundwater circulation and therefore the vertical development of secondary permeability. In certain situations, there may be horizontal development along these wayboards. This unit is also characterised by its steeply rising water table. The faulting may allow interconnection between formational units.

The Westphalian sandstones are considered to be locally important aquifers. Their permeability is related to the jointing. The transmissivity of these sandstones is relatively low but has been found to be an order of magnitude higher close to faults.

There are two possible sand and gravel aquifers present in the northern region, at Mocklershill (S 213 140) and Donaskeagh (R 194 141). These deposits are extensive and are greater than ten metres in thickness. No buried subsoil aquifers have been mapped out, therefore these aquifers are generally unconfined and are usually in continuity with the underlying strata. The thickness of the saturated zone determines the well yield. As these subsoil deposits have not been mapped in detail, it is difficult to define the exact extent and thickness of possible aquifers. Numerous limestones discharge to springs and streams *via* lenses of sands and gravels. The subsoil aquifers are considered to be locally important.

Where the sand and gravels are thin and permeable these deposits can have a major effect on the recharge and discharge of underlying rock aquifers and can also provide a source of additional storage for the bedrock aquifers. The flow in these deposits is intergranular.

3.5.2.1 Aquifer Characteristics

The permeability of the different parts of the Kiltorcan formation will depend primarily on the amount of the sandstone present, the thickness of the individual sandstone units and their degree of interconnection. The well yield and permeability is greatest in the south where the deformational intensity is greatest.

The dolomitisation of the original Waulsortian limestones resulted in increased porosity, vugs, cavities etc. Subsequently, this porosity was enhanced by the other processes such as faulting, weathering and karstification to create a considerable secondary permeability. The structural features, as in the southern region, create preferential flow pathways.

The flow in the karstified systems tends to be more conduit along the fault zones. In the upper and lower units of the Ballyadams formation the groundwater circulation is unhindered. There are considerable variations in the hydrogeological conditions in this aquifer unit, owing to the wide range in elevation of the outcrop areas and its karstic nature.

The well yields in limestones of the northern region as might be expected are very variable. This is a result of the localised development of the secondary permeability. As with the southern synclines the best recorded yields are found along fault zones with some associated karstification and dolomitisation. Some well yield, specific capacity and transmissivity values from the Nore River Basin are taken to represent the range of values attributable to the northern region (Table 3.2).

The hydraulic conditions of the sand / gravel aquifers depend on the type of deposit, whether outwash or valley train deposit. The outwash sand and gravel aquifers are cleaner and therefore more permeable. The water table in the sand and gravel aquifers is usually within 5m of ground level and its annual fluctuation will be less than 1m. As noted earlier they usually provide extra storage for the underlying rock aquifers.

3.6 SIMILARITIES BETWEEN THE TWO CONCEPTUAL MODELS.

There are a number of geological factors and processes which are responsible for the secondary permeability. The processes that are applicable in south Tipperary are; lithology, stratigraphy, dolomitisation, structural deformation, karstification, drainage history, topography and weathering. These factors are found in the two conceptual areas but with different intensities.

The structural deformation is involved in the development of the secondary permeability. In both the Southern Synclines and the Northern Region, karstification has developed under different conditions in the two areas. Depressions of the sea level allowed this karstification to go deep into the limestones e.g. Ballymacadam, and a later rise in relative sea level submerged the lower parts of the karst limestones and at the same time filled in the old channels with sediment (Wright, 1979).

The overall groundwater flow direction is towards the sea. This path is relatively open with a restriction west of Mooncoin, Co Waterford. The water level

Strata	Aquifer Type	Well Yield (m^3/day)		Specific Capacity (m^3/d/m)		Transmissivity (m^2/day)	
		South Tipperary	Nore River Basin **	South Tipperary	Nore River Basin **	South Tipperary	Nore River Basin **
Kiltorcan Fm.	Regionally Important	2509 - 2350	50 - 1300	4.12	2 - 270	---	40 -100
Waulsortian Fm.	Regionally Important	196 - 216000	300 - 3000	---	10 - 350		50 - 800
Ballyadams Fm.	Regionally Important	164 - 2273	10 - 2000	---	100 - 300	---	1 - 500
Rathronan / Ballyglasheen Unit	Regionally Important	600	---	150	---	100 - 2000	---
Sand and Gravel	Locally Important	1308 - 1820	200 - 1000	48 - 76	50 - 2000	---	100 - 2000
Crosspatrick Fm. Silverspring Fm.	Locally Important	436 - 654	250 - 2400	8.6	10 - 250	---	20 - 200
Westphalian Sandstones	Locally Important	1055	100 - 500	---	10	---	5 - 15

Table 3.2 Aquifer Characteristics related to south Tipperary.

** Source of information E.P. Daly, 1993.

in aquifer units are slightly lower than in aquitards. The flow is preferentially through the aquifer units i.e. they capture flow from fault zones.

3.7 GROUNDWATER DEVELOPMENT

Evidence from drilling in the Kiltorcan formation shows that the largest yields are obtained at relatively low lying locations, close to major structural features and where at least 40 m of the upper part of the Kiltorcan formation is penetrated. Optimum well yields from the Dinantian limestones will be obtained from boreholes drilled into one of the major fault zones and penetrating at least 50 -100 m of the aquifer. The extensive weathering in the dolomitised Waulsortian and Crosspatrick formations creates problems for drilling. The karstic nature of the Ballyadams formation also creates problems for the location of high yielding sources. These zones of karstification indicate productive zones and need to be identified. The locally important aquifers are most productive in low lying faulted ares, where over half the formation thickness is penetrated. Boreholes in the poor aquifers generally give supplies sufficient for a house and/or farm (10 - 40 m^3/day) (Daly, E.P. 1993).

3.8 REGIONALLY IMPORTANT AQUIFERS

3.8.1 Southern Synclines

3.8.1.1 Kiltorcan Formation

This unit includes the Kiltorcan and Porter's Gate formations. These strata are found over much of the southern part of Ireland and are the lowest aquifers in the sedimentary sequence. In the outcrop area it can be either unconfined in continuity with sands and gravels or confined by till. At depth it is confined by the overlying poor aquifers.

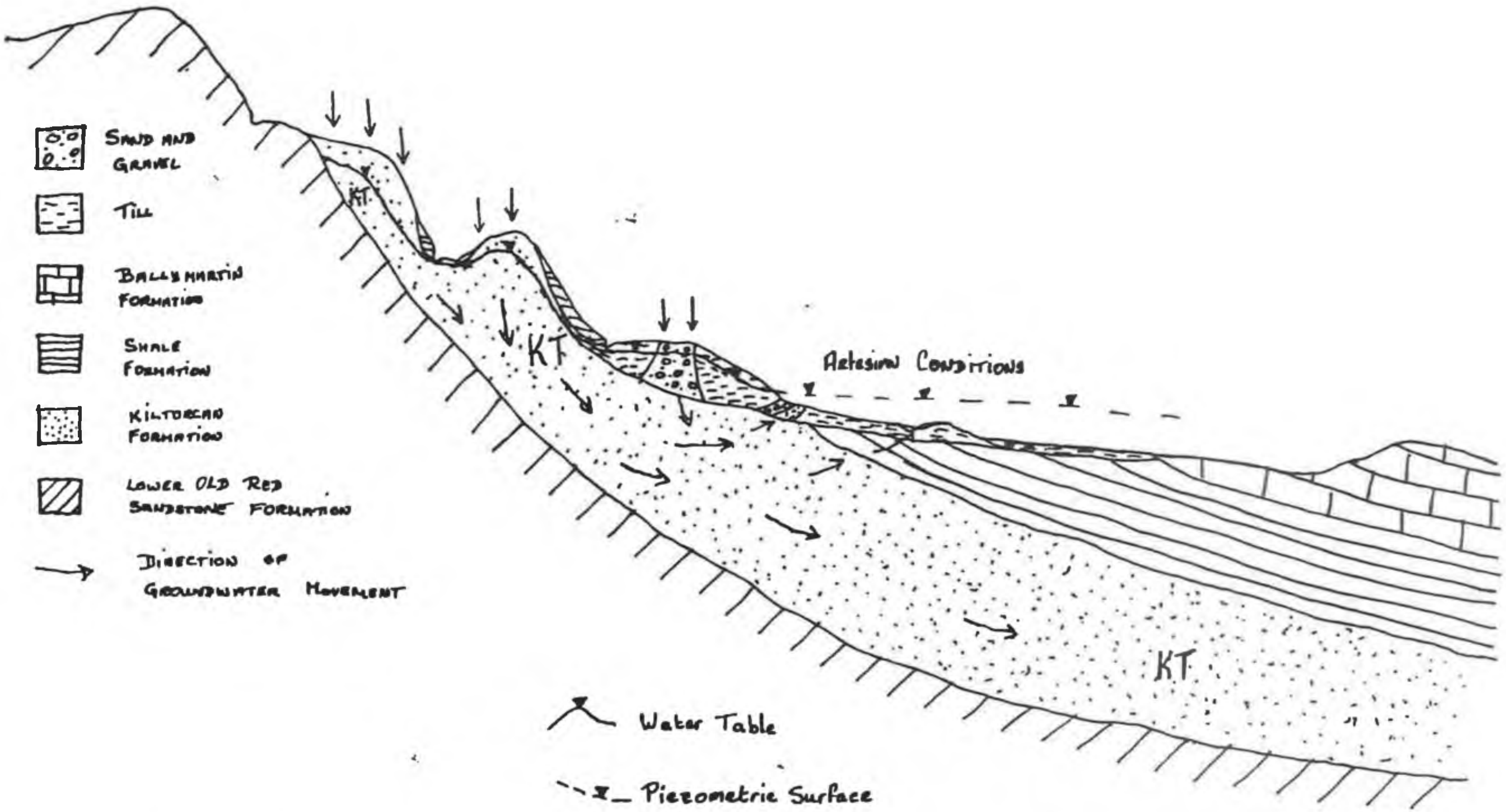
The permeability of this aquifer results from faults, joints and microfractures. Its permeability is greatest towards the base of the Porter's Gate and the upper half of the Kiltorcan formation and close to major structural features. The southern area was subject to more intense deformation. There will be a reduction in transmissivity at depth, where the Kiltorcan formation is thinner in the centre of the syncline. The permeability is also lower as the sandstones are deeply buried. Downdip towards the middle of the synclines, the aquifer becomes progressively more confined by an increasing thickness of the overlying poor aquifer. Substantial artesian flows have been recorded in this aquifer owing to the pressure created by the elevation of the water table in the outcrop area and the possibility of low-lying confined areas nearby (Fig. 3.2).

There is no obvious discharge zone for the groundwater moving at depth in this aquifer. It is likely that the groundwater flows, *via* large faults and complex pathways into shallower groundwaters. Large faults may also retard the circulation of groundwater at depth, either by isolating all or part of one block of an aquifer from another or isolating the recharge area from the deeper parts of the aquifer (Daly, E.P. 1988).

3.8.1.2 Waulsortian - Silverspring Unit

This unit is a highly productive, regionally important aquifer. Very high discharge springs, for example Poulalee and Poulatar near Ardfinnan, are found in this unit. These two springs are dealt with in detail in Chapter 3.11. The Silverspring formation is included in this aquifer as it is also affected by the intense faulting and is clean and is in continuity with the Waulsortian formation. It is bounded above in places by a locally important aquifer, the Kilsheelan formation and below by a poor aquifer, the Ballysteen - Ballymartin Unit. The limestone outcrops at the surface at the edges of the synclinal basin (Fig. 3.3). The overlying subsoil deposits are usually limestone till and generally tend to be less than five metres in thickness.

The extensive faulting in these synclines (Map 2) creates regular joints and makes the strata amenable to the development of karst. There is evidence of significant karstification in the southern synclines from the presence of numerous swallow holes at Raheen (south of the Galtees) and a number of springs including the very large one at Kedrah.



(Modified after Daly, 1988).

Fig. 3.2. Artesian Flow in Kiltorcan Aquifer System

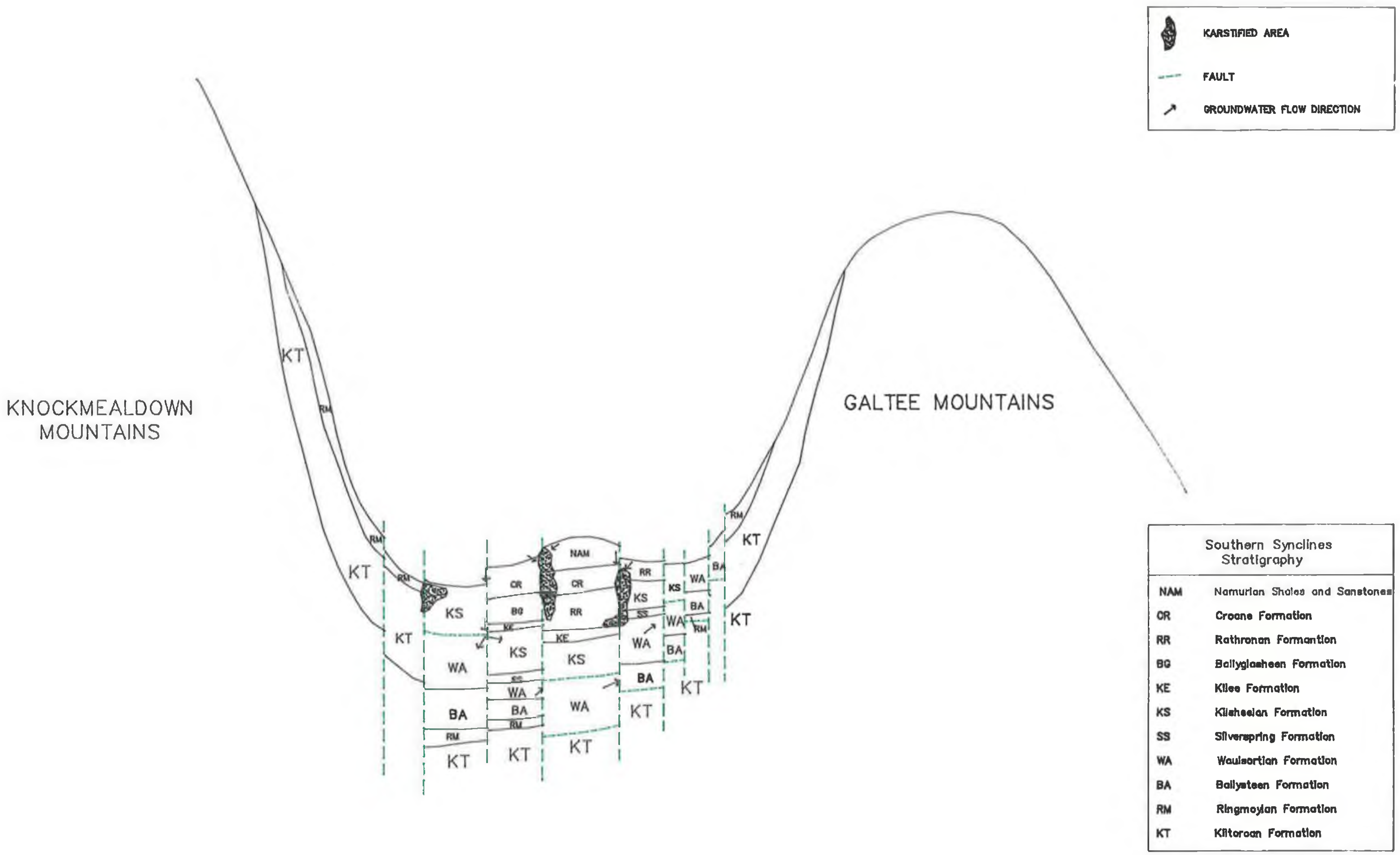


Fig. 3.3 Schematic Representation of Structural Deformation, Karstification and Groundwater Flow in the Southern Synclines. (Cross—section derived from Map 2 — Bedrock Geology)

Detailed work undertaken by Jones and Fitzsimmons (1992) at Kedrah discovered extensive dolomitisation within the Waulsortian formation. The dolomitisation, although part of a broad regional event, appears to be fault and/or joint controlled with a northeast trend. There is a variation in degree of dolomitisation exhibited in outcrop. The dolomitisation has not been mapped in detail; however the faulting creates a high permeability and the dolomitisation becomes a third factor. The dolomitisation is a more significant factor in the northern area and occurs only in small localised patches in the southern synclines.

3.8.1.3 Rathronan Unit

This unit contains the Rathronan and Ballyglasheen formations as the latter has not been mapped in detail in the western area. The lithological description of the Rathronan formation does not suggest it to be a regionally important aquifer, but the extensive faulting and the resultant karstification creates a good secondary permeability. There is very good evidence for the karstification The Thongue river sinks southeast of Ardfinnan, and approximately one kilometre east of the sink, located on the banks of the Suir, is a very large spring, Roaring Well. There is a postulated connection between the two (pers. com. G.L. Jones). The flow is more conduit than diffuse, but the faulting may tend to retard it as the groundwater has a tortuous pathway between blocks (Fig. 3.3).

The Ballyglasheen formation is oolitic and therefore is a clean limestone unit. This unit is underlain by the Kilsheelan Unit which is a locally important aquifer and is overlain by the Croane formation which is also of local importance. It is suggested that there is some vertical continuity through the faults between these units. The subsoil material overlying the outcrop area is predominantly limestone till with some smaller areas of sand and gravel and till with gravel. The depth to bedrock is usually less than five metres and so the aquifer is generally unconfined in the outcrop area.

Transmissivity values and storativity values are unknown for this unit but Wright (1979) suggested that these limestones have a moderate to high (100-2000 m^2/day) transmissivity. The shallow flow direction in this unit is towards the streams, but at depth flow direction is south easterly.

3.8.2 Northern Region

3.8.2.1 Kiltorcan Formation

This unit is very similar to that described in the section on the Southern Synclines. The intensity of the structural deformation decreases to the north and the dip of the strata becomes shallow also.

3.8.2.2 Waulsortian Unit

The dolomitised Waulsortian mudbank limestone is a major aquifer in this area, and is the source of large volumes of water for wells, springs and river baseflow. The less intense structure provides a situation in which dolomitisation can develop. As mentioned previously the dolomitisation causes an increase in porosity and hence permeability. The Waulsortian formation is overlain by the Crosspatrick formation and in places by the Aghmacart formation. In places it is assumed that the Crosspatrick has been so totally dolomitised that the boundary with the Waulsortian is obscured. The dolomitisation has locally spread up to the Aghmacart formation and as low as the underlying Ballysteen formation (Daly, E.P., 1992).

The transmissivity in this aquifer normally ranges from 20-400 m^2/d with a specific yield of up to 3%. The water table levels are normally close to the surface (5m) in the discharge areas and at considerable depth (up to 20m and over) in the more elevated recharge areas. The presence of numerous springs which possess large discharge rates indicates that the aquifer has a very high throughput.

3.8.2.3 Ballyadams - Lismalin Unit

The Ballyadams formation is very susceptible to karstification. The secondary permeability of these strata results from the development of fissures and joints which have then been enlarged by solution. These strata exhibit fissure flow and are very susceptible to pollution. This aquifer receives recharge from runoff from the Namurian hills through the swallow holes at the edges, as well as direct recharge through the subsoil. The presence of swallow holes, springs and a turlough in this strata type indicates varying degrees of karstification.

It is only possible to selectively exploit this aquifer but it does have a high baseflow output to the rivers. This is clearly seen in the area of Loughcapple Bridge (southeast of Fethard), where there is at least a four fold increase in baseflow in a 3 km interval. The area around Fethard is a very important example of this aquifer and will be discussed in detail in Chapter 3.11.

The Ballyadams formation is bounded at the base by the Aghmacart formation which is an aquitard and is overlain by the Lismalin formation which is included here as it also has extensive karstification in the lower part. In some places the Lismalin formation is faulted out and the formation is confined by the overlying Namurian shales. It is generally unconfined where it outcrops, the cover being shallow till with gravel or limestone till.

The well yields vary but some typical values are between 327 -2273 m^3/day.

3.9 LOCALLY IMPORTANT AQUIFERS

3.9.1 Southern Synclines

3.9.1.1 Old Red Sandstone Unit

This unit is considered to be a moderately productive local aquifer. The sandstones themselves are too indurated to contain a primary permeability. The faulting provides some very local zones of secondary permeability strata. This unit is bounded at the base by Silurian strata which are considered to have a low permeability and above by the Kiltorcan formation which is a major aquifer. It usually outcrops at high elevations and so the cover is very thin and the strata unconfined.

3.9.1.2 Kilsheelan - Killee Unit

This unit is comprised of the Kilsheelan and Killee formations and is considered to be moderately productive locally. The upper part of the Kilsheelan formation is predominantly coarse grained thick bedded packstones, grainstones and wackestones, susceptible to karstification as a result of the faulting. The extent of the karstification has not been mapped in identifiable units. However, there is evidence of karst at Garyclogher (S 202 123). There is an abundance of depressions, swallow holes and a local stream sinks during the summer. It was noted from the locals that these depressions are still active. The ground has collapsed beneath a horse and plough and even more recently engulfing a lawnmower . The Mitchelstown caves are found in the upper part of the formation. They show evidence of the north south fracturing at depth.

The upper part of the Kilsheelan formation appears to be more permeable than the rest of the unit, but unfortunately it has not been mapped in detail. The lithology suggests that the rest of the formation is impermeable but some secondary permeability is developed along and close to faults.

There are some similarities with the Killee formation which is similarly affected by localised karstification and faulting. Some dolomitisation occurs within this formation in isolated areas, especially west of Clonmel. Where the formations come to the surface they are covered by usually less than five metres of limestone till or till with gravel and are unconfined. There is not a lot of reliable well data for this aquifer unit and the largest yield noted during this study was 221 m^3/day.

3.9.1.3 Croane Formation

This formation consists of thin bedded dark micritic limestones with shales and cherts and is found along the synclinal fold axis. The Rathronan/ Ballyglasheen formations bound it at the base. It is generally unconfined except when it is overlain by approximately ten metres of impermeable subsoil. As it is found along the synclinal axis it was subjected to compressional forces and is compacted. The fine grained limestones do not have much permeability and so as with the other limestones it is dependent on secondary permeability resulting from the faulting. The faulting tends to connect different aquifers blocks and create a tortuous flow between the aquifers (Fig 3.3).

3.9.2 Northern Region

3.9.2.1 Old Red Sandstone Unit

This has been already described under the southern synclines. However, the intensity of the faulting is reduced therefore the localised permeability will also be reduced.

3.9.2.2 Crosspatrick Formation

This aquifer outcrops in thin narrow bands in the northern area. The strata boundaries are not well defined due to the extensive dolomitisation. It overlies the dolomitised Waulsortian limestones to the north east and the Ballysteen Unit, an aquitard, in the west. The Waulsortian formation only developed as mounds in the western area and so accounts for the connection with the Ballysteen formation. The upper boundary is with the Aghmacart formation, an aquitard. The formation is more permeable where dolomitised.

The formation becomes confined down-dip where it is likely to be much less permeable. Over the outcrop area the hydraulic conditions vary from unconfined when it is in continuity with overlying sands and gravel, to being confined by thick till or till with gravel. The aquifer is recharged in the more elevated areas where the subsoils are thin and permeable. It discharges into the small streams that cross it (Daly, E.P., 1992).

The well yields in the northern region have been found to be in the range of 250 - 654 m^3/day, with estimated specific capacities of 8 - 20 m^3/day/m and transmissivities in the Nore River Basin in the 20 - 200 m^2/day range.

3.9.2.3 Westphalian Sandstones

There are two important sandstone units and a number of minor ones in the Slieveardagh Uplands. The principal units are the Glengoole and Main Rock sandstones. The Glengoole formation is the most productive; the transmissivity is quite low but has been found to be higher close to faults.

These sandstones are recharged at the edges of synclines, are confined at depth by shales, coal seams, and fireclays and frequently give artesian flows. The mainly impermeable soils, strata and the geological structure in this area limit the amount of recharge available and therefore the throughput of these aquifers (Daly, E.P., 1992). The hydrogeology of this area has been described in detail in a report by E.P. Daly (1980b).

3.9.2.4 Sands and Gravels

The sands and gravels in south Tipperary are generally thin (< 10m) except for a few areas in the central region around Tipperary town. These thin deposits can have a major effect on the recharge and discharge of the underlying rock aquifers and also act as extra storage. Numerous limestone aquifers discharge via springs and streams through these deposits an example of this is seen at Rathcoole (S 219 137).

Where sand and gravel deposits are greater than ten metres, permeable, saturated and extensive they are considered to be aquifers in their own right. In south Tipperary the lack of detailed mapping of these deposits does not allow determination of these deposits as regionally important major aquifers, so they are considered to be locally important. The sources at Springmount and Ironmills are found in sand and gravel deposits. The well yield of these deposits varies significantly. Springmount, which is a clean sand and gravel deposit, has a yield of 1820 m^3/day and the fluvio-glacial deposit at Ironmills has a yield of 1325 m^3/day.

3.10 POOR AQUIFER / AQUITARDS

3.10.1 Southern Synclines

3.10.1.1 Silurian Unit

The Silurian strata are the oldest rocks in the succession in south Tipperary. They outcrop in the core of the mountains, forming the Lower Palaeozoic inliers of the Galtees, Slievenamon and the Knockmealdowns. As with the Old Red sandstone unit these rocks are very indurated and not as affected as the limestones by the intense faulting. Although the Silurian / Old Red Sandstone unconformity is a likely zone of higher permeability these strata are generally unproductive.

3.10.1.2 Ballysteen/Ballymartin Unit

These lower limestones are generally unproductive. Their lithology suggests that there is no primary permeability and they tend to deform plastically when subjected to a stress. They predominantly consist of shales and argillaceous limestones, bounded at the base by the Kiltorcan formation and at the top by the Waulsortian unit. They are generally unconfined where they outcrop as the subsoil cover is usually thin.

3.10.1.3 Giant's Grave formation / Namurian shales

This is one of the Upper Carboniferous units and is not productive. It contains a large amount of shales and argillaceous limestones which form a confining layer over the underlying formations. This is not a conformable contact and so the lower unit varies. Faulting has affected these strata and has cut off flow from one block to the other; therefore there is not a continuous flow system. There are unconfined units but they do not accept a lot of recharge and so there is a high percentage of run-off. This run-off then sinks underground through swallow holes in the adjoining limestone formations.

3.10.2 Northern Region

3.10.2.1 Aghmacart Formation

The argillaceous content and the interbedded nature of the clean and muddy limestones have restricted the groundwater movement and therefore prevented active karstification. Hence this formation has low permeability and is considered to be a poor aquifer.

3.10.2.2 Silurian Unit

3.10.2.3 Ballysteen - Ballymartin Unit

3.10.2.4 Giant's Grave / Namurian

The three units above units have already been described with regard to the southern synclines. In general they are similar in the northern regions, the main difference being that the structural deformation was not as intense here. This implies that these strata have even a lower permeability.

3.11 INDIVIDUAL GROUNDWATER SOURCES

3.11.1 Introduction

Detailed hydrogeological investigation of all major groundwater sources could not be undertaken within the time constraints of this study. As a consequence it was decided that a number of important sources be selected for detailed study. These were Mullenbawn; Ironmills; Springmount; Poulalee and Poulatar; and Roaring Well. Mullenbawn, Ironmills and Springmount are typical sources representative of the northern region. These are owned by the Local Authority. Poulalee, Poulatar and Roaring Well are indicative of the hydrogeological situation in the southern synclines. These are privately owned, undeveloped springs. A suite of maps for each site is found in the back pocket of this thesis.

3.11.1.1 Source Selection

The Local Authority have responsibility for twenty eight groundwater public supply sources in south Tipperary. A site selection process was employed to categorise each source in terms of its yield, aquifer type and vulnerability. Of the twenty eight sources (including Poulalee and Poulatar) only seven have yields greater than 1000 m^3/day (see Appendix B.3). Hence, the others were considered to be of minor importance. Although Coalbrook was initially under consideration due to the natural protection afforded by the overlying shales and sandstones, it was excluded from the group for detailed mapping. Similarly, Kedrah which is a major natural spring has been eliminated as its potential for investigation is hindered by the new Cahir by-pass and it is not considered a viable option.

The aforementioned sources (section 3.11.1) comprise the remaining sites for further investigation. During reconnaissance mapping a high yielding spring ie., Roaring Well (NW of Ardfinnan) was discovered. The Thongue river sinks approximately 1.5 km due west of this spring therefore it was thought to be worthy of detailed study.

3.11.1.2 Site Investigations

Detailed subsoil mapping was undertaken in the vicinity of each source. The locations of hydrogeological features were noted. The surface water flow direction was established and low flow measurements were recorded around the Fethard area (Mullenbawn) and at Ironmills. A thirty six hour pumping test was carried out at Ironmills.

The wellhead and spring outflows were inspected for the safeguarding of the sites. The vulnerability of each source was assessed and its implications for the groundwater protection plan were determined.

3.11.2 Northern Region

3.11.2.1 Mullenbawn

This is an important L.A. groundwater source, it is a large spring and is located south of the town of Fethard. The majority of the Fethard area is uplands which are rock-cored. Overlying these uplands is a thin layer of till. In the lowlying areas along the river Clashawley, there are irregular shaped deposits of sand and gravel. Between Pepperstown and Coolmore there is a lot of gravel present. In the Coolmore stud area, it has been observed that below 100 m asl there are extensive gravels; above this, rock is close to the surface with a very thin covering of till in places. Higher than 120 m asl the rock is extensively outcropping. Mullenbawn is a classic example of karst in the south midlands of Ireland. This source cannot be considered on its own as there is a major private source, Roaring Water at Kiltinan, approximately 1.5 km south of the local authority's supply.

The geology of the area is complicated by splayed normal faults. Also within 6 sq. kms of the L.A. source there are numerous swallow holes and active springs which indicate a complex karst environment. A large rotational fault parallel to the river east of Cramp's Bridge to Loughcapple Bridge in the south, is an important factor for the hydrogeology (Fig. 3.4).

There are a series of minor springs along the fault line which contribute to the baseflow in the river. This baseflow input is obvious at Loughcapple Bridge where the flow increases dramatically within 2 km downstream. Flow measurements have been taken using dye-dilution and current meter methods, to assess the baseflow contribution in the area (Appendix B.6). At Kiltinan there is evidence of springs within the base of the river bed beside the castle. The Roaring Water spring is very impressive and lives up to its name. The low flow was measured to be 159 l/s during September 1992, and the temperature and conductivity measures taken at the time were 11^0 C and 675 uS/cm respectively. The estate caretaker made suggestions of a connection between Roaring Water and a sinkhole outside Cashel but no details are known.

The groundwater flow in the Mullenbawn/Roaring Water area is towards the river. In the case of Mullenbawn the direction is westwards, while for Roaring Water it is eastwards. In the southern area of Loughcapple Bridge, the Aghmacart formation (poor aquifer) is found in contact with the Ballyadams formation (regionally important aquifer). The Aghmacart formation inhibits the groundwater flow and so as the general flow direction is southwards, the water backs up and emerges along the fault zone and into the river. The elevated area to the west between Kiltinan and Mullenbawn comprises Namurian shales and sandstones which is a poor aquifer and constricts the flow between it and the Aghmacart formation at Loughcapple Bridge. Similarly to the north-east of Mullenbawn there are elevated Namurian shales outcropping at the surface.

At Rathcoole, approximately 1 km north of Mullenbawn, there is a large gravel pit, which contains a number of large springs. 11365 m^3/day has to be pumped out to enable the quarry to be operated. The sands and gravels are clean and well sorted. The immediate area is surrounded by rock close to the surface. The gravel thins out

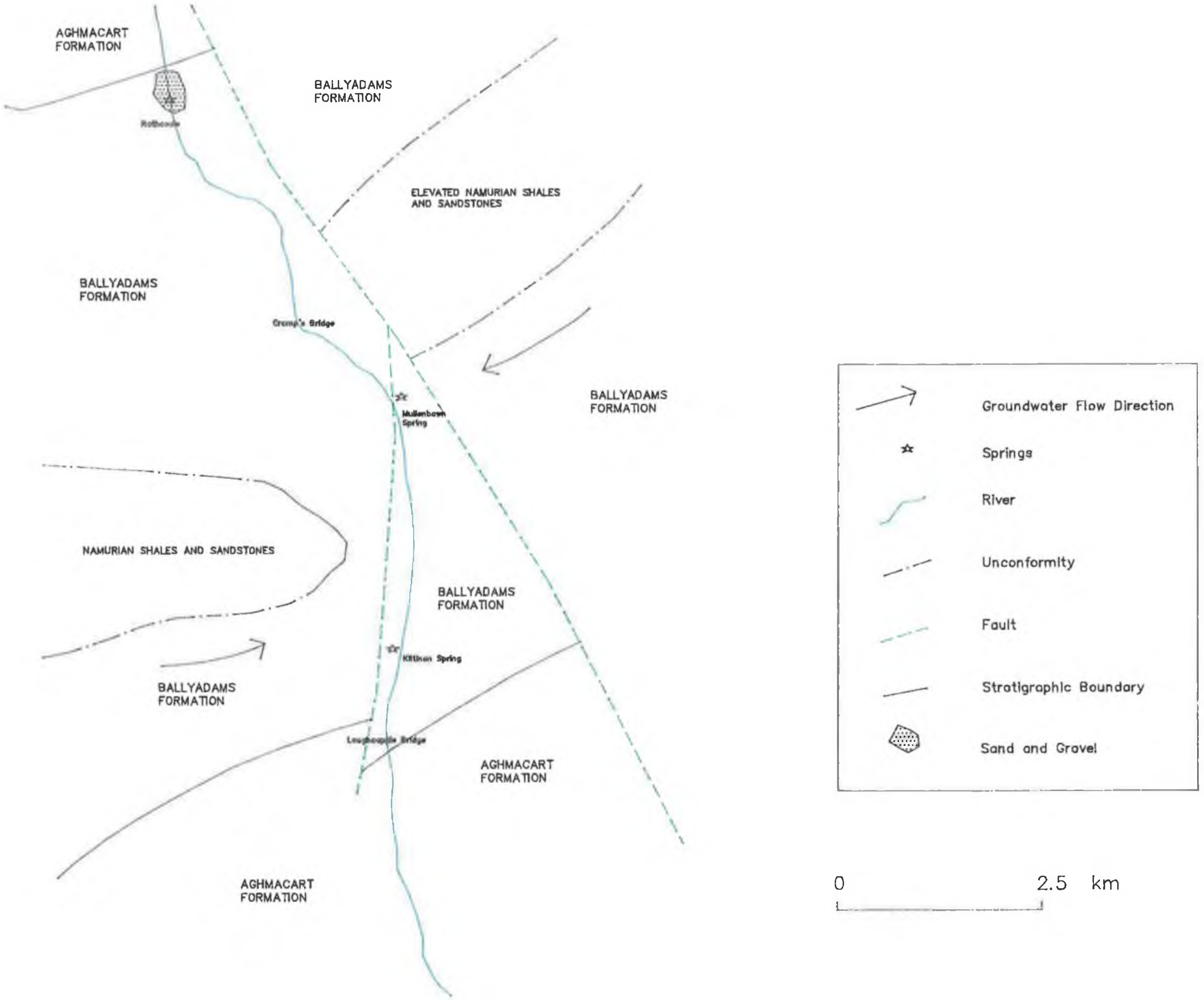


Fig. 3.4 Schematic Representation of the Hydrogeological Setting around Fethard.

from north to south. The springs at Rathcoole may be associated with the Aghmacart - Ballyadams formational divide.

It is obvious that the whole area contains very important resources and requires a lot of protection. It would be difficult to define source areas for these large springs in such a karstic environment. The map of the immediate source area is found in the map pocket, this is not adequate but any more detailed hydrogeological investigations were beyond the scope of this project. A major source of pollution is the sewage treatment works which is in close proximity to the source. The chemical analysis indicate that this source is frequently polluted by bacteria. This is not surprising considering that there is very little protection afforded to the resource.

3.11.2.2 Ironmills

This is an important L.A. source for the north-west of the county which provides 1325 m^3/day. This source is derived from a borehole within fluvio-glacial sands and gravels of thicknesses in the order of 20 m. The Multeen river flows immediately east of the source. The general area to the west is hilly and becomes flatter eastwards. The river provides the main drainage for the area. The groundwater flow direction is southward and reflects the surface flow as the aquifer is unconfined sands and gravels. There is a major watershed less than 1 km west of the source. The water west of this divide flows to the Shannon and the rest to the Suir catchment area. River flow measurements have been taken upstream from the L.A. source (Appendix B.5).

A thirty six hour pumping test was carried out to assess the impact of the source abstraction on a local dug well. Temperature and conductivity measurements were taken in the rivers and of the discharge from the source borehole to try and establish a hydraulic connection between them. It is thought that the river is leaky and not in full continuity with the borehole (Appendix B.6).

The immediate area of the source, along the river, is composed of sand and gravels with some Old Red Sandstone till surrounding it. The underlying bedrock is Old Red Sandstone which is considered to be a locally important aquifer. The vulnerability is determined to be high to extreme.

3.11.2.3 Springmount

This is an important source from the L.A. point of view. This spring outflows through gravels overlying the Aghmacart formation, a fine grained poor aquifer. It is typical of a gravel aquifer situation. The area is flat, low lying with an elevation generally less than 60m. The source bubbles up through a sandy floor in base of octagonal container. The source has an abstraction rate of 1820m^3/day.

The area between the spring and the river is marshy, with lots of reeds and rushes which indicate poor drainage. The area to the west is predominantly gravel /till with gravel with rock close to the surface in places. There are small gravel quarries in the area at Thomastown and at Ballinaclogh Bridge. The land has a very slightly undulating surface which is probably more a reflection of the subsoil deposition than of the subsurface topography. Artificial streams and lakes were created for Thomastown castle. These streams took water from the Multeen River around Morpeth Bridge and redirected it to the lakes at Thomastown. Most of the streams have since been filled in. There was difficulty in procuring water in the area up to the development of the Galtee Water Scheme. The gravels in most places are relatively thin, less than 5m and in the sand and gravel quarries the water table is deep.

The natural groundwater flow direction is towards the river and possibly the alluvium is very silty and clayey, therefore it forms an impermeable boundary and forces the groundwater to back up and come to the surface at Springmount. This is considered to be a locally important aquifer and it is unconfined. The groundwater flow is in these gravels as the Aghmacart formation which underlies these deposits is poor aquifer.

The area is defined as being extremely vulnerable as there is usually less than 5 m to bedrock and the overlying subsoil deposits are either till-with-gravel or sands and gravels. The chemical analysis (see Chapter 4) suggests that there is a high incidence of bacteria.

3.11.3 Southern Synclines

3.11.3.1 Poulalee and Poulatar

These are two very good examples of karst springs in the southern synclines as they are part of a large conduit system. Water from Poulalee flows east past Poulatar and picks up its water before joining the river Tar. The two sites are presumably linked and part of a big system which was dye-tested from the foot of the Knockmealdowns. The water therefore has to flow under the river to resurge, and probably on the way feeds water to Tobernacallin on the southern bank (Jones, G.Ll. 1989). The smaller southern spring never goes dry according to some locals. The low flow discharges are 5450 and 2725 m^3/day respectively. The temperature of both springs has been recorded as being 10.3^0 C (2/5/1993). The conductivity of Poulalee is 426 *u*S/cm @ 20 ^{0} C and for Poulatar is 413 *u*S/cm (2/5/1993). Poulalee outflows from a rock fracture which has reportedly been dipped to 30m.

The geology comprises Kilsheelan, Waulsortian and Silverspring formations. The Kilsheelan formation being the core of a tight syncline. The Tar River flows along the axis of this fold. It has one of the highest baseflows in the country with a dry weather flow of 5.68 1ps/sq. km (lowest published dry weather flow) (Wright, 1979). This indicates that the river is receiving groundwater along its length. There is a lot of rock outcropping in the immediate area of the springs. Elsewhere there is a thin covering of limestone till.

The chemical analysis (Chapter 4) of the water at these sites indicates serious bacterial problems. It is not clear from the data available to the author whether or not the bacteria come through the aquifer or are as a result of contamination at the sampling area.

3.11.3.2 Roaring Well and Thongue Sink

Roaring Well as its name suggests is a major spring. It is located north west of Ardfinnan. No flow measurements were taken but it is of the same order of magnitude as Roaring Water (Kiltinan). The hydrogeological situation is similar to Kiltinan as the flow is directly from a shear rock face and is fault related. There are a number of smaller springs discharging into the Suir River along the western bank. The temperature and conductivity of the spring was recorded on 12/08/1992 as being 12.2 ^{0} C and 160 uS/cm respectively. The conductivity value is low as the measurement was taken after a night of heavy rain.

The rock type is the Rathronan formation which is considered to be a regionally important aquifer. The area has substantial rock outcropping at the surface. The discharge from the spring was discoloured after a night of heavy rain, this may indicate a response time of a few hours.

Less than a kilometre west of these springs the Thongue River sinks in dry weather and loses half its water the rest of the time. Gunn (1984) states that water from the sink has been traced to three risings on the banks of the Suir. The average linear velocity - 135 m/h -, measured by Gunn, suggested that flow is turbulent in an open conduit system and this was confirmed by divers who entered Roaring Well and explored over 700m of largely water filled passage (Gunn, 1984). West of this sink there is a rock cored hill which has a small cave within it (60m long, 1-3m in diameter). This also indicates a karstic environment. The whole area is considered to be extremely vulnerable as it is a karstic area with rock outcropping close to the surface.

CHAPTER 4 - HYDROCHEMISTRY / WATER QUALITY

4.1 HYDROCHEMISTRY

4.1.1 Introduction

Groundwater is part of the hydrologic cycle and this involves the constant movement of water, above, on and below the Earth's surface. Most groundwater is meteoric water, i.e. derived from rainfall and infiltration within the normal hydrologic cycle. The chemistry of precipitation is that of a dilute acidic, oxidising solution which is altered during its passage through various strata. Increases in total dissolved solids and most of the major ions occur due to the solution of minerals in the strata through which the water is moving. These changes depend on the rate of groundwater movement (water moving rapidly dissolves less due to a shorter contact time), the temperature and pressure conditions.

Analyses of groundwater in south Tipperary were collected and compiled to investigate the hydrochemistry and water quality of the main strata.

4.1.2 Sources of information

Existing data from all available sources such as the County Council, Regional Water Laboratory, private springs and industrial water supplies were used to examine the hydrochemistry and water quality of south Tipperary. A total of 164 analyses were collected between 1984 to May 1993. Partial analyses were carried out for the majority of the samples, with full analyses for 93 of the samples. No regular sampling regime was in operation during this time. The data were entered into a computer package, HydroCOM, a user-defined database set up for the various ranges of parameters; access to these data is from the GSI.

The EC (Quality of Water Intended for Human Consumption) Standard (80/778/EC) is implemented in Irish law by Water intended for Human Consumption Standards (SI 81 of 1988) (Drinking Water Standards). There are some differences between the EC and Irish standards. The EC and Irish (Drinking Water) Standards have been used for comparison of the analyses taken for south Tipperary (Table 4.1). The EC standard refers to drinking waters irrespective of their source. A statistical analysis of exceedances and compliancies was carried out and provides a basis for the assessment of the groundwater quality.

The frequency of sampling does not allow the annual variations in chemistry and water quality to be assessed and could be regarded as inadequate. Additional sampling will be required to further verify the conclusions of this thesis.

4.2 HYDROCHEMICAL CHARACTERISTICS

4.2.1 Water Type

The majority of south Tipperary is underlain by limestone or Quaternary deposits derived mainly from limestone. Limestone dissolution is therefore the principal hydrochemical process in the strata of this area.

The water analyses for south Tipperary, are represented graphically by the use of trilinear diagrams; 1) Piper, 2) Durov (Figs. 4.1, 4.2). These trilinear diagrams indicate that in general terms the groundwater in south Tipperary is a calcium bicarbonate rich water. In a number of analyses the water type is sodium chloride rich, these samples are found in areas underlain by rocks of Silurian age; here the groundwater is soft due to the absence of limestones.

4.2.2 Variation within the Water Types

Within the major water types there are subtle variations in the chemistry of the groundwaters. These variations have been highlighted by investigation of total hardness and total alkalinity values and Mg/Ca ratios. One sampling event of fifteen groundwater sources by J. Keohane (Regional Water Lab. Kilkenny) was used to determine the variation of the water type as it represents a complete consistent

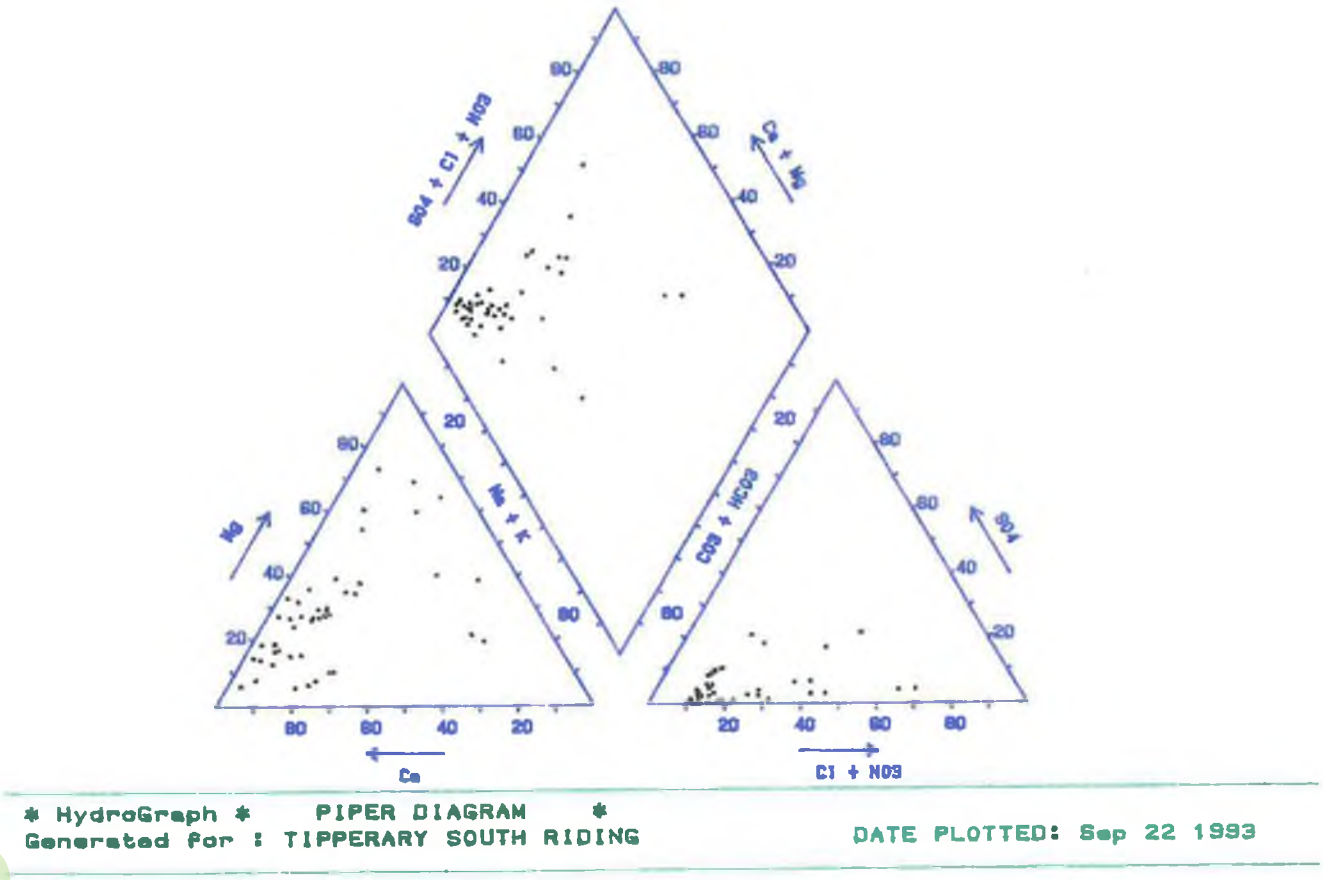


Figure 4.1 Trilinear Diagram - PIPER for chemical analysis in south Tipperary

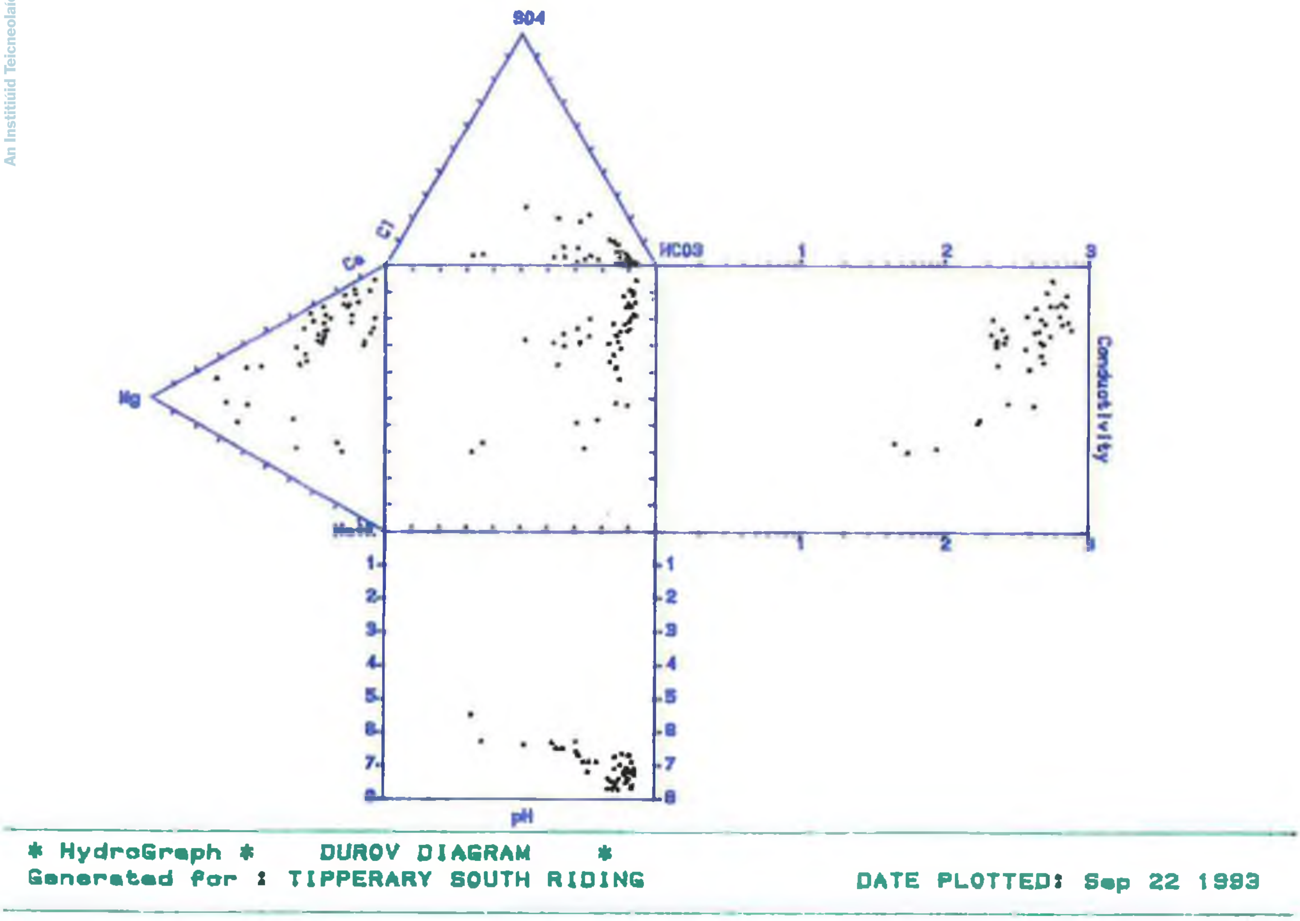


Figure 4.2 Trilinear Diagram - DUROV for chemical analysis in south Tipperary

PARAMETER (units)	EC Drinking Water Standard (80/778/EEC)		Water Intended for Human Consumption SI 81 of 1988	
	MAC value	No. of exceedances	MAC value	No. of exceedances
Calcium (mg/l)	N.S.	_	200	5
Chloride (mg/l)	N.S.	_	250	1
Ammonium (N mg/l)	0.38	2	0.23	3
Colour	20	6	20	6
Copper (mg/l)	-	-	0.5	1
Manganese (mg/l)	0.05	17	0.05	17
Magnesium (mg/l)	50	4	50	4
Nitrate as N (mg/l)	11.3	1	11.3	1
Total Iron (mg/l)	0.2	5	0.2	5
E. coli (/100ml)	0	22	0	22
T. Coliforms (/100ml)	0	37	0	37
Zinc (mg/l)	-	-	1	1

Table 4.1 Table of the parameters that have exceeded the EC Drinking Water and the SI 81 of 1988 Standards and the appropriate standard.

sampling event. Appendix C. contains this set of analyses.

The contact between the bedrock and water types is frequently offset because the groundwater is reflecting the mineralogy of the overlying subsoil deposits. A sandstone bedrock aquifer with limestone till overlying it would fall into the calcium bicarbonate - sodium chloride water type as there is a mixing of two water types.

Variation in total hardness is generally due to variations in the length of time the groundwater has been in contact with the aquifer. The carbonate bedrock aquifers and the Quaternary carbonate-rich sand and gravel aquifers have similar values. Recharge waters passing through the Quaternary deposits can dissolve substantial amounts of calcium/magnesium carbonate if it is available (before it drains into the underlying bedrock).

The groundwater in the Galtees and Slievenamon areas displays low total hardness values which indicates little limestone dominated subsoil overlying the Old Red Sandstone. The trends in total hardness are also reflected in the conductivity measurements. The waters in the Slieveardagh Uplands are relatively soft.

Mg/Ca ratios can be used to describe the groundwaters and confirm the conclusions derived from the hardness values (Daly, E.P., 1992). The Mg content in the groundwater in south Tipperary is usually less than 20mg/l except in four cases i.e. Kiltinan, Ballincurry, Laffansbridge and Ironmills. This is explicable by the presence of dolomite in all but the last source (pers.com. E.P.Daly). In general, limestone aquifers have a Mg/Ca ratio that is less than 0.3 (Table 4.2 a). In these studies seven sites have values exceeding this. This suggestts that lithology may be a dominant factor controlling the Mg/Ca ratio as all bar one of the sites is located in a non-limestone aquifer.

Natural ion exchange is another process that reduces the hardness level in groundwater. The onset of this is indicated by a decrease in the Total Hardness value to below the Total Alkalinity. Four out of the fifteen samples have ion balance errors greater than 6 % and so are not included for further examination. Natural ion exchange has been detected in seven out of the eleven sites sampled in south Tipperary (Table 4.2 a). These results are contradictory as the sites at Kiltinan and Poulatar are not confined situations and it is unlikely that ion exchange is taking place. Because only one sampling event was used for this assessment the results are

Source (No.)	Basic Geology	Mg/Ca ratio	TA : TH (mg/L)
Hollyford (1002)	Silurian Sandstone/Shales	0.22	232 > 217
Ironmills (1003)	Fluvio-glacial sands and gravels	3.14	116 > 110
Laffansbridge (1007)	Ballyadams Limestone	0.26	274 < 315
Coalbrook (1008)	Coal Measures	0.27	181 < 189
Ballincurry (1009)	Coal Measures	2.11	208 > 204
Tullohea (1018)	Coal Measures	1.13	64 > 56
*Cloran (1019)	Kiltorcan Sandstone	0.60	8 < 10
Mullenbawn (1020)	Ballyadams Limestone	0.10	340 > 326
Springmount (1021)	Sands and gravels	0.11	365 > 361
*Rossidrehid (1023)	Devonian Sandstones and Shales	2.00	31 > 19
*Kilcoran (1024)	Kiltorcan Sandstone	4.50	60 > 40
Coolnamuck (1026)	Sands and gravels	0.49	152 < 159
Poulatar (1030)	Waulsortian /Silverspring Limestones	0.14	199 = 199
*Poulalee (1031)	Waulsortian /Silverspring Limestones	---	219 > 207
Kiltinan (1032)	Ballyadams Limestones	0.22	334 > 318

Table 4.2 (a) Basic Geology, Mg / Ca ratios and Total Hardness, Total Alkalinity values for one sampling event (4/5/1993 to 10/5/1993).

* Sample has ion balance error greater than 6 %.

Source (No.)	K/Na ratio	Nitrate as N (mg/L)
Hollyford (1002)	0.1772	2.3
Ironmills (1003)	0.101	1.8
Laffansbridge (1007)	0.3925	4.4
Coalbrook (1008)	0.3404	0.7
Ballincurry (1009)	0.108	1.0
Tullohea (1018)	0.0784	1.2
*Cloran (1019)	0.056	0.1
Mullenbawn (1020)	0.457	3.6
Springmount (1021)	0.13	5.6
*Rossidrehid (1023)	0.0978	0.2
*Kilcoran (1024)	0.1194	0.3
Coolnamuck (1026)	0.17	3.1
Poulatar (1030)	0.1304	3.3
*Poulalee (1031)	---	3.6
Kiltinan (1032)	0.202	2.8

Table 4.2 (b) K / Na ratios and nitrate values for one sampling event (4/5/1993 to 10/5/1993).

* Sample has ion balance error greater than 6 %.

somewhat inconclusive and further sampling is necessary.

4.3 WATER QUALITY

4.3.1 Introduction

Statistical analysis of available water quality data enables background groundwater quality to be easily assessed. In the case of south Tipperary there was no frequent sampling regime ongoing at the start of this project. Therefore the frequency of sampling for the water quality analysis data used is variable. The assessment of the quality is related to the number of samples taken for each site. This is not ideal, but some generalisations can be made with regard to water type, quality and possible contaminants.

Parameters such as potassium, chloride, ammonia, nitrate and *E. coli* are usually independent of rock type, therefore are used as pollution indicators. K/Na ratios are useful indicators of local contamination by vegetable or plant organic matter (pers. comm. E.P. Daly).

There are a number of parameters such as magnesium and calcium whose presence in groundwaters has a nuisance rather than a harmful effect. Sudden elevation in the above parameters in conjunction with the presence of other pollution indicators (e.g. potassium, chloride etc) could imply that contamination has occurred. Some pollutants cause other relatively harmless substances to become more mobile and these show up as elevated values during routine analysis.

4.3.2 Pollution

Pollution is not a wide scale problem in the south eastern area of the country, although there are localised problems which are attributable to the siting of wells and boreholes in urban areas or closeness to waste sources such as manure and silage pits or septic tanks (An Foras Forbartha, 1986). In south Tipperary, the compliances and exceedances of the EC standards for water samples taken from the Council's sources were dealt with on a parameter by parameter basis. Table 4.3 shows the exceedances (EC Drinking Water Standards) which highlight the polluted sources.

The pollution status is divided into two categories; insufficient data, sufficient data - contaminated (frequently / infrequently). Table 4.3 represents a summary of the sample range, number of contaminated samples for each parameter and a brief note on the overall quality.

The elevated bacterial numbers indicate nearby pollution in most cases. The quality of the water demonstrates that the main concern originates from the presence of *E. coli* and Total Coliforms. *E. coli* are used as indicators of contamination and possible presence of pathogenic microbes because they are easy to measure relative to other bacteria and viruses. These elevated levels are therefore attributed to human/animal waste. Five sources were found to be frequently affected by bacterial contamination i.e., Ballinvir, Tullohea, Mullenbawn, Poulatar and Poulalee. These sources should be investigated further to define the source of pollution.

The K/Na ratios can be used tentatively to distinguish between septic tank systems and farmyards as sources of pollution. The ratio for cattle slurry is 10, whereas for septic tank effluent it is 0.1-0.3 (Henry, 1988). Consequently, entry of effluent from plant organic waste will result in an increase in the K concentration and more importantly in the K/Na ratio. The K/Na ratios in some of the analyses for south Tipperary are found in Table 4.2 b.

4.4 IMPLICATIONS FOR VULNERABILITY ASSESSMENT

Aquifer characteristics such as confining conditions, type of flow (conduit = short residence time), and thickness of unsaturated zone affect the pollution potential. High rainfall, evenly distributed throughout the year, provides substantial dilution for contaminants. As mentioned before, groundwater circulation in south Tipperary tends to be rather local and the effects of pollution tend to be localised both in space and time. Thus pollution tends not to affect a wide area (Daly, E.P., 1992). The pollution loading is directly linked to the vulnerability aspect of groundwater protection to

Source Name (No.)	EColi /100ml	TColi /100ml	T.Hardness mg/l	Conductivity uS/cm	Nitrate mg/l	Status
Glengar (1)	3,2	5	-	359	-	insufficient data
Hollyford (2)	16	16	-	280	-	insufficient data
Ironmills (3)	-	-	212	460	-	insufficient data
Coalbrook (8)	0,0,0,2	0	115,218,166, 224	465,519,453	0.2,0.25,0. 4,0.3	infrequently contaminated
Ballincurry (9)	0,0,0	0,0,0	238,224,-	291,473,466	0.2, 0.4,-	infrequently contaminated
Gorteen (10)	0	0	130	195	0.2	insufficient data
Commons (11)	-,0,-,0 -	-,-,-,0,0 0	76,107,84 96,43,86	261,250,223 227	0.6,0.6, 5,6.6	infrequently contaminated
Grangemockler (15)	0,0,0	0,0,0	74,76,85	208,175,189	1.5,1.4 1.3	infrequently contaminated
Ballinvir (16)	10,20,0 32,8,64 6,-,4		-	-	-	frequently contaminated
Ahenny (17)	0,0,-,-	-,0,0,0	85,88,78,72, 71	234,228,223, 231,205,235	4.7,-,4.5, 5,4.2	infrequently contaminated
Tullohea (18)	0,0,-,0, 54,6	0,2,12, 4,-,480, 12	-	165,176,177, 130,175,-,-	1,1.2,-,-,- ,-,-	frequently contaminated
Cloran (19)	0,0,-,-	-,2,0,6	-,-,8,-	45,56,53,575, 653	1,-,-,-,-	infrequently contaminated
Mullenbawn (20)	0,4,4,2	20,302	307,248,-	615,630,655	2.7,3.1, 2.2	frequently contaminated
Springmount (21)	0,-	2,2	-	696,737	4.9,5.4	insufficient data
Kedrah (25)	-	-	383	3.3	-	insufficient data
Clogheen (27)	-,0	2,-	-	-	-	insufficient data
Muskry Springs (29)	2	2	-	113	-	insufficient data
Poulatar (30)	-,0,-,-	32,4,52 0	190,230,224 240	359,404,394, 436	9.3,14.6, 11.1	frequently contaminated
Poulalee (31)	-	18,16, 24,20	198,230,220,-	376,412,403, 423	11.1, 16.4,11.1	frequently contaminated

Table 4.3 Indicators of Groundwater Quality for selected sources in south Tipperary.

(each value above represents a single sampling event)

- (indicates no sample taken)

loading is directly linked to the vulnerability aspect of groundwater protection to pollutants. Bacterial contamination of sources possibly indicates high vulnerability.

The overall quality of the large springs in Ireland is good but a recent study in the Nore River Basin (Daly, E.P., 1992) has shown that there is wide scale contamination of local shallow dug wells; this is an apparent contradiction. The results of a study of water quality in the Nore (Woods, 1990) show that waste produced by local point sources has a far greater impact on the capture zones of low yielding wells than it does on that of high yielding boreholes and springs. Most low yielding wells being used for farm and domestic water supplies in the Nore are accompanied by a potential point source of pollution within 50m and another within 100m of the source. Hence, these sources will be centrally located within the zones of contribution of most wells. A well providing a supply of 2-20m^3/day will be recharged from an area of 0.2 - 5 hectares, whereas, springs and boreholes producing 1,000 - 4,000 m^3/day under normal hydrogeological conditions will be recharged within an area in the order of 100 - 1000 hectares. Hence, the large boreholes and springs give a much better reflection of the overall groundwater quality in the southeast in general (Daly, E.P., 1992). It is probable that this is also the case in south Tipperary as the farming practices and hydrogeological situations are very similar.

4.5 QUALITY OF THE SOURCES

4.5.1 Ironmills

The Ironmills source is derived from a borehole in fluvio-glacial sands and gravels. The general quality of this site is good with no apparent problems with bacteria. As this is an unconfined aquifer it is therefore more susceptible to pollution and so has a higher vulnerability. The sands and gravels exhibit intergranular flow therefore there is some potential for attenuation of contaminants, but this is dependent on the thickness of the unsaturated zone.

4.5.2 Springmount

Springmount spring has an abstraction rate of approximately 1820 m^3/day from sands and gravels overlying a poor bedrock aquifer (Aghmacart formation). There are a limited number of samples for this source. The maximum admissible concentration (MAC) for bacteria and nitrate was exceeded by two out of the nine samples. There is one value of lead which exceeds the MAC; further sampling would be necessary to determine whether this indicates a problem. The flow in the gravels is intergranular and some attenuation can occur. As in Ironmills this is understood to be an unconfined aquifer overlying a poor aquifer so vulnerability is high.

4.5.3 Mullenbawn

Mullenbawn is a large karstic spring in the Ballyadams formation which is a major aquifer. The aquifer is unconfined in the immediate area of the spring as there is a lot of outcropping rock. Bacteria/Total Coliforms are a problem at this source as ten out of the thirteen samples showed exceedances of the MAC. The fact that the aquifer is unconfined and has conduit flow suggests that this is an extremely vulnerable site and the quality confirms this. This needs to be studied carefully in the groundwater protection plan.

4.5.4 Poulatar and Poulalee

Poulatar and Poulalee are both large karstic springs which discharge at the edge of the Tar river. They discharge from the Waulsortian formation and are unconfined. They are very open and not protected therefore it is to be expected that five out of the seven samples for Poulatar and all the samples for Poulalee are contaminated by bacteria. The nitrate level at Poulatar has only one sample over the MAC limit and more sampling / analysis for this parameter should be carried out. As in Mullenbawn the flow is thought to be conduit, with thin subsoil cover. The vulnerability at these sites is extreme.

CHAPTER 5 - VULNERABILITY

5.1 INTRODUCTION

Vulnerability depends on the physical circumstances at a location and provides a measure of the ease with which unacceptable impacts upon groundwater resources can take place. It is the intrinsic characteristic which determines the sensitivity of various areas of an aquifer to contamination by an imposed pollution load. Risk arises when an activity is proposed at a given location, but can be mitigated by preventative measures. Different levels of pollution loading will be acceptable in different vulnerability situations (* NRA, 1991). The concept of groundwater vulnerability recognises that the risks of pollution from a given activity are greater in certain hydrogeological, geological and soil situations than others.

The natural vulnerability of the groundwater to pollution is referred to in this study. The map shows the natural vulnerability irrespective of the type/concentration of the pollution source. This variable is dealt with in the groundwater protection matrices which categorise the pollution potential of a number of groups of activities. The vulnerability map (Map 8) depicts areas of equal vulnerability and must not be used for site specific work. At the site specific stage the vulnerability must be confirmed by on-site investigation.

It is assumed in this study that in the natural situation the pollutant is discharged at zero datum level. The system is not pollutant specific and some pollutants may penetrate the subsoils regardless of the type and thickness of the subsoil. When the natural situation is altered by removal of subsoil e.g., for a septic tank (where one to two metres of material is removed) or by changing the permeability (type of subsoil) by the importation of low permeability material e.g. (clayey till) to a gravel e.g., a natural liner, then the vulnerability changes. Therefore the pollution risk is different, as the point of discharge of pollution has been altered.

* The 1991 NRA document was a precursor to a final report in 1992 (NRA, 1992) and includes more technical data than the final version.

The vulnerability of groundwater to diffuse and point sources of pollution is dealt with in this study. The vulnerability of both the subsoil and the bedrock aquifer materials are dealt with separately and then merged to form an integrated vulnerability map. The vulnerability of the groundwater in the bedrock and subsoil aquifers is dependent on the overlying soil, subsoil and the thickness of the unsaturated zone.

In developing the vulnerability system for south Tipperary a conceptual rather than a quantitative approach has been used. The evaluation system is based on the permeability of the subsoil, soil, depth to bedrock and aquifer type (Zaporozec, 1985).

5.2 METHOD OF EVALUATION

In general five factors have been taken to define the vulnerability of groundwater resources to pollution, and these are discussed from the surface down.

- Soil Characteristics
- Subsoil Characteristics
- Thickness of Unsaturated Zone
- Hydrogeology
- Attenuation Processes

5.2.1 Soil Characteristics

Soil characteristics (topography, depth, texture, and permeability) are significant factors determining the infiltration of recharge and also the natural protection against infiltrating pollutants. Sorption, ion exchange and precipitation are vital chemical and biological processes in attenuating pollutants and occurring to varying degrees in different soil types. The effectiveness of these processes depends on the clay and organic matter content - the higher they are the greater the attenuation (Zaporozec, 1985).

5.2.2 Subsoil Characteristics

The nature of the subsoil plays an important role in determining the vulnerability of groundwater because of its attenuating properties. The permeability, ie. the ease with which it allows fluid and contaminants to flow through it, and the thickness of the deposit are directly associated with attenuation capacity. Great importance is placed on the subsoil type and thickness due to their ability to protect the underlying rock. Areas which have covering of a low permeability subsoil such as till, peat and marl with thicknesses of approximately 10 metres have a low vulnerability.

Situations with either a very permeable or very impermeable subsoil, can cause problems, the former being that contaminants will flow directly into the groundwater and the latter that ponding of contaminants occurs, with the possibility of surface water being affected.

5.2.3 Thickness of Unsaturated Zone

The unsaturated zone has an essential position between the land surface and the water table. It acts as a favourable environment for pollutant attenuation. The thickness of this zone and type of deposit are essential elements involved in the attenuating processes. The unsaturated zone contains some air spaces within the pores of the deposit and allows more attenuating processes to be carried out. The flow rates in this zone are usually slower than those in the saturated zone thus allow a longer time interval for attenuation.

5.2.4 Hydrogeology

The character of aquifers, especially the size and interconnection of the openings through which the water passes, is most essential to the pollutant attenuation process. Aquifers with intergranular flow, such as sand and gravel, permit pollutants to be only slightly retarded with a little reduction in concentration. The sands and gravel usually have some fine grained material with good attenuating capacity. Karst aquifers with cracks, fractures and solution channels are ineffective in removing pollutants as the flow is rapid. The attenuating capacity is negligible. The dilution capacity of the aquifer is related to the size of the aquifer.

5.2.5 Attenuation Processes

The potential for groundwater pollution depends upon the level of attenuation that takes place between a source of pollution and an aquifer. The attenuation of most pollutants as they travel through the unsaturated zone and groundwater system is dependant on a variety of naturally occurring chemical reactions and biological and physical processes that often cause the pollutant to change its physical state or chemical form. These changes may lessen the severity of pollution or amounts of pollutants. There are fewer attenuating mechanisms in the saturated zone than in the unsaturated zone. Dilution is an important mechanism in the saturated zone. Although the importance of these reactions in the attenuation of pollutants is widely recognised, the exact prediction of just how much attenuation will take place is difficult to determine (Aller and others, 1987).

The degree of attenuation that occurs in the unsaturated zone depends upon 1) the grain size and the physical, chemical and biological characteristics of the material through which the pollutant passes, 2) the time the pollutant is in contact with the material through which it passes, and 3) the distance that a pollutant has travelled through the unsaturated zone (Aller and others, 1987). In general, the longer the time and the greater the distance of travel, the greater the potential for attenuation. Attenuation processes can be bypassed completely if a pollutant is introduced directly into the aquifer.

Any or all of the above factors can be relevant in assessing the risk to groundwater resources. The vulnerability of groundwater can only be established with confidence by direct investigation. The balancing of pollution loading against vulnerability in any case necessarily means a subjective decision is made (NRA, 1991).

5.3 VULNERABILITY CLASSIFICATION

The vulnerability classification scheme proposed in Table 5.1 takes into account the main aquifer groups in south Tipperary; bedrock and subsoil. The depths referred to should be taken to be from the point of discharge, be that at the surface as for slurry spreading or at the base of the percolation system of a septic tank. The classification scheme precedes the groundwater protection plan which incorporates the vulnerability (see Chapter 7.5.4).

The vulnerability classification scheme is not dependent on the quality of data. However, the confidence of the vulnerability assigned to an area is reliant on the density of data points. The confidence is subjective and notes relating to the data should be included in the associated groundwater protection report. It would be very complicated to try to develop a system that includes this confidence component as there are varying levels of information throughout the area. As the vulnerability is an integral part of the groundwater protection plan and therefore the code of practice, the confidence level is carried on to the decision making process where a conservative stance should be taken where there is a doubt about the accuracy of the data.

Table 5.1

VULNERABILITY RATING	HYDROGEOLOGICAL SETTING
EXTREME	1. Outcropping rock and rock close to the surface i.e., considered to be less than 1m.
	2. Areas where bedrock is overlain predominantly by sand and gravel or till-with-gravel where the thickness is approximately less than 5m.

3. All karstic areas except where it can be demonstrated that there is at least 10m of till or till-with gravel. Areas particularly close to karstic features such as swallow holes, springs and losing streams are extremely vulnerable.

4. Sand and gravel aquifers (greater than 10 m thick) with a maximum water table level less than 3 m from surface.

HIGH

1. Areas of bedrock overlain predominantly by till, peat alluvium and marl where the thickness is approximately 1 - 5 m.

2. Areas of bedrock overlain predominantly by sand and gravel or till-with-gravel where the thickness is approximately 5 - 10 m.

3. Sand and gravel aquifers (greater than 10 m) and watertable level > 3m from surface.

MODERATE

1. Bedrock or sand and gravel aquifers overlain predominantly by approximate thicknesses of 5 - 10 m of till, peat, alluvium and marl.

2. Bedrock overlain predominantly by approximately 10 - 15 m of sand and gravel or till-with-gravel.

LOW

1. Bedrock overlain predominantly by till, peat, alluvium and marl where the approximate thickness is greater than 10 m.

2. Bedrock overlain by sand and gravel or till-with-gravel where the approximate thickness is greater than 15 m.

3. Sand and gravel aquifers overlain predominantly by greater than 10 m of till, peat, alluvium or marl.

4. Regionally and locally important aquifers where they are overlain by greater than 10 m low permeability bedrock.

In proposing the classification the following assumptions are made;

- It is assumed that the pollutants are discharged at zero datum level, i.e. in a natural situation this is at the surface whereas when the natural situation is changed, as with septic tanks the point of discharge is at the base of the percolation area of a septic tank which is usually below the ground surface. Therefore this has further implications since the type of pollutant is not specified. This classification should always be applied from the point of discharge of pollutant be it at the surface or at some distance below it.

- It is assumed that once contaminants enter bedrock there is little attenuation other than by dilution.

- It is assumed that the unsaturated zone does not have a significant attenuating effect on pollutants in bedrock.

5.4 APPLICATION OF VULNERABILITY CLASSIFICATION IN SOUTH TIPPERARY

5.4.1 Vulnerability Assessment for south Tipperary

The factors involved in determining the vulnerability of the aquifers in south Tipperary are discussed below:

- Soil Characteristics

The information on the soils in south Tipperary is based on an enlarged version of the soils association map of Ireland and so there is not much attention given to detail. The information is not detailed enough to determine the attenuation capacity that the soils provide and hence their signifance *vis a vis* effect on the vulnerability. Further work on the attenuating capacity of soils could assist in their usefulness for vulnerability assessment for diffuse pollution sources.

- Subsoil Characteristics

The surficial deposits in Tipperary vary vertically and laterally in both thickness and lithology within short distances. Depth to bedrock ranges from 0 to > 30m. The detailed composition of the subsoil is not known because no detailed mapping, drilling and geophysical investigations have been undertaken. Therefore, the permeabilities of these deposits are divided into broad groupings. The permeable group includes (predominantly) limestone sand and gravel and till-with-gravel whereas the less permeable group includes predominantly limestone and sandstone till, peat, marl and alluvium.

- Thickness of Unsaturated Zone

There is not sufficient water level information to enable a water table map to be constructed. The water level is very important in terms of the sands and gravels, where it is generally less than five metres from the surface in low lying areas. The vulnerability classification takes this in account.

- ☐ Hydrogeology

One of the principal factors determining the vulnerability of groundwater to pollution is the division of the strata into either an aquifer or an aquitard category i.e., is the rock capable of storing and transmitting significant quantities of groundwater or not. For the pupose of this study which was concerned, *inter alia,* with groundwater vulnerability it has been assumed that in the absence of significant quanities of groundwater in an aquifer that the vulnerability classification is reduced by one class.

In south Tipperary the aquifers exhibit fracture / fissure flow, or in the karst areas conduit flow. Since the flow is rapid the attenuation capacity is reduced and the vulnerability is therefore always high.

- ☐ Attenuation Processes

In south Tipperary the types of pollutants have not been specified and the attenuation capacity of the soils and subsoils have therefore not been explored as this is outside the scope of the project. The attenuation processes should be dealt with on a pollutant and site specific case. In groundwaters which show evidence of contamination on a chemical basis, a cover of unsaturated Quaternary deposit is considered to be effective in attenuating bacteria (Woods, 1990).

5.4.2 Overall Vulnerability

The overall groundwater vulnerability is reliant on the associated vulnerability of the bedrock and subsoil (sand and gravel) aquifers. To determine the overall vulnerability, the vulnerability of the bedrock and the subsoil aquifers were examined separately and then integrated. The vulnerability of the bedrock aquifers is determined by the type and thickness of the overlying subsoil deposit as it is within this deposit that attenuation occurs. The vulnerability of the subsoil aquifers is dependent on the overlying soil or in the case of a buried aquifer, by the overlying subsoil. Another factor in these intergranular sand and gravel aquifers is the depth to the water table. An integrated vulnerability map depicts the vulnerability of south Tipperary (Map 7).

5.4.2.1 Vulnerability of the Bedrock Aquifers

This vulnerability is concerned with the type and thickness of the subsoil deposits as this provides the protection for the bedrock aquifer. The subsoils have been broadly divided into:

- Predominantly gravel areas
- Predominantly till areas - subdivided into limestone and Old Red Sandstone areas.
- Till-with-gravel areas (describes kame and kettle deposits)
- Alluvium, Marl, Peat

  (Alluvium in the GSI guidelines include high permeability river gravels and so may be a higher risk deposit)

The vulnerability of the bedrock aquifer is directly related to the ability of the subsoil to attenuate or impede pollutants which is a function of the subsoil permeability, clay content and thickness. The subsoil deposits have been broadly divided into permeable and less permeable categories. Sands and gravels and till-with-gravel are permeable, whereas till, alluvium, marl and peat are less permeable.

Contours depicting shallow (probably less than 5 metres) and thick (probably greater than 10 metres) subsoil have been drawn to indicate areas of different vulnerability on Map 8. The presence of outcropping rock assists in delineating the shallow subsoil areas, whereas borehole depth to rock records and topography are required for the thicker subsoil areas. Depth to rock relates two variable surfaces, i.e. the bedrock surface and topography. Hence, dramatic changes over very short distances are common. Areas with thick subsoil are used to indicate less vulnerable areas and bedrock aquifers begin to be confined where they are saturated and have around 10m of impermeable material overlying them. In certain areas where the data are densely distributed contours of 15m have been drawn up to depict a significant thickness of deposit. Any type of subsoil this thickness over a bedrock or buried sand and gravel aquifer confers a low vulnerability on the groundwater, as it is likely that even sand and gravel would have some till present within these thicknesses.

An overriding feature for bedrock vulnerability is karstified areas as they are very vulnerable due to their rapid throughput and low storage. In karstified limestone areas with sinking streams, polluted surface water can recharge aquifers with little or no attenuation. Recharge by percolation through soil and subsoil allows the attenuating processes to be carried out (Daly and Quinn, 1989). This is taken into account by locating karstic features (in red) on the overall vulnerability map.

5.4.2.2 Vulnerability of the Subsoil Aquifers

The subsoil aquifer vulnerability refers only to sand and gravel aquifers. These are deposits of sand and gravel of thicknesses greater than 10m and locally extensive. No buried/confined sand and gravel aquifers have been delimited, that is to say that the sand and gravels do not have great thicknesses of subsoil overlying them. Therefore, in the unconfined sand and gravel aquifer the vulnerability is said to be high as there is no protection afforded to the deposits except by soil cover, about which too little detail is known for their attenuating ability to be determined. The importance of the water table is evident in these aquifers, as once a pollutant gets into the groundwater it quickly spreads throughout the whole system. When the water table is less than three metres below ground level these areas are allocated to an extremely vulnerable classification as less than 3m of an overlying unsaturated material provides little or no attenuation.

5.4.3 Conclusion

The vulnerability map gives a county wide view of groundwater vulnerability and highlights pollution-sensitive areas. Owing to the map scale, it is impossible to illustrate the properties of every parcel of land and it therefore cannot be used for site specific purposes. However, it does reduce the number of areas to be studied in detail by identifying those areas with the greatest or least limitations (Zaporozec, 1985).

Approximately 60 % of south Tipperary is designated as being extremely or highly vulnerable. The northern region is overlain by a thin cover of permeable sand and gravel and till-with-gravel but this area is underlain by the Aghmacart formation which is considered to be a poor aquifer. In the southern region there is a cover of less permeable limestone and sandstone till which provided some protection for the regionally and locally important aquifers beneath it. There are some localised areas with a significant thickness of subsoil, permitting these areas to be considered to be of moderate to low vulnerability, and these sites are preferred for the location of potentially polluting activities.

All the sources examined in some detail demonstrated extreme to high vulnerability. The data quality of the five sources examined in detail is good as the areas were examined at a 1:10,560 scale. Outside these areas the data confidence decreases. The depth to bedrock information and the subsoil map play an integral part in vulnerability, therefore the confidence in these data has also to be considered. Appendix B contains 1:10,560 scale source protection zones. The source areas are delimited by means of circles of 300m and one km radii. This is the Fixed Radius Method and is simplest available (EPA, 1991).

Mullenbawn is a very complicated source and requires more detailed investigation before the capture zone of this spring can realistically be determined. Roaring Well should also be included in the detailed examination of the area. It is thought that the resource as a whole will have to be very much protected.

The information for Springmount did not allow for any detailed examination of the capture zone, so as in the other cases the fixed radius method was used.

CHAPTER 6 - GROUNDWATER LEGISLATION

6.1 INTRODUCTION

Preparation of the groundwater protection plan, since it incorporates codes of practice related to legislation and standards, must be closely related to the understanding of the legal basis. This chapter reviews the legal base on which a groundwater protection plan may be founded.

Legislative backing for the groundwater protection plan is essential. A number of Local Government Acts as well as recent EC Directives provide this support. County planners and officials have statutory authority under the Local Government (Planning and Development) Acts 1963 and 1990 to regulate and control development in the interest of the common good. The groundwater protection plan should be incorporated into the County Development Plan in order to provide the statutory backing and strong control measures under the Planning Acts necessary to enforce the proposed restrictions. These restrictions imposed in the various zones should be perceived as being reasonable and as serving the common good (Hore, 1991).

6.2 LEGISLATION

6.2.1 General

The enforcement of any groundwater protection plan is reliant on relevant legislation. A review of this legislation has been undertaken so that one has a clear understanding of what restrictions can be implemented. Table 6.1 is a summary list of Irish and EC legislation relating to groundwater.

Once an EC Directive has been signed it must be implemented and administered in Irish law. In Ireland, the EC Directive may be implemented through existing legislation but more usually the Directive is implemented by issue of regulations by the relevant Minister. These regulations must not be confused with the EC Regulations. The Irish regulations take the form of what is known as a Statutory

Table 6.1 Irish and Community Legislation Relating to Groundwater Quality (June 1993)

General Title	Important Sections	Reference Number
Local Government (Planning and Development) Acts, 1963 and 1990.	Sections 19,26 Third Schedule. 1990 Act; Third Schedule, paragraphs 7 & 8. Fourth Schedule, paragraph 22.	1963, No. 28
Local Government (Planning and Development) Regulations, 1990		
Building Regulations, 1991.	Article 5, Technical Guidance Document H, refers to SR6, 1975 and 1991.	
Local Government (Water Pollution) Act, 1977.	Sections 1, 3, 4	1977, No. 1
Local Government (Water Pollution) Act, 1977 (Control of HCH and Mercury Discharges) Reg. 1986.		1986, SI No. 55
Local Government (Water Pollution) Act, 1977 (Control of Cadmium discharges) Reg. 1985.	Sections 12, 14, 15, 22, 26.	1985, SI No. 294
Local Government (Water Pollution) (Ammendment) Act, 1990.	Section 2, 21.	1990, No. 21
Local Government (Water Pollution) Regulations 1992.	Articles 40, 41, 46.	
Council Directive of 17th Dec. 1979 on the protection of Groundwater against pollution caused by certain dangerous substances.	Article 1.2.	80/68/EEC
EC (Waste) Regulations, 1979.		
EC (Toxic and Dangerous Waste) Regulations, 1982.		1988, SI No. 33
EC (Environmental Impact Assessment) Regulations, 1989.		1989, SI No. 349
Dircetive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources.		
EC (Use of Sewage Sludge in Agriculture) Regulations, 1991. (formal effect to EC Directive 68/278/EEC)		1991, SI No. 183
EC (Quality of Water Intended for Human Consumption) Regulations, 1988 (formal effect to EC Directive 80/778/EEC)		1988, SI No. 81
Environment Protection Agency Act, 1992.	Sections 52, 62, 63, 69, 71, 75, 76.	1990, No. 46d
Proposal for a Council Directive on Landfill of Waste, (91/C190/01)		
Waste Bill (In Preparation)		

Instrument which translates the relevant EC Directive into the Irish situation.

Irish Local Governments Acts relating to Planning and Development and Water Pollution have recently been updated taking account of groundwater. The older legislation, although it referred to the control of abstraction of groundwater, is limited in effectiveness and not geared to modern conditions. Stronger powers for protection of groundwater were not available until the enactment of Water Pollution Act, 1977. The definition of groundwater throughout the Irish and EC legislation varies and the definitions are summarised in Table 6.2.

6.2.2 Detailed Legislation

The following section dealing with Irish and EC legislation draws heavily on the experience of Mr. Owen Boyle and his presentation to the International Association of Hydrogeologists (Irish Branch), Portlaoise, 1993 (Boyle, 1993).

(i) Water Supplies Act, 1942

Where a Sanitary Authority is empowered to take a supply of water from a source, Section 20 of this Act gives to the sanitary authority the same rights to prevent pollution of such source as an owner of land contiguous to it.

(ii) Local Government (Planning and Development) Acts, 1963 and 1990

A number of provisions in the Planning Acts can be used to protect groundwater. Every planning authority is required to make a development plan (Section 19) which must include objectives for preserving, improving and extending amenities in its area. This plan provides the framework which will support the groundwater protection plan. The purpose of the County Development Plan is as follows:

1) To guide the day to day activities of the Co.Co. in relation, to roads, housing, sanitary services, development control and the other various functions which are the responsibility of the Co.Co.

WATER SUPPLIES ACT, 1942	LOCAL GOVERNMENT (PLANNING AND DEVELOPMENT) ACTS, 1963 & 1990	LOCAL GOVERNMENT (WATER POLLUTION) ACT, 1977	LOCAL GOVERNMENT (WATER POLLUTION) AMENDED ACT, 1990	EC DIRECTIVE 80/68/EEC
"Source of water" is defined as "any lake, river, stream, well or spring".	Third schedule states that the County Development Plan objectives may provide for prohibiting, regulating or controlling the pollution of rivers, lakes, ponds, gullies and the seashore. GROUNDWATER is notable by its absence.	Section 1 of this Act defines *waters* as including *aquifers* and defines an aquifer as any combination of strata that stores or transmits sufficient water to act as a source of water supply.	The previous definition has been changed to cover "any stratum or combination of strata that stores *or* transmits water.	Article 1.2 definitions; Groundwater means all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil.

Table 6.2 Summary of relevant Groundwater definitions from various Acts and Directives.

2) To provide a framework for development over the next five years within a longer term context.

3) To provide guidelines for the general public in relation to the policies and objectives of the Planning Authority and its development control decisions.

In the Third Schedule to the Act it is stated that these objectives may provide for prohibiting, regulating or controlling the deposit or disposal of waste materials and refuse and the disposal of sewage. Presumably, this includes situations where such deposit or disposal could endanger groundwater or at least groundwater sources of water supply.

However, the Third Schedule goes on to state that the plan objectives may provide for prohibiting, regulating or controlling the pollution of rivers, lakes, ponds, gullies and the seashore. Groundwater is notable by its absence. Permission may be refused for development which conflicts with the proper planning and development of the area, regard being had to the provisions of the County Development Plan (Section 26).

The 1990 Act provides that no compensation is payable in respect of certain reasons for refusal or conditions attached to a planning permission. The reasons for refusal include situations where the proposed development would cause, inter alia, serious water pollution or pollution connected with the disposal of waste (paragraph 7) or would be prejudicial to public health (paragraph 8, (vii) of the Third schedule to the 1990 Act). Non-compensatable conditions that may be attached to a planning permission relate to prohibition, regulation or control of the deposit or disposal of waste materials and refuse, the disposal of sewage and the pollution of rivers, lakes, ponds, gullies and the seashore (paragraph 22 of the Fourth Schedule).

The groundwater protection plan infringes on the above statements as it may prohibit certain activities in designated areas, therefore affecting planning decisions. The County Development Plan would inform the public on the restrictions and direct them in making informative planning applications. Appendix D of this thesis contains statements where reference to the groundwater protection plan could be included in the County Development Plan.

(iii) NSAI Irish Standard Recommendation No. 6, 1991

In assessing applications for planning permission for single dwelling houses, local authorities are guided by the recommendations for the construction of septic tanks set out in the above document. They have been urged to have regard to SR6 1991 in their implementation of the Planning Acts by circular Letter PD 1/92 of the 8th January 1992, which refers specifically to the fact that septic tank pollution is a health hazard and that there is increasing concern with the dangers of polluting groundwaters.

(iv) Government Building Regulations, 1991

Technical Guidance document H, Drainage and Waste Disposal, has been published by the Minister for the Environment under Article 5 of the Building Regulations, 1991 for the purpose of providing guidance with regard to compliance with the requirements of Part H of the First Schedule.

The Guidance Document, in relation to septic tanks for single houses, refers to SR6 1975, which has now been superseded by SR6 1991. For septic tanks serving more than one house, it refers to BS 6297: 1983, Design and Installation of Small Sewage Treatment Works and Cesspools.

Where works are carried out in accordance with Guidance Document H, this will, *prima facie*, indicate compliance with the requirements of the Building Regulations.

(v) Local Government (Water Pollution) Act, 1977

Obviously, any provision of the 1977 and the 1990 Acts relating to water also relates in particular to aquifers.

Section 3 states that a person shall not cause or permit any polluting matter to enter waters. This prohibition does not apply to *inter alia* discharges of trade or sewage effluent, provided these effluents are licensed under Section 4.

Section 4 prohibits the discharge of any trade or sewage effluent to waters except under and in accordance with a licence granted by the relevant Local Authority. Discharges from sewers are exempted from this licensing requirement.

A Local Authority may refuse to grant a licence under Section 4 or may grant the licence subject to such conditions as it thinks appropriate. In considering the grant or refusal of a licence the Local Authority would have to consider the need to protect aquifers from pollution.

A Local Authority may not grant a licence if the effluent concerned would not comply with, or would result in the waters to which the discharge is made not complying with, any relevant standard prescribed under Section 26, of the Act.

Section 12 of the Water Pollution Act empowers a Local Authority to serve notice on any person having custody or control of polluting matter specifying the measures to be taken in order to prevent entry of such polluting matter to waters and the period within which such measures are to be taken.

Section 13, as substituted by Section 10 of the 1990 Amendment Act, provides that a Local Authority, for various purposes, such as to prevent pollution of water in its area or to remove such polluting matter, may take such steps as it considers necessary to prevent such matter from entering waters, may mitigate the effects of any pollution caused and may recover the cost of such operations from the person responsible.

Section 14 requires the person responsible for an accidental discharge of polluting matter to waters to notify the Local Authority in the area as soon as possible.

Section 15 empowers a Local Authority to make a water quality management plan for any waters in its functional area. The plan shall contain objectives for the prevention and abatement of pollution of waters.

Section 22 requires a Local Authority to carry out or cause to be carried out such monitoring of waters and discharges to waters as it considers necessary for the performance of its functions.

Section 26 provides that the Minister may prescribe quality standards for waters, trade effluents and sewage effluents. Regulations under this section may relate, *inter alia*, to

- all or specified classes of waters
- waters in specified areas
- waters specified by reference to their use

The 1977 Water Pollution Act is a far reaching piece of legislation which would appear to provide a licensing system for all effluent discharging to either surface waters or groundwater. As most if not all overburden or bedrock strata can be classed as aquifers as defined in this Act, the disposal of farm effluent to land would appear to be covered by the licensing system provided by the Act. In this case, spray irrigation systems may require a licence and theoretically the farmer discharging a tanker of effluent to their land might also require a licence as a person shall not cause or permit any polluting matter to enter waters (Cullen, 1989).

(vi) Local Government (Water Pollution) Regulations, 1978

This allows effluent exemptions for domestic sewage discharges of less than $5m^3$/day or trade effluent discharges by local authorities. All agricultural effluent discharges would appear to be covered by the 1977 Act whether they are discharged to surface water or to aquifers by land disposal, (Cullen, 1989)

(vii) Local Government (Water Pollution) (Amendment) Act, 1990

A number of provisions relating to penalties and enforcement have been strengthened. Section 21 allows a LA to make bye-laws relating to all or a particular part of its functional area where the authority considers it necessary to do so in order to prevent or eliminate the pollution of waters.

The bye-laws may prohibit or regulate specified activities carried on for the purposes of agriculture, horticulture or forestry. Bye-laws under the section may be made in respect of activities such as collection, storage and disposal of agricultural wastes, and the use of manure, fertilizers and pesticides. Bye-laws may prohibit certain activities in particular areas, or regulate the manner in which they are conducted by subjecting them to conditions.

(viii) EC Directive of 17 December 1979 on the protection of groundwater from pollution caused by certain dangerous substances (80/68/EEC)

Purpose of the Directive is :-

a) To prevent the pollution of groundwater by substances in List I or List II.

b) As far as possible to check or eliminate the consequences of pollution which has already occurred.

Member states are required to :-

a) prevent the introduction into groundwater of substances in List I; and

b) limit the introduction into groundwater of substances in List II so as to avoid pollution.

To comply with these obligations Member states are required to prohibit all direct discharges of List I substances. They may authorise any disposal of tipping for the purposes of disposal which might lead to indirect discharge of List I substances only after prior investigation, and provided that all technical precautions necessary to prevent such discharge are observed.

Discharge of List I substances to groundwaters is allowed, however, if the groundwater is permanently unsuitable for other uses or if the discharge is due to re-injection of water into the same aquifer in certain limited circumstances. Artificial recharge of groundwater is also allowed.

With regard to List II substances, authorization for direct discharge, or for tipping for the purpose of disposal which might lead to indirect discharge, is allowed only after prior investigation, and provided that all technical precautions for preventing groundwater pollution are observed.

(ix) Local Government (Water Pollution) Regulations, 1992

The provisions of Part VI of these Regulations deal with the control of discharges to aquifers. These provisions complement controls under other legislation, and, taken together, are intended to ensure full transposition into Irish Law of relevant provisions of Council Directive 80/68/EEC, described above.

Further statutory provision remains to be made in regard to aspects of the directive relating to tipping or landfill of waste containing List I or List II substances.

The pollution control provisions of the Local Government (Water Pollution) Acts, 1977 and 1990 are fully applicable to water contained in an aquifer. Such water accordingly enjoys the protection afforded by the general prohibition on the entry of polluting matter to waters, the requirements in relation to the licensing of trade and sewage effluent discharges and the other pollution prevention provisions e.g. the issue of notices under Section 12.

The 1977 and 1990 Acts, together with the procedures set out in the associated Regulations, are generally adequate to ensure compliance with relevant provisions of Council Directive 80/68/EEC. These statutory controls are supplemented by the European Communities (Waste) Regulations, 1979 and the EC (Toxic and Dangerous Waste) Regulations, 1982, in the case of potential pollution of groundwater arising from activities involving the disposal or tipping for the purpose of disposal of those harmful substances.

Part VI of the 1992 Regulations introduces a number of additional requirements in respect of the licensing of trade and sewage effluent containing any of the harmful substances specified in the First or Second Schedules where it is proposed to discharge such effluent to an aquifer.

These requirements build on the procedures contained in Part II of the 1978 Regulations on licence applications. They introduce specific obligations in relation to conducting prior investigations and the matters to be addressed in conditions attached to a licence, and provide for a periodic review of such licences and monitoring for the purpose of determining compliance with the licence conditions and the effects of a discharge on water in an aquifer.

Article 40 requires an applicant for a licence to carry out a prior investigation into specified matters relating to the aquifer to which it is proposed to make the discharge. The applicant is also required to make an assessment of the environmental impact of alternative methods of disposal of the harmful substance(s) concerned.

There is provision to dispense with the prior investigation requirements in a situation where the licence applicant can satisfy the authority that the harmful substance in the effluent is present in so small a quantity and concentration as to obviate the danger of deterioration in the quality of the water in the aquifer concerned. Article 41(1) establishes a quality standard of zero mg/L for the harmful substances specified in the First Schedule in the case of sewage and trade effluent discharged to an aquifer. The effect of a zero standard is to prohibit such discharges; except in specific situations described below, a licence could not be granted for the discharge of effluent containing such substances. A standard different from the quality standard prescribed in Article 41(1) may, however, be specified, in conditions attached to a licence if the water in the aquifer has been shown by prior investigation to be permanently unsuitable for domestic, commercial industrial, agricultural, fisheries or recreational uses, and where all technical precautions have been taken to prevent the entry of First Schedule substances into other (ground or surface) waters.

A different standard may also be specified in conditions attached to a licence where the discharge concerns the re-injection into the same aquifer of water used for geothermal purposes, water pumped out of mines and quarries or water pumped out for civil engineering works.

A quality standard of zero mg/L is prescribed for water in an aquifer in respect of the harmful substances specified in the First Schedule which might be caused or permitted to enter the water as a result of any disposal or tipping of the substances, or of any material containing them, or as a result of any activities on or in the ground. (Article 46).

A standard other than the quality standard of zero mg/L may be specified for a harmful substance in the Second Schedule in conditions attached to a licence for a discharge of sewage effluent or trade effluent to an aquifer provided that all practical technical precautions are observed to prevent the water in the aquifer being so affected by the harmful substance as to endanger human health or water supplies, harm living resources and the aquatic ecosystem or interfere with the beneficial use of the water (article 42).

Sub-article 42 (2) requires Local Authority to take such steps as may be appropriate to secure compliancies with the prescribed quality standard for water in an aquifer. Statutory provisions which may be relevant in this regard are sections 3, 10, 11, 12, 13 and 23 of the Water Pollution Act, 1977, as amended by the Water Pollution (Amendment) Act, 1990 and section 21 of the 1990 Act.

(x) EC (Waste) Regulations 1979, and the EC (Toxic and Dangerous Waste) Regulations, 1982.

These two sets of regulations transpose into Irish law the provisions of: Directive 75/442/EEC on Waste, and Directive 78/319/EEC on Toxic and Dangerous Waste. (More recently two new EC Directives on Waste (91/156/EEC) and Hazardous Waste (91/689/EEC) have been brought into effect by the European Commission. These two Directives have not been brought into force in Ireland by the Director of Regulations as yet.)

Directives 75/442/EEC and 78/319/EEC provide for control of the storage, treatment, transport and deposit of waste. They make Local Authorities responsible for the planning, organisation, authorization and supervision of disposal of waste in their areas. They include arrangements for the issue by the Local Authority of permits for storage, treatment or deposit of waste, and for the preparation by them of general waste and toxic and dangerous waste plans.

(xi) EC Directive on the assessment of the effects of certain public and private projects on the environment (85/337/EEC)

The directive sets out under what conditions the environmental assessment of a project is required, the minimum information it should contain and the consultations which need to accompany the process. When an assessment is required, its results have to be taken into account in the granting Authority's decision on the project (Timpson, 1991).

The Directive contains two lists of projects in Annex I and II. Those in Annex I require an Environmental Impact Assessment in *all* cases. A summary of the classes of projects in Annex I, is as follows

Crude oil refineries.

Thermal stations/installations/nuclear power stations/nuclear reactors.

Installations designed for permanent storage of radio-active waste.

Installations for melting of cast iron and steel.

Installations for extraction and processing of asbestos and products.

Integrated chemical installations.

Construction of motorways/express roads/railways/airstrips.

Trading ports.

Waste disposal installations (incineration/chemical treatment/landfill of toxic and dangerous wastes).

The projects listed in Annex II may require an Environmental Impact Assessment, where Member States consider that their characteristics so desire. The words that guide the authorising agency on the need to have an assessment submitted as part of the project proposals are whether they are "likely to have significant effects on the environment by virtue, *inter alia*, of their nature, size or location". Member States may establish the criteria and/or thresholds necessary to determine which Annex II projects are to be subject to an assessment. This relatively straightforward sounding procedure is complicated by a number of factors which reflect the diversity of administrative practice and different legal interpretations to the Directive in the Member States. One factor concerns the determination of thresholds, including the issue of how to deal with the cumulative effects of many smaller projects (O'Sullivan, 1990). Another factor concerns the information requirements of the assessment itself, outlined in Annex III, and its applicability to all forms of project. The projects which may be the subject an EIA in Annex II are presented below

Agriculture

Extractive Industry

Energy Industry

Processing of metals

Manufacture of glass

Chemical Industry

Food Industry

Textile, leather, wood and paper industries

Rubber Industry

Infrastructure projects

Modifications to projects included in Annex I

The Council Directive stresses that the best environmental policy is in preventing the creation of pollution at source rather than subsequently trying to counteract its effects (Timpson, 1991).

This Directive is one of the most important piece of planning legislation, from a groundwater interest point of view.

(xii) EC (Environmental Impact Assessment) Regulations, 1989 and Local Government (Planning and Development) Regulations, 1990

These two regulations provide for the incorporation into Irish Law of the provisions of Council Directive 85/337/EEC (on the assessment of the effects of certain public and private projects on the environment) for relevant development other than motorways.

The Council Directive 85/337/EEC and these Regulations give effect to Community policy for prevention of pollution at source, and ensure that the effects of development on the environment are taken into account at the earliest possible stage in the planning and decision making processes. They require that relevant projects which are likely to have significant effects on the environment be subjected to an assessment of such effects (that is environmental impact assessment) before development consent is given to them. They provide for participation by the public in the decision making process, by giving them the opportunity to express their opinions and by requiring that their opinions be taken into account.

The developments (other than motorways) which must be subjected to EIA in Ireland are specified in the First Schedule to the 1989 Regulations. The EIA process in respect of these developments must, of course, include assessment of potential effects on groundwater, where appropriate.

Of particular interest for the protection of groundwater, however, are the following three types of development included in the first schedule:-

PART I, 9 A waste disposal installation for the incineration or chemical treatment of hazardous waste, or the filling of land with such waste.

PART II,2(b) Drilling for water supplies where the expected supply would exceed 5,000 m^3/day.

PART II,11(c) Installation for the disposal of industrial and domestic waste with an annual intake greater than 25,000 tonnes.

National courts, Local Authorities and An Bord Pleanala are bound under EC law to *interpret* Irish law implementing a Directive so as to give effect to the objectives of the Directive in cases of ambiguity and where they have a discretion do to so. A cursory comparison with the thresholds and criteria adopted in other Member States indicates that the Minister has subjected far more projects to mandatory EIA than many other Member States and that the thresholds triggering the obligation to submit EIS are comparatively low in Ireland for most projects (Scannell, 1991).

There is scope for arguing that Irish legislation does not implement, or does not properly implement, a Directive when the defendant is the State or a public authority where the defendant is a private sector developer.

There are some projects that are outside the development control system. Planning permission is not required for the construction of public roads and motorways. The EC (Environmental Impact Assessment) (Motorways) Regulations 1988, require the authorities to provide EIS's of proposed motorways and submit them to the Minister of Environment. Also, for activities that have obtained Structural Funding from the EC, the Commission have adopted procedures for the assessment of the impact of the development on the environment (Woodford, 1990).

There are few agricultural developments that require an EIS to be submitted with the planning application. They are as follows: a) the use of uncultivated land or semi-natural areas for intensive agricultural practices, b) water management projects for agriculture, c) afforestation and land reclamation where the area involved would be greater than 200 hectares, d) poultry rearing installations, e) pig rearing installations.

(xiii) EC Directive concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC)

The Directive reflects concern about the high levels of nitrates in waters in many parts of the Community. It covers surface freshwater, estuarine, and coastal water and groundwater.

The Directive requires Member States to:

a) establish a code of good agricultural practice by 19 December 1993, for the purpose of providing a general level of protection for all waters against pollution by nitrates.

b) identify waters affected by pollution or which could be so affected in the absence of action programmes to reduce nitrate losses from agriculture.

c) designate as vulnerable zones all areas of land which drain into waters identified at b) above and which contribute to pollution. Designations are to be made in the first instances by 19 December 1993 (Article 3.2) with the position to be reviewed at least every four years (article 3.2 and 3.5)

d) establish action programmes in respect of designated vulnerable zones within two years of the initial designation and within one year of each additional designation.

The programmes which are intended to achieve significant reductions in nitrate losses to waters, must include measures contained in Annex III. In addition, any elements of the Code of Good Agricultural Practice which have not been superseded by measures listed in Annex III must be included.

A monitoring programme to determine the nitrate concentration in surface freshwater and in groundwater and to identify waters at b) above and areas of land requiring designation as at c) above must, therefore, be put in place by Local Authorities.

The Directive is targeted at combating water pollution caused by nitrates in livestock manure, chemical fertilizer, residues from fish farms, sewage sludge and other substances containing a nitrogen compound, which are applied to land to enhance the growth of vegetation in the pursuit of agriculture. "Fertilizer" is intended to embrace these sources and any other potential sources of a "nitrogen compound" which is used on land for that purpose. These pollution sources would be diffuse in nature.

Point sources could include defective farm effluent or waste storage facilities, problems due to the failure to segregate and deal properly with rainwater and soiled water from farmyards and other contaminated open areas, inadequate arrangements to collect and dispose of parlour washings, etc. Such sources of pollution, of course are not acceptable and are controllable under the Water Pollution Acts.

(xiv) EC (Use of Sewage Sludge in Agriculture) Regulations, 1991

These regulations give formal effect in Irish law to Council Directive 86/278/EEC of 12 June, 1986. The purpose of the regulations is to control the use of sewage sludge in agriculture in such a way as to prevent harmful affects on soil, vegetation, animals and man. They make Local Authorities responsible for the supervision of the supply of sewage sludge in agriculture.

Only treated sewage sludge, as defined in the regulations, may be used in agriculture, except where it is injected or otherwise worked into the soil. The regulations set out the restrictions and conditions applying to the use of sludge in agriculture. These include the requirements to ensure that the quality of surface water and groundwater is not impaired. Advice on how water quality can be protected is given to Local Authorities in Circular Letter L8/91 of 12 July, 1991, which was issued with the regulations.

The regulations fix the maximum allowable concentrations of heavy metals in both the receiving soil and sewage sludge used for agricultural purposes. They also fix the maximum amount of sludge which may be applied to soil at 2 tonnes dry matter per hectare per year.

(xv) EC (Quality of Water Intended for Human Consumption) Regulations, 1988

These regulations give formal effect in Irish law to EC Directive 80/778/EEC of 15 July, 1980. They apply to all water intended for human consumption whether it is used in its original state or after treatment, and cover all water, other than natural mineral water, whether supplied for consumption or used in food production and affecting the wholesomeness of the foodstuff.

In many cases water from private boreholes serving small numbers of houses receives no treatment, and even in the case of major public groundwater supplies no treatment may be necessary other than disinfection. The standards, therefore, are of considerable significance for water quality control in aquifers which are, or have the potential to be used as sources of water supply.

(xvi) Local Government (Environmental Protection Agency) Act, 1992

The new agency has wide ranging functions and powers relating to environmental control generally, including protection of the quality of groundwater. The functions of the Agency include :-

(a) Licensing, regulation and control of activities for the purpose of environmental protection,

(b) Monitoring of the quality of the environment, including the establishment and maintenance of databases of information related to the environment and the making of arrangements for the dissemination of such information and for public access thereto,

(c) the provision of support and advisory services for the purposes of environmental protection to local authorities and other public authorities in relation to the performance of any function of those authorities,

(d) the promotion and co-ordination of environmental research, the provision of assistance and advice in relation to such research and the carrying out, causing to be carried out, or arranging for such research (Section 52).

(xvii) Proposed EC Directive on the landfilling of waste (91/C190/01)

This proposed Directive states that it is necessary to clearly point out the general requirements with which landfills must comply, dealing with location, development, control and protective measures to be taken, in particular against the pollution of groundwater by leachate infiltration into the soil. The proposed Directive defines different classes of landfill; - landfill for hazardous waste, landfill for municipal and non-hazardous wastes and for other compatible wastes, as defined in the compatibility criteria set out in Annex III. A landfill may also receive a multiple classification, provided that disposal is carried out in separate areas of the site and that each of these areas complies with the specific requirements set for that class of landfill. The general requirements for all classes of landfills (only those that affect groundwater) are;

1. Location

1.1 Location of a landfill must take into consideration requirements dealing with:
The existence of groundwater or nature protection zones in the area;
The hydrogeological conditions of the area;

1.2 The landfill can be authorised if the characteristics of the site with respect to the above mentioned requirements, or the corrective measures to be taken, when considered in an EIA in the meaning of Directive 85/337/EEC indicate that the landfill does not pose a serious environmental risk.

2.2 All roads and service areas within the boundary of the landfill must be built and maintained to comply with the water control and soil and groundwater protection measures required for the site itself.

8. Protection of Soil and Groundwater.

8.1 A landfill must reach the necessary conditions, naturally or artificially achieved, to prevent pollution of the soil or groundwater.

8.2 The non-saturated geological formations constituting the substratum of the landfill base and sides shall satisfy the following permeability and thickness requirements.

- ☐ Landfill for hazardous waste; $K=1.0 * 10^{-9}$ m/s,
- ☐ Landfill for municipal and non hazardous wastes and for other compatible wastes; $K=1.0 * 10^{-9}$ m/s,

☐ Landfill for inert waste; K= no limit value.

Where these conditions are not met naturally, engineering measures shall be taken to achieve at least the same level of safety.

6.3 LEGISLATIVE IMPLICATIONS FOR THE GROUNDWATER PROTECTION PLAN

The groundwater protection plan that is proposed in the following chapter (Chapter 7.3) is similar to the County Development Plan required by the Local Government (Planning and Development) Acts, 1963 and 1990. They both consist of a suite of maps with an accompanying explanatory report. The County Development Plan controls development and provides a mechanism for the inclusion of the aspirations of the proposed groundwater protection plan. A detailed assessment of the integration of these two plans is beyond the scope of this project. Appendix D lists statements where the Groundwater Protection Plan may be integrated into the County Development Plan.

It has been noted that the land zoning in the County Development Plan is crude as it divides land only into urban areas and agricultural areas. A more subtle zoning of zoning of the agricultural areas may be necessary in light of the recommendations arising from the groundwater protection plan. The groundwater protection plan will identify zones of greater / lesser degrees of protection. Such an approach has been taken by the Dutch, with the introduction of a Soil Protection Act (1986), the standards of protection of which allow for a differentiation according to land use, namely arable land, grassland and fodder maize land. Similar sub-divisions for the agricultural zones are suggested for the county development plan of south Tipperary.

The Local Authority may require that an EIS be submitted in cases where they consider that the proposed development would be likely to have significant effects on the environment. These areas are known as being pollution sensitive and are defined in the groundwater protection map.

The Local Government (Water Pollution) Regulations, 1978 allow effluent exemptions only for domestic sewage discharges of less than $5m^3$/day or trade effluent discharges by local authorities. All agricultural effluent discharges would therefore appear to be covered by the 1977 Act whether they are discharged to surface water or to aquifers by land disposal.

Similarly with regard to the EC (EIA) Regulations, 1990, agriculture is listed in Annex II which *may* require an EIA where Member States consider that their characteristics so desire. Member States may establish the criteria and/or thresholds necessary to determine which Annex II projects are to be subject to an assessment.

The Local Government (Water Pollution) Amendment Act, 1990 under section 21, allows a Local Authority to make bye-laws relating to all or part of a particular part of its functional area where the authority considers it necessary to do so in order to prevent or eliminate the pollution of waters. The bye-laws may prohibit or regulate specified activities carried on for the purposes of agriculture, horticulture or forestry. The above legislation can implement the restrictions decided in the groundwater protection plan.

The EC Commission has adopted procedures for the assessment of the impact on the environment of plans, programmes and projects presented in the framework of the Structural Funds. These use the assessment principles of the EC Directive (85/337/EC) as a reference.

6.4 CONCLUSION

The present legal status with regard to groundwater protection has been outlined above. The approaches adopted are:

- Legal redress, where groundwater has been proven to be polluted.
- The inclusion of measures to protect groundwater in the form of the county development plan through the Local Government (Planning and Development) Acts, 1963 and 1990.
- Protection of groundwater can be managed through the various EC Directives and Local Government Acts, eg Nitrates, EIA's and proposed Landfill Waste.

CHAPTER 7 - GROUNDWATER PROTECTION

7.1 INTRODUCTION

A groundwater protection plan has been devised subsequent to an understanding of the aquifer systems, an assessment of vulnerability and a review of Irish planning, environmental law and the planning system. The proposed groundwater protection plan for south Tipperary is based on the above factors and experience gained from a review of protection plans and procedures in operation elsewhere.

A groundwater protection plan combines the vulnerability of an aquifer to pollution and the potential pollution loading. The degree of protection required is a function of the natural vulnerability of a site and the pollution load that will be applied to it. The pollution control efforts should be concentrated on regulating land uses and on controlling pollution at the source (Zaporozec, 1985).

Groundwater protection decisions are complex. They involve consideration of soils, geology, subsoils, hydrogeology, hydrochemistry and ecology. The study has dealt with all excluding the latter. They may require information on the type of potential pollution load, very detailed site investigations and monitoring over time before decisions can be made. Considerations will often need to be given to the balance of interests both within the groundwater environment and in a wider context. The plan and associated map provide a framework for decision-making, but they are not prescriptive and need to be qualified by site-specific considerations and expert technical advice.

In the light of the recent requirements for discharge licences, EIA's and planning applications, environmental protection is now a major issue and involves lengthy and time consuming procedures. Groundwater protection plans are a necessary input to the planning process that will enable it to be more efficient. They act as guides for Local Authorities by providing a primary warning system which can be used when assessing planning applications, therefore allowing informed decisions to be made quickly.

7.2 GROUNDWATER PROTECTION PLANS: A REVIEW

7.2.1 Introduction

The basic aim of all groundwater protection policies is to protect groundwater from contamination. However, the methods and degree of protection vary from country to country. The responses of different countries depend on a number of factors such as, the physical characteristics, the level of development, the type and extent of environmental problems, the legal and planning systems and the level of enforcement of environmental regulations. This results in two main types of approach : a statutory or a strategic approach but a combination is also possible.

(i) Statutory Approach

In countries such as Germany and certain states in the United States, groundwater protection zones is established by legislative procedures. This approach applies to both source and resource protection but is more applicable in source protection. Potentially polluting activities, such as waste disposal, are prohibited within a specified distance of a public water supply source.

(ii) Strategic Approach

This is an alternative approach which sets out a policy for the protection of groundwater resources and provides a basis for its implementation. It offers a common regional approach to the assessment of groundwater pollution hazards, but also considers the geological and hydrogeological conditions, along with the extent and location of existing and future resources. This type of policy is able to distinguish and prevent unacceptable proposals or actions so that resources can be more effectively protected.

In reality most policies are not clarified by straightforward statutory or strategic approaches. A combination of the two is generally the case: in that way the protection of the source and the resource is assured.

7.2.2 United States of America

Individual policies for the different States have not been researched but the most recent work by the regulatory body in the US, the Environmental Protection Agency (EPA), has been examined.

In 1987, the US EPA published guidelines for delineation of wellhead protection areas to meet the requirements of the Amendments (1986) to the Safe Drinking Water Act (1974). These guidelines concentrated on common types of aquifers in the U.S. -- granular, porous aquifers under unconfined conditions.

The DRASTIC approach has been recommended by the EPA to determine the vulnerability (Lance, Bitner and Graves, 1990). The DRASTIC approach is a useful tool and can be modified to suit each particular site. It is an EPA developed method for assessing groundwater pollution potential. The vulnerability of groundwater to contamination is related to the hydrogeologic conditions in the vicinity of the contaminant source. DRASTIC uses a numerical ranking system to systematically evaluate the pollution potential of any hydrogeological setting. The groundwater protection plans and associated code of practice are defined by each individual State, therefore they are varied depending on the geological situation and type of pollution loading. These groundwater protection plans have Federal backing.

7.2.3 European Policies

In general, European programmes involve the delineation of at least three zones of protection for the source, defined by distance and/or TOT (time of travel) within the saturated zones. An outermost zone is drawn to the recharge area boundary. Within these zones, restrictions are imposed on a number of activities. The degree of restriction decreases as the distance from the wellhead increases.

There follows summary excerpts of aquifer protection plans from various European countries, which illustrate different statutory and strategic approaches taken.

7.2.3.1 Germany

Germany has been at the forefront of groundwater protection, developing bacteriological protection zones around groundwater pumping stations in the early 20th century. The approach they have taken is a statutory one. A detailed and specific enquiry must be undertaken before a Groundwater Protection Zone can be established. This only applies to existing or proposed sites and is legally enforceable. The policies have arbitrary restrictions not hydrogeologically related. These are difficult to change if the level of risk from a potential pollutant increases or decreases.

The zones are largely based upon prohibition and will not allow a balance and are difficult to enforce (Woods, 1990).

The German wellhead strategy depends largely on analytical solutions. Zone 1 covers the immediate wellhead area, to a radius of 10-100m. Zone 2 is bounded by an area of equal delay time of 50 days - the average time to eliminate the pathogens in the aquifers. The "water protection area" Zone 3 is subdivided into inner and outer areas, if greater than 2km. The value of 2km originates from past experience in industry and no pollution effects have been found originating at greater distances. The restrictions relate mostly to protection against activities spreading pathogens and readily degradable chemicals (EPA, 1987).

7.2.3.2 The Netherlands

In the Netherlands, the groundwater strategy is a modification of that employed in Germany. It is based on techno-economic conditions translated into delay times of groundwater, and the same restrictions as in Germany apply.

The Netherlands delineates three or more zones based on aquifer type. These zones are generally defined using analytical models whose applications require some degree of technical expertise. Numerical methods for WHPA (wellhead protection area) assessment around important wells are increasingly common.

The first protective area lies immediately around the wellhead, up to 30 m away and is purchased by the water authority. The second zone is defined by a 60-day TOT within the saturated zone and is designed to protect the well from microbial contaminants. There is a "water protection" area, which is sub-divided into areas within 10 year and 25 year TOT, roughly 800m and 1200m from the well. An outermost zone, the "far recharge area", is delineated to the outer boundary of the well recharge area (EPA, 1987).

The Dutch introduced a Soil Protection Act in 1987. The consideration of soil and groundwater as a unity facilitates the protection of both as they adversely effect each other, eg: purification of waste water by filtration through the soil may lead to a polluted soil, especially if the waste water contains persistent pollutants (Woods, 1990).

7.2.3.3 Britain

In Britain water resource protection is under the control of the National Rivers Authority (NRA), which is a public body set up under the Water Act (1989). Its duties include maintenance and improvement of:

(i) water quality of water under their control.

(ii) conservation and proper use of water resources.

Prior to 1989, various Regional Water Regions (Severn Trent, Southern etc) had their own aquifer protection policies, these have been modified and incorporated into the NRA framework.

The NRA (1992) has produced a new national statement on the "Policy and Practice for the Protection of Groundwater". The Authority has reviewed the practices of the former Water Authorities, the practices in Europe, the U.S. and Canada. The key objective has been to devise a framework which covers all types of threats to groundwater, large or small, point sources or diffuse, by both conservative or degrading pollutants. It is designed to provide a basis for implementation of legislation in England and Wales.

There are several factors which may be used to assess aquifer pollution vulnerability. The most significant and generally applicable factors are the proximity to the groundwater source, (defined by Source Protection Zones) and the nature of the geology, (defined by the types of strata). The latter is used for Resource Protection Zones.

(i) Source Protection Zones

- Zone 1 (Inner Source Protection)
- Zone 2 (Outer Source Protection)
- Zone 3 (Source Catchment)

The orientation, shape and size of the zone are determined by the hydrogeological characteristics of the strata and the direction of groundwater flow.

Zone 1 (Inner Source Protection)

This zone is located immediately adjacent to the groundwater source and is designed to protect against the effects of human activity which might have an immediate effect on the source. It is an area defined by a 50 day travel time from any point below the water table to the source. It has a minimum radius of 50 metres from the source. This zone is based on the decay period for biological contaminants and on established practice in many other countries.

Zone 2 (Outer Source Protection)

This zone is of larger areal extent than Zone 1 and is defined by a 365 day travel time from any point below the water table to the source. The travel time is based upon that required to provide delay and attenuation of slowly degrading pollutants. Because of the need to ensure a reasonable level of dilution and to allow for the variable and unpredictable presence of fissuring in porous aquifers, Zone 2 will not be less than 25% of the source catchment area. This zone is not generally defined for confined aquifers.

Zone 3 (Source Catchment)

This zone defines the complete catchment area of a groundwater source such that all groundwater within it will eventually discharge to the source. It is defined on the basis of average annual groundwater recharge (effective rainfall). For wells and boreholes the area will be defined on the abstraction rate whilst, for springs, the area will be defined by the total discharge.

7.2.3.4 Ireland

In Ireland the strategy for groundwater protection is voluntary. In early 1980's it was proposed that a national policy for groundwater protection should be adopted. Since then various Local Authorities have informally adopted this policy around new sources and certain vulnerable area eg., Clonaslee. Some counties are now commissioning plans which eventually it is hoped will be adopted as part of the County Development Plan.

A groundwater protection plan sets out a policy for protection of groundwater resources and provides a technical framework for its implementation. It consists of a groundwater protection map with zonal divides and a Code of Practice. It enables Local Authorities to take account of groundwater when locating potentially polluting developments. The extent in which the groundwater protection plan can assist in making decisions on the control of potentially polluting activities is dependent on the type of activity. When planning permission is sought for a septic tank (activity III) in a moderately vulnerable poor aquifer situation the LA planner would be guided to grant permission subject to SR6 and provided an investigation by a non-groundwater professional was carried out (R3). Whereas, if planning permission was sought for an integrated chemical installation (activity I) in the same situation, the groundwater protection plan would guide the planner to request a "desk type" study with a walk over of the site and normal sampling by a groundwater professional (R2). This is further discussed in Chapter 7.3.4.

The present proposal in Ireland, is based on the division of the country into three zones based on the ability of the underlying rocks to yield water, with an additional safety zone designated around each public supply source (Daly, D., 1991). Within each zone, activities which should not be allowed are defined. Sources of potential contamination such as waste disposal sites, where known, are shown on maps.

The plan should be continually revised as geological and hydrogeological knowledge improves. In the plan the greatest protection is given to the source area and the regionally important aquifers (Appendix B).

The existing proposal at the national level is outlined below, however it is under review at the moment by the GSI.

- Zone 1

Is that area within 1km radius, or such other greater or lesser distance as deemed appropriate in the particular circumstances of existing or designated future groundwater sources for public supply. Generally excluding areas where the aquifer is overlain by thick overburden.

It is divided into three sub-zones ;

- Zone 1A: Area within 10m of source.

  No acceptable pollution source allowed here (Water Supply only).

- Zone 1B: Area between 10 and 300m of source .

  Developments which either individually or in combination with other similar developments would result in or would be likely to result in pollution of groundwater or derogation of a groundwater source should be prohibited. These include septic tanks, slurry spreading, burial grounds, waste disposal sites, industrial development which involves the use, production or storage of toxic materials, intensive agricultural activities, main foul sewers, sewage and trade effluent treatment works.

- Zone 1C: Area between 300 and 1000m of source.

  Well designed septic tanks, well managed farmyards and farming activities and burial grounds only are allowed here.

- Zone 2

Zone 2 comprises the regionally important resource aquifers but excludes both Zone 1 and those areas whose regionally important aquifers are overlain by thick subsoil cover or other impermeable confining strata. These aquifers are capable of yielding a large proportion of supply, so a high degree of protection is required so that neither their current use nor future development is needlessly affected.

Activities which should be prohibited include:

1. waste disposal sites intended to receive hazardous or toxic wastes, including domestic wastes, industrial and chemical wastes and sewage sludge.

2. major industrial and agricultural developments which involve the use, storage or handling of toxic potentially polluting materials, unless adequate protective measures are agreed.

- Zone 3

Zone 3 comprises the locally important resource aquifers, but excludes both Zone 1 and areas where locally important aquifers are overlain by thick subsoil or impermeable confining strata. These aquifers may yield locally important supplies of water, but do not have the same potential as Zone 2 aquifers. The degree of protection will depend on the local conditions. A balancing of interests between the need to protect groundwater resources and the need to find suitable waste disposal sites may often be necessary.

- Zone 4

Zone 4 comprises the remaining areas, excluding Zones 1, 2 and 3. Groundwater in this zone is of no regional importance, although small domestic supplies may be obtained. There should not be objections to any activities in this zone from the groundwater viewpoint. However, groundwater flow in such areas will be shallow and pollutants may re-emerge quickly to pollute surface sources.

The following counties have produced Groundwater Protection Plans: North Cork, Wexford, Galway, Mayo and Offaly, which has been updated. Plans for Waterford are near completion. The groundwater protection plan for Mayo was not implemented and is now currently being reviewed under the EC/DOE funded research project (STRIDE Programme of ERDF) and a plan for Roscommon is in progress under STRIDE. Source protection mapping with particular emphasis on catchment delineation is currently being addressed under a STRIDE project for counties Galway, Mayo and Roscommon.

The various Local Authorities in Ireland, all base their aquifer protection plans on criteria above (Daly and Wright 1979, Daly, D., 1991), with modifications to suit each area. As mentioned previously the Groundwater Section of the GSI are currently reviewing the structure of this policy. The policy outlined in Chapter 7.3 should form a basis for discussion following recent work in this area.

7.3 GROUNDWATER PROTECTION PLAN FOR TIPPERARY SOUTH RIDING

7.3.1 General

The proposed groundwater protection plan for Tipperary (South Riding) draws upon the most recent information available. This plan is a modification of that proposed by Daly, D., (1991), as it addresses in detail the vulnerability aspect and takes into account the physical characteristics of south Tipperary and some of the concerns of the Local Authority. The groundwater protection plan for south Tipperary attempts to integrate the concept of groundwater vulnerability to pollution and acceptable pollution risks on a county wide basis. This is one of a number of possible approaches and will require evaluation by all involved in the protection of groundwater, including especially Local Authorities, EPA and those working in the groundwater field. The existing groundwater plan takes into account the type of aquifer and source area but not the vulnerability of these areas. The integration of vulnerability is important because risk is then taken into consideration.

Different land uses and associated activities vary in their potential to pollute groundwater from the relatively innocuous to those involving hazardous substances. In addition, certain areas are particularly susceptible to pollution. In this study these pollution sensitive areas are divided into two groups; naturally vulnerable areas and wellhead protection (source) areas. The naturally vulnerable resource areas are delimited on the vulnerability map, and the source areas will be protected by circular areas with a radius of one kilometre. The resource protection examines the vulnerable areas in light of the type of aquifer. The importance of the vulnerability classification in relation to the Aquifer Protection Plan is obvious and can not be stressed enough.

The Groundwater Protection Plan deals primarily with the restrictive practices in each of the vulnerability categories. It is based on the natural vulnerability and the category of the aquifers. It becomes less restricted as one moves from regionally important to poor aquifer.

7.3.2 Resource Protection

This deals with the aquifer type and therefore the resource as a whole. This is not as restrictive as source protection as it is only a broad guideline for the protection of the groundwater. The restrictions applied to these areas are based primarily on the vulnerability. The concept of vulnerability has been outlined in detail in Chapter 5.

- Zone Definitions

- Zone 2 — Regionally Important Aquifers
  (Karstified areas and confined areas should be indicated on the map)

- Zone 3 — Locally Important Aquifers
  i) Generally moderately productive.
  ii) Generally unproductive except for local zones.

- Zone 4 — Poor Aquifers / Aquitards
  i) Locally productive.
  ii) Generally unproductive.

7.3.3 Source Protection

The objective of source protection areas is to provide a special additional element of protection for selected groundwater sources (borehole or springs). This is achieved by placing tighter controls on activities within all or part of their recharge area (Adams, 1991). This implies that the immediate area around the source (approximately 10 - 30 sq. metres), be it the well head or spring outflow, must be securely protected as per drilling practice. This area should be fenced in and all potentially polluting activities are prohibited.

In south Tipperary karst features are abundant and therefore must be treated as special cases. These hydrogeological features such as springs, swallow holes and sinking streams are very important in vulnerability terms. These features are shown on the vulnerability map (Map 7) and are extremely vulnerable.

Zone Definitions for south Tipperary

These zone definitions are a first approximation and it is noted that the zone of capture for most springs is not circular.

- ☐ Zone 1A — Area within 300m radius of the source excluding the fenced in area of the wellhead/spring outflow.

- ☐ Zone 1B — Area between 300 - 1000m or the catchment area where known.

In many cases the source is a spring. Here it is more difficult to define the catchment area or the zone of contribution. This is the area that is required to contribute the flow to the spring under natural recharge conditions. Detailed water level mapping and flow metering is required before this area is defined. In absence of such information, variable shapes such as recommended by the Southern Water Authority, UK (SWA, 1985) or calculated fixed radius shapes should be applied.

The karstic features (such as sink holes) that were dealt with already from a vulnerability point of view need stringent protection as they contribute to the groundwater directly. Other forms of conduits including mine shafts and abandoned boreholes between the surface and aquifers should also be included as they constitute potential entry points into aquifers for any pollutants found on the land surface and also need to be mapped (Adams, 1991). Influent rivers also should be considered, as any potentially polluting activity in its catchment area, could lead to the transport of the contamination and thus affect groundwater quality.

The vulnerability of areas within these zones may not always be the same. The risk of groundwater pollution therefore may also be different depending on the vulnerability classification. The groundwater protection matrices takes this into account firstly, by being pollutant group specific.

7.3.4 Groundwater Protection Statements (Codes of Practice)

The groundwater protection plan proposed for south Tipperary is a planning tool which takes into account the vulnerability of the groundwater, type of aquifer and proximity to the source. This protects both the source and the resource as a whole. The EC and Irish legislation as mentioned before in Chapter 6, requires that all groundwater be afforded protection. This plan attempts to protect in general terms the resource using the vulnerability as a guide and more specifically the source zones which are defined by their proximity to the source itself. The objective of the plan is to control development within the aquifer zones in such a way as to prevent pollution and contamination of water resources. The development control measures are divided into four levels of restriction based the level of information that is required to make an informed decision.

Levels of Restrictions

R1 Only acceptable subject to detailed investigations (including intervention type techniques, such as drilling etc.,) and assessment by a groundwater professional and possibly an independent review.

R2 Only acceptable subject to a "desk type" study and walk over of the site and normal sampling by groundwater professional.

R3 Only acceptable subject to a non-groundwater professional investigation and assessment.

R4 Acceptable

These restrictions impose certain investigative requirements on the proposed groups of polluting activities. The scope of a hydrogeological investigation depends on the nature of pollutant, the vulnerability and the type of aquifer zone. Therefore, the most intensive investigations (R1) will be directed where the threat is greatest or where conflicts of interest are most likely to occur (Hore, 1991).

Where there are Standard Conditions, Regulations, Guidelines and Codes of practice already emplaced these should ALWAYS be adhered to when granting / refusing planning permission.

The potentially polluting activities have been divided into four groups based on the planning system;

I Activities always requiring an Environmental Impact Statement (both Public and Private Developments)

Crude oil refineries.
Thermal stations/installations/nuclear power stations/nuclear reactors.
Installations designed for permanent storage of radio-active waste.
Installations for melting of cast iron and steel.
Installations for extraction and processing of asbestos and products.
Integrated chemical installations.
Construction of motorways/express roads/railways/airstrips.
Trading ports.
Waste disposal installations (incineration/chemical treatment/landfill of toxic and dangerous wastes).

Motorways.

Developments that acquire Structural Funding.

II Activities that *may* require an EIS/EIA

These are activities that have limiting thresholds. Those that exceed the threshold automatically require an EIS. Those that do not exceed the threshold may require an EIS if the Council decides for particular reasons (eg., environmentally sensitive area) to request an EIS to be carried out. The threshold values are found in Statutory Instrument No. 349 of 1989.

Agriculture.

Extractive Industry.

Energy Industry.

Processing of metals.

Manufacture of glass.

Chemical Industry.

Food Industry.

Textile, leather, wood and paper industries.

Rubber Industry.

Infrastructure projects.

Modifications to projects included in Group I.

Water Abstractions.

Other projects including installations for the disposal of industrial and domestic waste.

III Activities not requiring an EIS/EIA but may require Planning Permission / Discharge licence with conditions which will include recommendations and standard conditions, such as SR6, landspreading guidelines - Teagasc. Some examples are as follows;

Septic tanks.

Burial grounds.

Some agricultural activities.

Discharges via soil and subsoil > 5 m^3/day.

etc....

IV Activities requiring minimum planning attention.

Houses, hay sheds, etc....

These activity groups are used as they conform with the planning structures already in place. This project uses the vulnerability of the area criteria as a screening method on the basis that the environmental results of a project are a consequence of the sensitivity of the receiving environment. The vulnerability map designates these vulnerable (sensitive) areas. There are different levels of restrictions which depend on the type of pollutant and the sensitive areas.

The acceptability matrices (Table 7.1,2,3,4) relate to the groundwater aspect of a development or activity and therefore the investigation type restrictions only refer to groundwater. These matrices include source protection zones and the groundwater resource and include the vulnerability, aquifer type zone and the activity. These matrices are to be used only in conjunction with the groundwater protection map which illustrates the vulnerability and aquifer zone but is not pollutant specific. Some of the gradings in the matrices might have to be altered in the case of further detailed information on the particular activity from experts in each activity.

Appendix B includes source protection areas for the five areas examined in detail. The source areas are defined using the fixed radius method. The lack of detailed hydrogeological information requires that a lot more detailed work be undertaken to determine capture zones for these sites and eventually for all the Local Authority sources.

GROUP I ACTIVITY

	VULNERABILITY	zone	EXTREME	HIGH	MODERATE	LOW
	SOURCE	1A	*	*	*	*
		1B	*	*	R1	R1
RESOURCE	REGIONALLY IMPORTANT AQUIFER	2	R1	R1	R1	R1
	LOCALLY IMPORTANT AQUIFER	3	R1	R1	R1	R2
	POOR AQUIFER	4	R2	R2	R2	R2

Table 7.1 Acceptability matrix for Group I activities.

* Group I activity not permitted in these zones.

GROUP II ACTIVITY

	VULNERABILITY	zone	EXTREME	HIGH	MODERATE	LOW
	SOURCE	1A	*	*	R1	R1
		1B	*	*	R2	R2
RESOURCE	REGIONALLY IMPORTANT AQUIFER	2	R1	R1	R2	R2
	LOCALLY IMPORTANT AQUIFER	3	R1	R2	R2	R2
	POOR AQUIFER	4	R3	R3	R3	R3

Table 7.2 Acceptability matrix for Group II activities

* Group II activity not permitted in these zones.

GROUP III ACTIVITY

	VULNERABILITY		EXTREME	HIGH	MODERATE	LOW
		zone				
	SOURCE	1A	*	*	R2	R2
		1B	R1	R2	R2	R2
RESOURCE	REGIONALLY IMPORTANT AQUIFER	2	R1	R2	R2	R2
	LOCALLY IMPORTANT AQUIFER	3	R2	R2	R2	R2
	POOR AQUIFER	4	R3	R3	R3	R3

Table 7.3 Acceptability matrix for Group III activities.

* Group III activity not permitted in these zones.

GROUP IV ACTIVITY

	VULNERABILITY		EXTREME	HIGH	MODERATE	LOW
		zone				
	SOURCE	1A	*	R2	R3	R3
		1B	R2	R3	R3	R3
RESOURCE	REGIONALLY IMPORTANT AQUIFER	2	R3	R3	R4	R4
	LOCALLY IMPORTANT AQUIFER	3	R3	R4	R4	R4
	POOR AQUIFER	4	R4	R4	R4	R4

Table 7.4 Acceptability matrix for Group IV activities.

* Group IV activity not permitted in these zones.

The groundwater protection map illustrates the aquifer category-vulnerability codes. It is a complicated map and should not be solely used to decide on site specific situations. It gives an indication of the sensitivity of the groundwater and therefore suggests restrictions for certain practices.

CHAPTER 8 - CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Groundwater Protection Plans by their nature are multifaceted documents which require input from a variety of groups and individuals. There was effective communication and constructive assistance provided by the GSI, Tipperary South Riding County Council, Sligo RTC and Teagasc and other organisations with an interest in groundwater protection.

During the development of such a plan the compilation process comprised a substantial proportion of the work. Primary data in the form of bedrock geology maps, subsoil maps including borehole records and gas pipeline information; hydrogeological information such as well records and consultant reports; and hydrochemical analyses, provide the basis for the development of hydrogeological and vulnerability concepts. The quality of the primary data infers a degree of confidence. Therefore this confidence is transferred to the secondary (derived) maps and consequently to the final groundwater protection plan. The quality status of the data used throughout the study should be clarified within the final groundwater protection document.

Geological and hydrogeological factors are critical to the determination of the groundwater vulnerability, the assessment of potentially polluting developments and the alleviation of groundwater pollution problems. The main sources of groundwater pollution are considered to be farmyard wastes and septic tank effluent. However, the vulnerability approach taken is non-pollutant specific and is based on the assumption that the potential pollutant is discharged at zero datum (usually at the surface or generally below the surface in the case of septic tanks).

The groundwater protection plan is influenced by the physical characteristics of the area, the resource potential and the demand for siting of potentially polluting activities. In the Irish context the hydrogeology of a region may change dramatically within short distances. Often there are conflicts of interest between the groundwater resource and the need to site essential developments e.g., sewage treatment plants, therefore an acceptable and sensible balance must be reached.

The groundwater protection plan proposed in Chapter 7 is one of a number of approaches which may be adopted. Following careful consideration and consultation between those involved in groundwater protection, the EPA and the enforcing Local Authority, a pragmatic decision should be taken to adopt the most appropriate approach. Responsibility for the implementation of these guidelines rests primarily with the Local Authority. These guidelines are such that they may be altered to become more stringent/lenient depending on site specific information.

8.2 RECOMMENDATIONS

- The centralisation of data storage may be undertaken by the GSI in the forwarding of well records, hydrochemistry analyses, geotechnical reports and consultant reports to the groundwater section. This would prevent the duplication of work and thus provide economic resources for additional site investigations.
- Water abstraction data and discharge licence information should be made available for public scrunity.
- All well records should be sent to the GSI and special emphasis is now on the drilling companies to record exact locations, borehole logs and possible pumping test data and forward to the GSI.
- A national programme of regular chemical and bacterial monitoring of groundwater in representative sources of major aquifers is required to provide an overview of the present situation and to enable a check on future changes. This programme should also take account of the temporal variation in water quality when deciding on the sampling frequency. The programme should also allow for the sampling of waters pre-chlorination (as well as post-chlorination) so that the bacterial quality of the raw water can be assessed.
- Resources should be made available to investigate the hydrogeological situation in the vicinity of productive and potential sources. Further research is required for the delineation of spring capture zones and zones of influence of boreholes.
- Wellheads and spring outflows need to be adequately protected by covering and fencing to reduce access by animals and vandals. Pump houses should be fitted

with sampling taps to facilitate the frequent sampling and monitoring.

- The attenuation capacity of the soil and subsoil for specific pollutants and associated travel times requires detailed research. Following on from these studies, pollutant specific groundwater protection plans could be developed.

8.3 FINAL STATEMENT

In summary, south Tipperary's groundwater is an important natural resource whose value has not been sufficiently appreciated in the past. The necessary legal and administrative framework for the proper development and protection of groundwater is still at an early stage. It is hoped that this study will be implemented by incorporation into future County Development plans. Moves towards groundwater management have been encouraged by a perceived need to protect the resource from pollution rather than by any pressure on groundwater availability. European Community Directives stimulated recognition of the value of groundwater and the need for protection.

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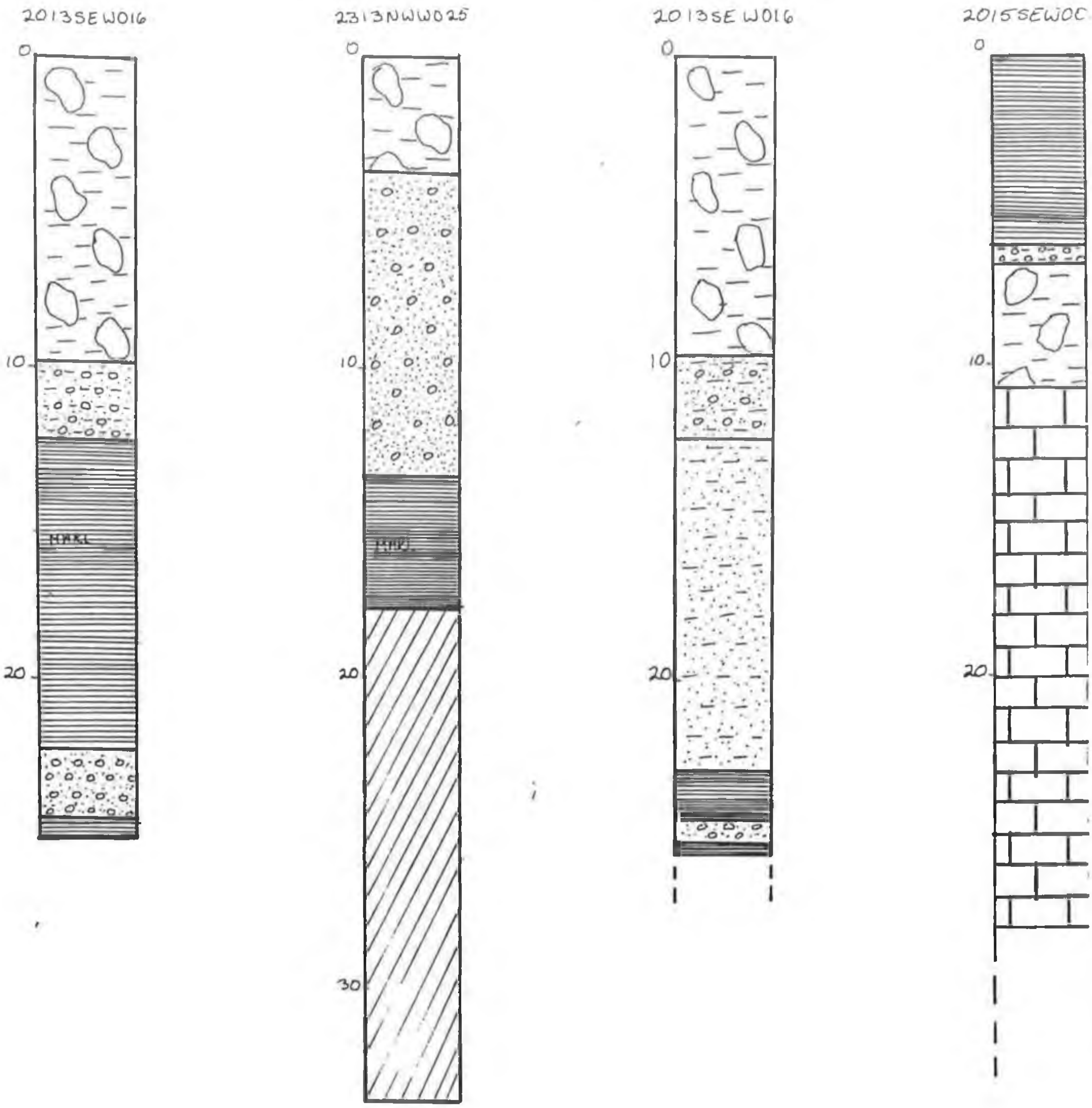
APPENDIX A

GEOLOGICAL SETTING

APPENDIX A.1

VERTICAL GEOLOGICAL LOGS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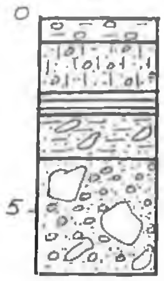
2313NWW025
2013SEW016
2015SEW0C
0
10
20
30
MARL
MARL

23100, 12650
Ballypatrick 1



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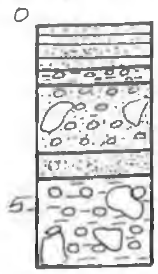

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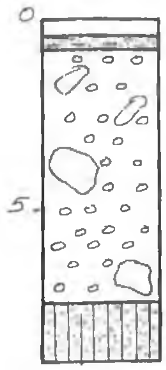

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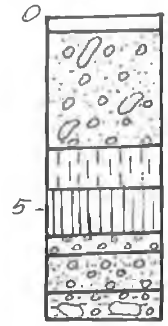

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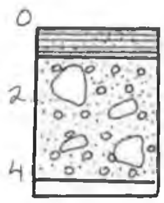

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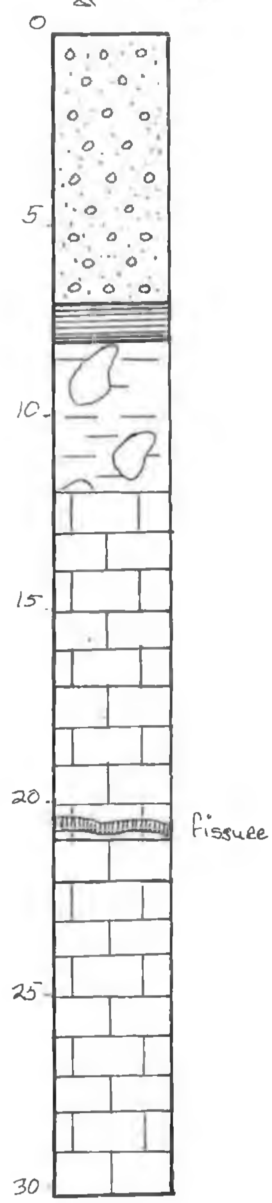
Ballypatrick 6



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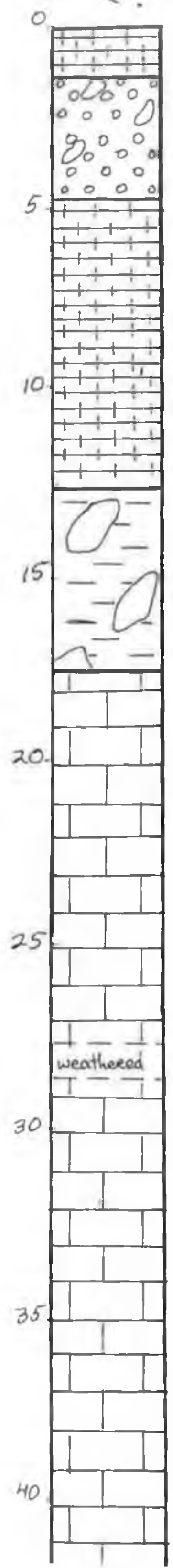
Ballypatrick 7



APPENDIX A.2

CORRELATION OF DINANTIAN STRATIGRAPHY

A.2 Correlation of Dinantian Stratigraphy

Table 2.3 includes all previous nomenclatures used in this area, as can be seen, the Kiltorcan Fm. spans the Devonian / Carboniferous boundary, the Cappagh White Fm. of Doran (1971) is assumed to be laterally equivalent.

The Porters Gate Fm., from Waterford/Wexford encompasses the Mellon House Fm. and Ringmoylan Fms., these formations are quite thin and may not always be mappable as separate units in the field.

The Gortdrum Fm. (Doran,1980) may be laterally equivalent to the Porter's Gate Fm. and the overlying Ballymartin Fm.

The Hook Head Fm. of the south east region has been taken to be equivalent to both the Ballymartin Fm. and the Ballysteen Fm. which is also known as the Argillaceous Bioclastic Limestones (ABL) by the exploration companies. The Solohodbeg Fm. as well as upper part of the Gortdrum Fm. are also assumed to be laterally equivalent to the Ballysteen Fm. and the Ballymartin Fm.'s.

The Waulsortian Fm. is a widely recognisable unit and so it has been found continuously in all the previous work. It thins out as it moves into progressively deeper water and as it gets younger in the sequence. It thins out as it moves northwards. The Waulsortian Fm. spans the Tournaisian/Visean (or Courceyan/Chadian) boundary. These limestones become dolomitised in patches throughout the area.

The Courceyan succession in both the South Central and Southern Syncline regions is taken to be the same. The nomenclature has been summed up in Table 2.4 and for the Visean is divided into two. This is done for convenience because of the structural and other geological deformational differences between these two regions. The significance of this difference is expanded upon in Chapter 2.9 and Chapter 3.

NORTHERN REGION

The Crosspatrick Fm. (CS) which is of Chadian age is assumed to be laterally equivalent to the Allenwood Beds (AW) used in the Chevron Facies map and the Knockordan Fm. (KD) from Carruthers, (1985).

Moving up into the Arundian, the Aghmacart Fm. (AG) has been taken to be equivalent to the Basinal limestones (CPL) from Chevron, and the Athassel Fm. (AS), Suir Fm. (SU), Lagganstown Fm. (LG) all from Carruthers.

The Ballyadams Fm. represents the unit from the Holkerian to the Brigantian which may be laterally equivalent to the Hore Abbey Fm. (HA) after Carruthers, the Cullahill Fm. (CH) from EP Daly, and the Shallow water limestones (SHU) from Chevron.

The Clogrennan Fm. (CL) of Brigantian age and may be laterally equivalent to the upper part of the Cullahill Fm., the Lackanetdante Fm. and the Farranacliffe Fm. of Carruthers.

The Namurian will not be dealt with in much detail and will be referred to as the Namurian sandstones and shales. The Westphalian in the Slieveardagh plateau is also known as the Coal Measures.

SOUTHERN SYNCLINE REGION

The Silverspring Fm.(SS) of Keeley is taken to be laterally equivalent to the Johnstown Red Marble Fm. (JRM) and the Magherareagh Fm. which are of Chadian age.

The Kilsheelan Fm. (KS) which is of upper Chadian to lower Asbian in age is thought to be laterally equivalent to the Cloneen Fm. and the Ballykeefe Fm. of Jones, the Garrane Fm. and Killavenoge Fm. both from Shearley.

The Kilee Fm.(KE) of Shearley overlies the Kilsheelan formation in the eastern section.

The Asbian is made up of three formations, the Ballyglasheen Fm. (BG), Rathronan Fm. (RR),and the Croane Fm. (CR) all taken from Keeley.

The Namurian in this region is known as the Giantsgrave Fm. (GG).

APPENDIX B

GROUNDWATER/HYDROGEOLOGY

APPENDIX B.1

DRY WEATHER FLOW ANALYSIS (1976)

GAUGING STATION	RIVER/ TRIBUTARY	FLOW DURATION CURVE 1976 Q25/75	TOTAL AREA TO STATION Km^2	TOTAL BASEFLOW L/s	AREA WHICH ONLY CONTRIBUTES FLOW TO THIS STATION Km^2	ACTUAL BASEFLOW OF THIS AREA L/s	SPECIFIC BASEFLOW OF AREA $L/s/Km^2$	NOTES
1604 Thurles Bridge	Suir	2.828	236	140 8/9/1976	236	140	0.59	
1601 Athlummon Bridge	Drish	4.12	140	120 8/9/1976	140	120	0.86	
1602 Beaktown Bridge	Suir	6.29	512	350 9/9/1976	136	90	0.66	
1603 Rathkennan Bridge	Clodiagh	7.259	236	230 8/9/1976	236	230	0.974	
1605 Aughnagross Bridge	Multeen	5.931	87	170 8/9/1976	87	170	1.95	
1606 Ballinclogh Bridge	Multeen	3.046	75	160 8/9/1976	75	160	2.13	
1608 New Bridge	Suir	6.634	1120	1970 7/9/1976	125	1060	8.48	
1617 Cappagh Old Bridge	Aherlow	---	179	579 2/9/1976	179	579	3.23	
1607 Killardy Bridge	Aherlow	4.982	273	1160 28/8/1976	97	581	5.98	

GAUGING STATION	RIVER/ TRIBUTARY	FLOW DURATION CURVE 1976 Q25/75	TOTAL AREA TO STATION Km^2 DATE	TOTAL BASEFLOW L/s	AREA WHICH ONLY CONTRIBUTES FLOW TO THIS STATION Km^2	ACTUAL BASEFLOW OF THIS AREA L/s	SPECIFIC BASEFLOW OF AREA $L/s/Km^2$	NOTES
1609 Cahir Park Bridge	Suir	3.917	1602	4300 28/8/1976	206	1170	5.67	
1619 Glengarra Wood	Burncourt	2.314 (1981)	12.5	119 6/9/1976	12.5	119	9.52	
1618 Knockballiniry	Glengarra	2.72 (1981)	12.5	84 7/9/1976	12.5	84	6.72	
1612 Tar Bridge	Tar	2.859	228	1620 6/9/1976	203	1417	6.98	
1613 Fourmilewater Bridge	Nire	3.888	19	260 6/9/1976	19	260	13.6	
1611 Gashouse Bridge	Suir	3.991	2172	7060 27/8/1976	324	880	2.72	

GAUGING STATION	RIVER/ TRIBUTARY	FLOW DURATION CURVE	TOTAL AREA TO STATION Km^2	TOTAL BASEFLOW L/s	AREA WHICH ONLY CONTRIBUTES FLOW TO THIS STATION Km^2	ACTUAL BASEFLOW OF THIS AREA L/s	SPECIFIC BASEFLOW OF AREA $L/s/Km^2$	NOTES
1622 Fethard	Clashawley		---	16 7/9/1976	160	16	0.1	
1621 Annsfort Bridge	Moyle		—	59 7/9/1976	55.7	59	1.06	
1610 Anner Bridge	Anner	2.849	422	960 7/9/1976	227	885	3.9	
1616 Lingaun Dale	Lingaun		84	228 2/9/1976	84	228	2.71	
1662 Dillion Bridge	Suir		—	—	—	—	—	

GAUGING STATION	RIVER/ TRIBUTARY	FLOW DURATION CURVE	TOTAL AREA TO STATION Km^2	TOTAL BASEFLOW L/s	AREA WHICH ONLY CONTRIBUTES FLOW TO THIS STATION Km^2	ACTUAL BASEFLOW OF THIS AREA L/s	SPECIFIC BASEFLOW OF AREA $L/s/Km^2$	NOTES
1624 Toberadora	Spring		—	87 6/9/1976				
1623 Kedrah	Spring		—	125 6/9/1976				
1625 Poulalee	Spring		—	93 7/9/1976				
1627 Poulalee and Poulatar	Springs		—	127 7/9/1976				

APPENDIX B.2

AQUIFER DEFINITIONS

DEFINITION OF AQUIFERS

SAND AND GRAVEL AQUIFERS
(i.e. Intergranular Flow Aquifers)

Two Categories

1. **Extensive** > 25 km^2
2. **Local** < 25 km^2

BEDROCK AQUIFERS
(i.e. Fissure Flow Aquifers)

Three Categories

1. **Regionally Important** (or Major)
   Karstified areas and areas confined by up to 150m low permeability bedrock should be indicated.

2. **Locally Important** (or Minor)
   Two subdivisions:
   (i) Generally Moderately Productive
   (ii) Locally Moderately Productive (or Generally Unproductive except for Local Zones)

3. **Poor** (or Aquitard)
   Occasionally this might be subdivided into:
   (i) Generally Unproductive
   (ii) Locally Productive

In defining the bedrock aquifers, some and preferably all of the following (somewhat arbitrary) quantitative characteristics should be used: areal extent, well yield, specific capacity, throughput/baseflow.

	Regionally Important	Locally Important	Poor
Areal Extent (km^2)	> 25	-	-
Spring Lowflow (m^3/d)	> 4000		
Well Yield (m^3/d)	> 400	100 - 400	< 100
Specific Cap. ($m^3/d/m$)	> 40	10 - 40	<10
Throughput (Mm^3/d)	> 8	-	-

(based largely on the views of Eugene Daly, GSI).

APPENDIX B.3

LOCAL AUTHORITY SOURCE INFORMATION

NAME & BOREHOLE NUMBER	AQUIFER TYPE	YIELD m^3/day	SUBSOIL	VULNERABILITY	BORE/ SPRING
1. (1715SEW001) GLENGAR 18612,15102	Poor	312	Rock close to surface	High	SPRING
2. (1715SEW002) HOLLYFORD 19336.15376	Poor	220	ORS Till	Moderate - High	SPRING
3. (1713NEW028) * IRONMILLS 19154,14683	Locally Important	1325	ORS Till	Moderate - High	BORE
4. (2013NWW041) GOOLD'S CROSS 20320,14820	Locally Important	237	Till-with - gravel	Extreme	BORE
5. (2013NWW032) SYNONE 20780,14600	Poor	280	Till-with - gravel	Moderate	BORE
6. (2015SWW010) HOLYCROSS 20785,15275	Poor		Till-with - gravel	High	
7. (2013NEW008) LAFFANSBRIDGE 22185,14613 21976,14712 21905,14675	Poor Regionally Important Regionally Important	980	Rock close to surface Limestone Till	Extreme High - Extreme High	BORE
8. (2015SEW011) * COALBROOK 22742,15085 22745,15081	Locally Important	1055	Rock close to surface	Extreme	BORE
9. (2013NEW006) BALLINCURRY 22793,14864	Locally Important	190	Limestone Till	High - Extreme	BORE
10. (2013NEW007) GORTEEN 22922,14950	Locally Important		Limestone Till	Moderate - High	
11. (2315SWW004) COMMONS 23108,15368	Poor	117	Limestone Till	Low	SPRING
12. (2015SEW010) RATHBEG 22745,15904	Regionally Important		Till-with - gravel	High	BORE
13. (2015NEW001) TRIANDRA 22796,16058	Regionally Important		Peat	High	BORE
14. (2015NEW002) INCHIROURKE 22630,16318	Regionally Important		Till-with - gravel, Peat	High	BORE
15. (2313SWW043) GRANGEMOCKLER 23624,13283	Poor		ORS Till	Low	
16. (2313SWW044) BALLINVIR 23660,13120	Poor	100	Limestone gravel	High	BORE

17. (2311NWW028) AHENNY 24135,12940	Poor	80	Rock close to surface, limestone till	High	BORE
18. (2313SWW042) TULLOHEA 23202,13055	Poor	271	Rock close to surface	High	SPRING
19. (2013SEW043) * CLORAN 22802,13338	Locally Important	2509	Rock close to surface	Extreme	SPRING
20. (2013SEW041) * MULLENBAWN 22245,13440	Regionally Important	2273	Rock close to surface	Extreme	SPRING
21. (2013SWW017) * SPRINGMOUNT 20093,13935	Locally Important (gravel)	1820	Gravel and Till-with-gravel	High	SPRING
22. (1713SEW011) FAWNAGOWAN 19055,13420	Poor		Till-with-gravel	High	BORE
23. (1711NEW003) * ROSSIDREHID 19308,12730	Locally Important	2350	Rock close to surface	Extreme	B + S
24. (1711NEW004) KILCORAN 19863,12178	Regionally Important		ORS Till	High	BORE
25. (2011NW039) * KEDRAH 20660,12775	Regionally Important	216000	Till-with-gravel, gravel	Extreme	SPRING
26. (2311NWW029) COOLNAMUCK 23837,12146	Locally Important (gravel)		Gravel, alluvium	High	BORE
27. (1711SEW009) CLOGHEEN 20078,11263	Regionally Important	136	Limestone Till	Moderate-High	SPRING
28. (1711SEW008) BALLYPOREEN 19331,11285	Regionally Important		Limestone Till	Moderate-High	SPRING

* high yielding sources.

APPENDIX B.4

GSI WELL DATABASE INFORMATION

Well No.	Grid ref.	Townland	Co	Six	Elev	Type	Use	Yield	Depth	Diam
2015SEW010	22745 15904	RATHBEG	TI	43	-1.0	WB	P		-1.0	-1
2015SEW009	22864 15125	COALBROOK	TI	46	-1.0	WB	D	P	37.4	-1
2015E W011	22742 15085	COAL BROOK	TI	49	-1.0	WB	P	E	-1.0	-1
11713WW027	17662 13188	REDHILL	TI	0	61.0	WB	D	P	28.0	-1
1713SWW018	18376 13322	MOUNT BRUIS	TI	000	-1.0	WB	D	P	58.0	-1
1713SWW019	18377 13304	MOUNT BRUIS	TI	000	-1.0	WB	D	P	58.0	-1
2011NWW021	21274 12577	WOODROFF	TI	026	-1.0	WB	O	P	44.2	-1
2011SWW035	21155 11680	MOANCREA	TI	035	-1.0	WB	D	P	14.6	-1
2015SEW008	22495 15656	BAWNREAGH	TI	036	-1.0	WB	D	P	18.8	-1
2011SWW039	20872 11567	CARROW	TI	039	45.7	WB	D	P	24.4	-1
1713SWW025	17638 13131	BALLYLOOBY	TI	041	-1.0	WB	A	P	29.5	-1
1713SWW014	18055 13152	KILROSS	TI	041	-1.0	WB	A	P	20.4	-1
2013NWW005	20710 14465	SYNONE	TI	041	107.0	WB	D	G	68.2	-1
2015SEW007	22452 15648	BAWNREAGH	TI	042	-1.0	WB	P	G	62.0	-1
2015NEW002	22630 16318	INCHIROURKE	TI	042	-1.0	WB	P		-1.0	-1
2015NEW003	22723 16165	FENNAR	TI	042	-1.0	WD	I		10.6	-1
2015NEW004	22723 16175	FENNAR	TI	042	-1.0	WB	I	P	33.5	-1
2015NEW005	22992 16048	LISDUFF,URLINGFD	TI	043	-1.0	WB	D	G	88.0	-1
2015NEW001	22796 16058	TRIANDRA	TI	043	-1.0	WB	P		-1.0	-1
1715SEW001	18612 15102	GLENGAR	TI	044	-1.0	WS	P	G	-1.0	-1
1715SEW002	19336 15376	HOLLYFORD	TI	045	-1.0	WS	P	P	-1.0	-1
2015SWW008	20420 15575	MOYALIFF	TI	046	-1.0	WB	D	P	24.6	17
2015SEW006	21569 15025	CURALEEN,H&J	TI	047	-1.0	WB	D	P	67.9	-1
2015SWW010	20785 15275	HOLYCROSS	TI	047	-1.0	WU	P		-1.0	-1
2015SWW007	20744 15160	GLENBANE	TI	047	-1.0	WB	D	P	25.3	-1
2015SWW006	20842 15447	HOLYCROSS	TI	047	-1.0	WB	D		104.5	-1
2015SWW005	20998 15133	KILLOUGH QUARRY	TI	047	152.4	WB	D	G	96.0	20
2015SWW009	20841 15447	HOLYCROSS	TI	047	-1.0	WB	P	G	36.5	-1
2015SWW001	20924 15414	HOLYCROSS	TI	047	-1.0	WB	D		30.5	-1
2015SWW002	20874 15405	HOLYCROSS	TI	047	-1.0	WD	D		24.0	-1

Rockhead	Strata	SWL	Disch.	Drawdown	Geol-logs	Analyses
-1.0	WAULSORTIAN LMSTN	-1.0	-1.0	-1.0		
3.6	CLAY+STONES/SHALE	-1.0	76.3	-1.0		
-1.0	SHALE/SSTN	-1.0	1055.0	-1.0		
18.3	LMSTN	12.2	22.0	-1.0		
5.5		27.0	54.5	-1.0		
5.5	SSTN	27.0	54.5	-1.0		
-1.0		12.2	4.0	-1.0		
11.6	LIMESTONE	11.3	27.0	-1.0		
-1.0		6.0	6.0	-1.0		
-1.0	LIMESTONE	-1.0	55.0	-1.0		
-1.0		12.1	87.2	-1.0		
-1.0		6.1	54.5	-1.0		
8.5	LMSTN	11.0	272.5	-1.0		
-1.0		20.0	300.0	-1.0		
-1.0		-1.0	-1.0	-1.0		
-1.0		26.1	-1.0	-1.0		
-1.0		-1.0	7.6	-1.0		
12.0	LIMESTONE	22.0	500.0	-1.0		
-1.0		-1.0	-1.0	-1.0		
-1.0	SANDSTONE	-1.0	321.0	-1.0		
-1.0	MUDSTONE	-1.0	220.0	-1.0		
5.5	LIMESTONE	1.5	97.1	1.5	Y	Y
10.7	LIMESTONE	-1.0	42.7	-1.0	Y	
-1.0		-1.0	-1.0	-1.0		
2.4	LIMESTONE	3.7	218.0	-1.0		
12.2	LIMESTONE	-1.0	-1.0	-1.0	Y	
0.0	LIMESTONE	-1.0	490.0	-1.0	Y	
-1.0		4.5	654.0	-1.0		
-1.0		-1.0	-1.0	-1.0		
-1.0		18.0	-1.0	-1.0		

2015SWW003	20732	15155	GLENBANE	TI	047	-1.0	WB	D	P	49.0	-1
2015SWW004	20867	15293	GRAIGUENOE	TI	047	-1.0	WB	D		46.0	-1
2015SEW006	22864	15125	COALBROOK	TI	048	-1.0	WB	D	P	37.4	-1
2015SEW001	21620	15232	PARKSTOWN	TI	048	-1.0	WB	D	P	33.5	-1
2015SEW002	21580	15205	PARKSTOWN	TI	048	-1.0	WB	D	P	35.0	-1
2015SEW003	21522	15180	HORSE & JOCKEY	TI	048	-1.0	WB	D	P	24.5	-1
2015SEW005	22560	15295	POYNSTOWN	TI	048	-1.0	WB	D		30.5	-1
2315SWW011	23323	15090	FARRANRORY	TI	049	182.0	WB	D	G	6.0	-1
2315SWW010	23020	15645	SPRINGFIELD	TI	049	-1.0	WB	D	P	43.9	-1
2315SWW006	23123	15477	BOULEA,COMMONS	TI	049	-1.0	WB	D	P	39.6	-1
2315SWW007	23125	15490	BOULEA,COMMONS	TI	049	-1.0	WB	D	P	67.1	-1
2315SWW008	23415	15258	BOULEAKEALE	TI	049	-1.0	WB	D	P	33.8	-1
2315SWW009	23256	15367	WILLIAMSTOWN	TI	049	-1.0	WB	D	P	32.0	-1
2315SWW005	23110	15365	BOULEA,COMMONS	TI	049	-1.0	WB	D	P	48.8	-1
1713NEW010	19119	14305	CHURCHFIELD	TI	049	91.4	WD	D	P	5.2	-1
2313NWW015	23459	14939	JESSFIELD	TI	049	-1.0	WB	D	P	49.6	152
2315SWW004	23108	15368	COMMONS	TI	049	-1.0	WS	P	P	-1.0	-1
2013NEW007	22922	14950	GORTEEN	TI	049	-1.0	WB	P		-1.0	-1
2315SWW001	23088	15290	COMMONS	TI	049	240.0	WB	D		-1.0	-1
2315SWW002	23032	15195	BOLINTLEA UPPER	TI	049	-1.0	WD	D		-1.0	-1
2315SWW003	23032	15150	BOLINTLEA LOWER	TI	049	213.0	WD	D		-1.0	-1
2015SEW004	22970	15995	LISDUFF	TI	049	-1.0	WB	D	P	27.0	-1
2315SWW012	23088	15290	COMMONS	TI	049	240.0	WD	D	G	7.5	-1
1713NEW019	18522	14908	CARNAHALLIA	TI	050	104.5	WB			24.0	-1
1713NEW018	18662	14400	DRUMWOOD,MONARD	TI	050	-1.0	WB	D	P	35.9	-1
1713NEW017	18563	14468	CLONLIRCK	TI	050	-1.0	WB	I	G	60.9	-1
1713NEW016	18738	14572	CLONGANHUE	TI	050	91.4	WB	D	P	14.9	-1
1713NEW009	19070	14295	DONOHILL	TI	051	-1.0	WB	I	P	9.1	-1
1713SWW024	18475	13965	LWR. MONARD	TI	051	-1.0	WB	D	P	7.6	-1
1713NEW026	18797	14615	PHILIPSTOWN	TI	051	-1.0	WB	D	P	6.0	-1
1713NEW025	19122	14430	BALLINVASSA	TI	051	-1.0	WB	D	P	3.3	-1
1713NEW024	19730	14395	SCARROUGH	TI	051	-1.0	WB			22.8	-1

9.0	BLUE LMSTN	16.5	17.0	-1.0	
-1.0		-1.0	-1.0	-1.0	
3.6	CLAY+STONE/SHALE	-1.0	76.3	-1.0	Y
-1.0		6.7	35.0	-1.0	
6.5	BLUE LMSTN	12.5	26.0	-1.0	
5.5	DRIFT/?	10.5	14.1	-1.0	
-1.0		-1.0	-1.0	-1.0	
-1.0	LIMESTONE	-1.0	-1.0	-1.0	
4.6	LIMESTONE	6.1	38.2	-1.0	
7.3	SLIG	7.6	32.7	-1.0	
-1.0	SANDSTONE	12.2	43.6	-1.0	
5.5	SLIG	9.5	38.2	-1.0	
5.5	SLIG	8.5	32.7	-1.0	
12.2	SLIG	7.6	27.3	-1.0	
5.2		3.7	65.4	-1.0	
4.9	SHALE	-1.0	21.8	-1.0	Y
-1.0	NAM/SHALE/SSTN	-1.0	117.0	-1.0	
-1.0	SHALE/SSTN	-1.0	-1.0	-1.0	
7.5	DRIFT/CLAY	-1.0	-1.0	-1.0	
9.0	DRIFT/CLAY	-1.0	-1.0	-1.0	
5.5	DRIFT/CLAY	-1.0	-1.0	-1.0	
3.6	LMSTN	6.7	54.5	-1.0	
-1.0		-1.0	-1.0	-1.0	
-1.0		-1.0	-1.0	-1.0	
35.9		14.6	65.4	-1.0	
-1.0		12.1	763.0	-1.0	
14.9		6.7	91.4	-1.0	
-1.0		3.7	54.5	-1.0	
-1.0		-1.0	32.7	-1.0	
6.0	CLAY+STONES	4.8	26.0	-1.0	
903.3	GRAVEL+SAND	2.2	16.3	-1.0	
-1.0		-1.0	-1.0	-1.0	

1713NEW028	19154	14683	IRONMILLS	TI	051	-1.0	WB	P	E	-1.0
1713NEW001	18802	14630	PHILIPSTOWN	TI	051	137.0	WB	D	P	14.0
1713NEW002	18738	14586	CLONGANHUE	TI	051	91.0	WB	D	P	-1.0
1713NEW003	19105	14295	CHURCHFIELD	TI	051	92.0	WD	D	P	5.2
1713NEW004	19008	14312	DONOHILL	TI	051	-1.0	WB	I	G	122.0
2013NWW016	20555	14649	ARDMAYLE	TI	052	-1.0	WB	D	P	40.8
2013NWW041	20320	14830	GOOLD'S CROSS	TI	052	-1.0	WB	P	P	-1.0
2013NWW014	20765	14970	TOBERADORA	TI	052	-1.0	WB	D	P	19.0
2013NWW015	20430	14780	BALLYROE	TI	052	-1.0	WB	D		-1.0
2013NWW011	20165	14972	SHARANAVARALLA	TI	052	-1.0	WB	D		61.0
2013NWW009	20285	14870	PIERCETOWN	TI	052	91.0	WB	D	G	38.0
2013NWW030	21075	14535	NEWTOWN	TI	053	-1.0	WB	D	P	47.5
2013NWW026	20728	14685	BOHERLAHAN	TI	053	-1.0	WB	I	G	57.0
2013NWW032	20780	14600	SYNONE	TI	053	-1.0	WB	P	G	-1.0
2013NEW012	22707	14807	BALLINCURRY	TI	054	-1.0	WB	D	P	36.6
2013NEW004	22070	14434	RATHMOLEY	TI	054	-1.0	WB	D	G	61.9
2013NEW003	22687	14598	CROHANE	TI	054	-1.0	WB	D	P	43.5
2013NEW002	22230	14620	KILLENAULE	TI	054	-1.0	WB		P	37.5
2013NEW001	22224	14648	KILLENAULE	TI	054	-1.0	WB		P	37.4
2013NEW013	22225	14602	KILLENAULE	TI	054	-1.0	WB	D	P	31.7
2013NEW014	22250	14630	CARGOE	TI	054	-1.0	WB	D	P	28.0
2313NWW025	23030	14910	BALLINGARRY	TI	055	-1.0	WB	D	P	33.5
2313NWW023	23155	14412	KYLE,LISMOLAN	TI	055	-1.0	WB	D	P	43.5
2313NWW017	23227	14853	TINNOCK	TI	055	-1.0	WB	D	P	49.7
2313NWW016	23189	14600	MULLINAHONE	TI	055	-1.0	WB	D	P	43.5
2313NWW027	23300	14930	FOYLE	TI	055	-1.0	WB	D	P	49.6
2313NWW028	23100	14438	KNOCKULTY	TI	055	-1.0	WB	I	G	30.4
2313SWW026	23365	14558	MOHABBER	TI	055	-1.0	WB	D	P	39.6
2313NWW031	23194	14591	UPR. GRAEGAUGH	TI	055	-1.0	WB	D	P	39.6
2013NEW014	22981	14523	WILLFORD	TI	055	-1.0	WB	D	G	49.6
2313NWW034	23124	14837	BOULEA,COMMONS	TI	055	-1.0	WB	D	G	37.4
2313NWW026	23124	14852	BALLINGARRY	TI	055	-1.0	WB	D	P	31.4

-1	-1.0	SANDS/GRAVELS/SSTN	-1.0	1325.0	-1.0	Y	Y	Y
-1	14.0		5.0	65.5	-1.0			
-1	15.0		6.7	32.7	-1.0			
-1	5.2		3.7	65.4	-1.0			
-1	19.0	SAND/GRAVEL	-1.0	491.0	-1.0			
-1	-1.0		9.1	13.1	-1.0			
-1	-1.0	LMSTN	-1.0	237.0	-1.0			
-1	4.5	LMSTN+CLAY FILLED	7.5	109.0	-1.0			
-1	-1.0		11.0	64.5	-1.0			
-1	1.5	LMSTN	6.0	-1.0	-1.0			
-1	3.0	LMSTN	12.0	327.0	-1.0			
-1	8.5	LIMESTONE	3.0	38.2	-1.0			
-1	-1.0		6.1	1090.0	-1.0			
-1	-1.0	LMSTN	-1.0	280.0	-1.0			
-1	6.1	SLIG	1.5	54.5	-1.0			
152	4.6	SHALE	-1.0	327.0	-1.0	Y		
-1	2.4	SHALE	-1.0	43.6	-1.0	Y		
-1	-1.0	SHALE & SHALY LIME	-1.0	87.3	-1.0	Y		
-1	2.7	SHALE & SHALY LIME	4.5	32.7	-1.0	Y		
-1	-1.0	SLIG	5.5	38.2	-1.0			
-1	-1.0	SLIG	13.5	22.0	-1.0			
152	13.4	SHALE	7.6	218.0	-1.0	Y		
152	3.6	SHALE	-1.0	109.0	-1.0	Y		
-1	4.8	SHALE	6.0	43.6	-1.0	Y		
-1	1.2	SHALE	-1.0	43.8	-1.0	Y		
152	1.8	SHALE	-1.0	32.7	-1.0	Y		
-1	-1.0		3.0	490.0	-1.0			
-1	3.7	MUDSTONE & SHALE	9.1	163.5	-1.0	Y		
-1	6.1	SLIG	3.9	91.4	-1.0			
203	3.7	SHALE & LIMESTONE	7.9	654.0	-1.0	Y		
-1	16.7	CLAY+STONE/SANDY S	-1.0	272.5	-1.0	Y		
-1	18.2	CLAY+STONE/SANDY S	15.2	109.0	-1.0			

2313NWW033	23184	14618	UPPER GRAEGAUGH	TI	055	-1.0	WB	D	P	39.6	-1
2013NEW006	22793	14864	BALLINCURRY	TI	055	-1.0	WB	P	P	-1.0	-1
2313NWW010	23221	14708	BALLAGHBOY	TI	055	-1.0	WB	D	P	31.0	-1
2313NWW011	23462	14937	JESSFIELD	TI	055	-1.0	WB	D	P	49.0	-1
2313NWW009	23214	14078	BALLYVADLEA	TI	056	-1.0	WB	D	P	26.0	-1
1713SWW020	18105	13980	FORTYACRES,TIPP	TI	057	122.0	WB	D	P	11.0	-1
2013SEW035	22552	13682	BALLINARD	TI	058	-1.0	WB	D	P	48.7	-1
1713SWW016	18460	13990	CULLEEN	TI	058	-1.0	WB	D	P	13.0	-1
1713NEW005	18672	14408	DRUMWOOD	TI	058	118.0	WB	D	P	36.0	-1
1713NEW006	18662	14417	DRUMWOOD	TI	058	118.0	WB	D	P	36.0	-1
1713SEW004	18915	13782	SADLIERSWELL	TI	059	91.4	WB	D	P	28.9	-1
1713NEW011	19080	14180	GRANGE	TI	059	-1.0	WD	D	P	25.9	-1
1713NEW012	19407	14180	ALLEEN	TI	059	-1.0	WB	I	P	4.2	-1
1713NEW013	19685	14237	BALLINTEMPLE	TI	059	97.5	WB	O	E	42.9	-1
1713NEW014	19029	14298	DONOHILL	TI	059	-1.0	WB	O	E	33.5	-1
1713NEW021	19016	14320	DONOHILL	TI	059	121.9	WB	I	G	121.9	-1
1713NEW020	18960	14310	LISHEENDARBY	TI	059	-1.0	WD	D	P	5.1	-1
1713NEW015	19080	14190	GRANGE,DONOHILL	TI	059	-1.0	WD	D	P	3.9	-1
1713NEW027	19075	14298	FARRNACLARA	TI	059	105.1	WB	D	P	3.1	-1
1713NEW008	18800	14268	GURTANERRIG	TI	059	-1.0	WB	D	P	11.0	-1
2013SWW008	20134	13845	GOLDEN	TI	060	-1.0	WD	I	G	3.1	-1
2013NWW029	20453	14028	BALLINAMONA	TI	060	-1.0	WB	D	P	28.9	-1
2013SWW017	20093	13935	SPRINGMOUNT	TI	060	-1.0	WB	P	E	-1.0	-1
2013SWW006	20778	13872	OWEN BIGGS LOT	TI	060	-1.0	WB	D		67.9	203
2013NWW040	20345	14190	BALLINAHINCH	TI	060	-1.0	WD		P	-1.0	-1
2013NWW039	20344	14207	BALLYNAHINCH	TI	060	-1.0	WB	D	P	63.3	-1
2013NWW037	20530	14189	MONAGEE	TI	060	-1.0	WB	D	P	12.2	-1
2013NWW028	20484	14250	CAMAS,CASHEL	TI	060	-1.0	WB	D	P	54.8	-1
2013NWW027	20484	14237	CAMAS,CASHEL	TI	060	91.5	WD		P	-1.0	-1
2013NWW025	20713	14044	THE COMMONS	TI	061	-1.0	WB	D		51.2	203
2013SWW009	21495	13805	RATHBRIT	TI	061	-1.0	WD		P	-1.0	-1
2013SWW007	21149	13762	BALLYCOMISK	TI	061	-1.0	WB	B	P	86.2	152

6.1	SHALE	4.0	91.4	-1.0		
-1.0	SSTN	-1.0	190.0	-1.0		
3.0	LMSTN	2.0	54.5	-1.0		
9.0	LMSTN	-1.0	87.2	-1.0		
6.0		11.0	65.0	-1.0		
4.0	LMSTN	4.0	66.0	-1.0		
9.1	LIMESTONE	9.1	87.0	-1.0		
-1.0	LMSTN	2.5	55.0	-1.0		
36.0		14.5	65.5	-1.0		
36.0	DRIFT/SAND	14.0	87.2	-1.0		
28.9		-1.0	32.7	-1.0		
-1.0	LIMESTONE	-1.0	-1.0	-1.0		
-1.0		2.7	141.7	-1.0		
-1.0		-1.0	-1.0	-1.0		
-1.0		-1.0	-1.0	-1.0		
18.9	LIMESTONE & SANDST	-1.0	490.5	-1.0	Y	
5.1		3.0	32.7	-1.0		
3.9		2.4	32.7	-1.0		
3.1	CLAY+GRAVEL /SAND	1.5	22.0	-1.0		
-1.0		2.0	77.0	-1.0		
-1.0		1.2	163.5	-1.0		
3.0		18.2	26.1	-1.0		
-1.0	SANDS/GRAVELS/LMST	-1.0	1820.0	-1.0		
-1.0	LIMESTONE	31.6	-1.0	-1.0		
-1.0		-1.0	-1.0	-1.0		
3.7	LIMESTONE	15.2	5.4	-1.0		
12.2	DRIFT/LIMESTONE	-1.0	164.0	-1.0		
0.0	LIMESTONE	2.7	27.3	-1.0		
-1.0		-1.0	-1.0	-1.0		
-1.0	BLACK LIMESTONE	15.8	-1.0	-1.0		
-1.0		-1.0	-1.0	-1.0		
26.8	LIMESTONE	52.4	59.9	-1.0	Y	Y

2013SWW005	21393	13855	KILCONNELL	TI	061	-1.0	WS	D	G	-1.0	-1
2013SWW004	21256	13834	SANDYGROVE HSE.	TI	061	-1.0	WS	D	G	-1.0	-1
2013SWW003	21188	13834	BALLYDUAG	TI	061	-1.0	WB		G	106.6	-1
2013NWW038	20677	14323	FREAGHDUFF	TI	061	-1.0	WD		P	15.2	-1
2013NWW036	20919	14381	GALMALCELLIS	TI	061	-1.0	WU		P	6.0	-1
2013NWW035	21435	14175	CAHERBAWN	TI	061	-1.0	WB	D	P	13.4	-1
2013NWW042	20750	14240	DEANSGROVE	TI	061	-1.0	WB	D	P	30.5	-1
2013NWW034	21184	14320	DUALLY	TI	061	-1.0	WB		P	30.5	-1
2013NWW031	20792	14102	LADYSWELL	TI	061	-1.0	WB	D	P	37.4	-1
2013NWW033	20994	14338	GLANANMORE	TI	061	-1.0	WB	D	P	59.0	-1
2013NWW017	20837	14223	CASHEL(DUB.RD.)	TI	061	-1.0	WB	O		76.5	-1
2013NWW018	21267	14636	ERRY,CASHEL	TI	061	-1.0	WB	D	P	24.0	-1
2013NWW019	21220	14990	AUGHNAGOMAWN	TI	061	-1.0	WB	D	P	25.0	-1
2013NWW020	21253	14268	RATHCLOGH	TI	061	-1.0	WB	D	P	31.6	-1
2013NWW021	20763	14034	CASHEL	TI	061	-1.0	WB	O	P	51.8	-1
2013NWW022	20750	14240	DEANSGROVE,CASHE	TI	061	-1.0	WB	D	P	48.7	-1
2013NWW023	20687	14313	FREIGHDUFF	TI	061	-1.0	WB	D	P	73.2	-1
2013NWW024	20718	14049	ROCK ABBEY	TI	061	-1.0	WB	D		90.9	203
2013SEW006	21812	13451	BARRETTSTOWN	TI	061	-1.0	WB	D	P	67.0	-1
2013SWW001	21386	13655	KILBRAUGH	TI	061	260.0	WB	D		12.0	-1
2013NWW012	21192	14790	BALLYTARSNA	TI	061	-1.0	WB	D	P	31.0	-1
2013NWW013	21283	14782	BALLYTARSNA	TI	061	118.0	WB	D	P	28.0	-1
2013NWW010	20293	14870	GOOLD'S CROSS	TI	061	-1.0	WB	D	P	19.0	-1
2013NWW006	20963	14492	AUGHNAGOMAUN	TI	061	-1.0	WB	D	P	24.0	-1
2013NWW007	20870	14506	AUGHNAGOMAUN	TI	061	-1.0	WB	D	P	58.0	-1
2013NWW008	20213	14815	PIERCETOWN	TI	061	92.0	WB	D	G	38.0	-1
2013NWW002	20779	14264	DEANSGROVE	TI	061	-1.0	WB	D	P	49.0	-1
2013NWW003	20803	14245	DEANSGROVE	TI	061	-1.0	WB	D	P	24.0	-1
2013NWW004	20762	14048	CASHEL	TI	061	-1.0	WB	D	P	67.0	-1
2013NWW001	20857	14372	GORTMACELLIS	TI	061	-1.0	WB	D	P	29.8	-1
2013SEW032	22097	13736	KILKNOCKIN	TI	062	-1.0	WB	B	P	85.3	152
2013SEW031	22247	13750	KNOCKKELLY HSE.	TI	062	-1.0	WB	D	P	28.6	-1

-1.0	GRAVEL	-1.0	-1.0	-1.0	
-1.0	GRAVEL	-1.0	-1.0	-1.0	
-1.0		4.5	545.0	-1.0	
915.2		-1.0	-1.0	-1.0	
-1.0		-1.0	-1.0	-1.0	
7.6	SHALE	9.0	17.4	-1.0	Y
-1.0		-1.0	27.3	-1.0	
-1.0		-1.0	-1.0	-1.0	
4.9		10.7	32.7	-1.0	
24.3		18.2	38.2	-1.0	
-1.0	SHALE	31.6	-1.0	-1.0	
3.0		-1.0	109.0	20.0	
5.0		8.2	78.5	-1.0	
4.6	LIMESTONE	4.3	43.6	-1.0	
-1.0	LIMESTONE	13.7	16.4	-1.0	
-1.0	LIMESTONE	3.0	65.4	-1.0	
4.9	LIMESTONE	18.2	32.7	-1.0	
-1.0	BLACK LIMESTONE	17.6	-1.0	-1.0	
2.5	LIMESTONE	14.5	81.0	-1.0	Y
-1.0		-1.0	-1.0	-1.0	
6.5	HARD BLUE LMSTN	6.5	60.0	-1.0	
21.0	LMSTN	17.5	71.0	-1.0	
9.0	WM. RYAN	4.5	87.2	-1.0	
5.5	DRIFT/LMSTN.BROKEN	5.5	109.0	-1.0	
3.0	LMSTN	12.0	38.0	-1.0	
3.0	LMSTN	12.0	327.0	-1.0	
-1.0	LMSTN	3.0	182.0	-1.0	
17.0	LMSTN	0.5	65.4	-1.0	
-1.0	SHALE	-1.0	54.5	-1.0	
6.7	LMSTN/CHERT	13.7	65.4	-1.0	
7.6		-1.0	6.5	-1.0	
5.2	SHALE	27.4	43.6	-1.0	

2013NEW005	22170	14255	LISMORTAGH	TI	062	-1.0	WB	D	P	37.4	152
2013NEW011	22277	14030	COOLMORE	TI	062	-1.0	WB	O	E	30.5	-1
2013SEW036	22045	13968	COOLANURE	TI	062	-1.0	WD	D	P	9.1	-1
2013SEW013	22094	13749	KILNOCKAN	TI	062	-1.0	WB	D	P	116.7	-1
2013SEW014	22070	13740	KILMOCKIN	TI	062	-1.0	WB		P	116.7	152
2013SEW009	22290	13868	KNOCKELLY	TI	062	-1.0	WB	D	P	19.5	-1
2313SWW010	23504	13965	CLONAGOOSE	TI	063	-1.0	WB		G	23.0	-1
2013SWW015	21222	13660	BULLOCKPARK	TI	063	-1.0	WS	D	G	1.0	-1
2313NWW022	23145	14397	KNOCKNULTY	TI	063	-1.0	WB	D	P	15.0	-1
2313NWW021	23132	14400	KNOCKULTY	TI	063	-1.0	WB	D	P	18.0	-1
2313NWW020	23112	14403	KNOCKULTY	TI	063	-1.0	WB	D	P	14.5	-1
2313NWW019	23095	14415	KNOCKULTY	TI	063	-1.0	WB	D	P	21.0	-1
2313SWW007	23194	13774	BALLYCULLIN	TI	063	-1.0	WB	D	P	19.8	-1
2313SWW006	23500	13982	CLONAGOOSE	TI	063	62.4	WB	D	P	54.8	-1
2313SWW005	23215	13659	GORTEEN	TI	063	85.3	WB	D	P	12.1	-1
2313NWW018	23075	14415	KNOCKULTY	TI	063	-1.0	WB	D	P	18.0	-1
2313NWW024	23042	14412	LISMALIN	TI	063	-1.0	WB	D	P	24.6	152
2313NWW030	23360	14034	MULLINAHONE	TI	063	-1.0	WB	I	E	54.8	-1
2013SEW041	22875	13988	KNOCKROE	TI	063	-1.0	WB	D	P	49.6	-1
2013SEW040	22658	13992	CURRAHEEN	TI	063	-1.0	WB	D	P	61.8	-1
2313NWW012	23590	1424	GRAIGUE	TI	063	-1.0	WB	D		24.0	-1
2313NWW001	23635	14026	GURTEENE	TI	063	-1.0	WB	D	P	22.8	-1
2313NWW002	23662	14035	GURTEEN	TI	063	-1.0	WB	D	P	16.0	-1
2313NWW003	23766	14074	COOLOGUE	TI	063	-1.0	WB	D	P	16.0	-1
2313NWW004	23746	14160	COOLOGUE	TI	063	-1.0	WB	D	P	15.0	-1
2313NWW005	23970	14132	AHENURE	TI	063	-1.0	WB	D	P	19.5	-1
2313NWW006	23528	14340	MODESHILL	TI	063	-1.0	WB	D	P	40.0	-1
2313NWW007	23486	14335	MODESHILL	TI	063	-1.0	WB	D	P	24.0	-1
2313NWW008	23392	14335	CLASHBEG	TI	063	-1.0	WB	D	P	23.0	-1
2013SEW008	22773	13872	TUULACOSSAN	TI	063	-1.0	WB	D	P	33.5	-1
2313SWW002	23504	13965	CLONAGOOSE	TI	063	-1.0	WB	D	G	23.0	-1
2313SWW003	23615	13937	RAHEEN	TI	063	-1.0	WB	D	P	17.0	-1

1.8	SHALE	10.4	21.8	-1.0	Y
-1.0	GRAVEL	-1.0	1308.0	-1.0	
-1.0		-1.0	-1.0	-1.0	
70.1	LIMESTONE	-1.0	8.7	-1.0	Y
5.2	LIMESTONE	-1.0	8.7	-1.0	Y
3.0	LMSTN	8.5	54.5	-1.0	
14.0		6.0	220.0	-1.0	
-1.0		-1.0	-1.0	-1.0	
915.0		-1.0	87.2	-1.0	
11.0		-1.0	218.0	-1.0	
14.5		14.5	218.0	-1.0	
2.5		-1.0	87.2	-1.0	
15.2		12.1	27.2	-1.0	
12.1	LIMESTONE	15.2	65.4	-1.0	
7.3	LIMESTONE	7.6	65.4	-1.0	
9.0		-1.0	64.5	-1.0	
11.5	SHALE	1.8	87.2	-1.0	Y
-1.0		6.1	1090.0	-1.0	
-1.0	CLAY+STONES/SANDY	-1.0	22.0	-1.0	
17.7	TILL/MARL/SHALE/LM	3.7	163.0	-1.0	
-1.0		6.0	-1.0	-1.0	
6.0	LMSTN	12.0	64.5	-1.0	
7.5		11.0	65.0	-1.0	
6.0		3.0	60.0	-1.0	
14.5		8.0	174.4	-1.0	
5.5		4.0	57.0	-1.0	
10.5	LMSTN	12.0	65.0	-1.0	
5.0		11.0	64.5	-1.0	
6.0	LMSTN	-1.0	65.0	-1.0	
0.6		15.8	54.5	-1.0	
14.0		6.0	220.0	-1.0	
7.0	LMSTN	-1.0	76.0	-1.0	

2013NEW008	22185	14613	LAFFANSBRIDGE	TI	064	-1.0	WB	P	G
1713SWW007	18035	13320	MOORESFORT	TI	065	-1.0	WB	D	P
1713SWW002	17940	13112	BALLYWIRE	TI	065	137.0	WB	D	P
1713SWW017	17670	13110	BALLYLOOBY	TI	065	-1.0	WB	D	P
1713SWW010	17860	13438	LISSOBIHANE,EMLY	TI	065	-1.0	WB	D	P
1713SWW012	17380	13198	BALLYHOLAHAN,WES	TI	065	-1.0	WB	D	P
1713SWW008	17988	13305	MOORESFORT	TI	065	-1.0	WD	D	P
1713SWW005	18127	13162	KNOCKBALLYMALOOG	TI	065	-1.0	WD	D	P
1713SWW004	18043	13176	KILROSS	TI	065	152.0	WB	D	P
1713SWW003	17970	13194	HILL HSE,KILROSS	TI	065	192.0	WB	D	P
1713SWW001	17940	13088	BALLYWIRE	TI	065	115.0	WB	D	P
1713SWW021	17651	13477	EMLY	TI	065	-1.0	WB	D	G
1713SWW013	17625	13649	CHANCELLORSLAND	TI	065	120.0	WB	D	
1713SWW006	18172	13236	KILPATRICK	TI	066	-1.0	WB	D	P
1713SWW015	18110	13500	GLENBANE	TI	066	122.0	WB	D	P
1713SWW011	18390	13550	SHRONELL,LATTIN	TI	066	105.0	WB	D	P
1713SWW009	17955	13308	MOORSEFORT	TI	066	-1.0	WB	D	P
1713SEW009	18509	13422	BALLINAHOW	TI	066	-1.0	WB	D	P
1713SEW008	18508	13435	BALLINAHOW	TI	066	-1.0	WD	D	P
1713SWW022	18321	13349	KILROSS	TI	066	-1.0	WB	A	G
1713SWW023	18404	13715	BALLYCOHY	TI	066	120.0	WD	D	P
1713SEW011	19055	13420	FAWNAGOWAN	TI	067	-1.0	WB	P	
1713SEW007	29227	13424	KILSHANE	TI	067	-1.0	WB	D	P
1713SEW005	18690	13450	CLONPET	TI	067	-1.0	WB	D	P
1713SEW006	19226	13424	SPRINGHOUSE	TI	067	-1.0	WB	D	P
1713SEW010	18850	13560	TIPPERARY	TI	067	-1.0	WB	I	G
1713NEW007	18715	14583	CLONGANHUE	TI	067	-1.0	WB	D	P
1713SEW001	18570	13340	BALLINLEENTY	TI	067	118.0	WB	D	P
1713SEW002	18545	13227	FARRNACLIFFE	TI	067	-1.0	WD	D	P
1713SEW003	18735	13413	CLONPET	TI	067	118.0	WB	D	P
2013SWW012	20582	13640	TEMPLEROE	TI	068	106.0	WB	D	
2013SWW011	20232	13685	CLOUGHALEIGH	TI	068	121.9	WD		

-1.0	-1	-1.0	LMSTN	-1.0	980.0	-1.0	
65.0	-1	-1.0		18.0	131.0	-1.0	
32.0	-1	30.0	LIMESTONE	14.0	55.0	-1.0	
18.0	-1	3.0		7.5	109.0	-1.0	
10.5	-1	1.5	LIMESTONE	3.0	109.0	-1.0	
25.0	-1	925.0		9.0	131.0	-1.0	
3.0	-1	-1.0		-1.0	65.0	-1.0	
7.0	-1	7.0		3.0	87.0	-1.0	
18.0	-1	918.0		10.0	109.0	-1.0	
27.0	-1	5.0	LIMESTONE & SANDST	6.0	55.0	-1.0	
23.0	-1	22.0	LIMESTONE	5.5	55.0	-1.0	
19.2	-1	920.0	CLAY+STN/S+G/MARL	-1.0	65.4	-1.0	Y
22.0	-1	22.0	BLK CLAY/RED CLAY/	-1.0	-1.0	-1.0	Y
21.0	-1	921.0		3.5	55.0	-1.0	
42.0	-1	12.0	SANDSTONE	4.5	109.0	-1.0	
24.0	-1	924.0		5.0	87.0	-1.0	
22.0	-1	-1.0		8.0	65.0	-1.0	
25.3	-1	19.8	DRIFT/LIMESTONE	15.5	54.5	-1.0	
7.6	-1	97.6		1.2	21.8	-1.0	
-1.0	-1	-1.0		-1.0	436.0	-1.0	
3.5	-1	903.5		1.0	27.0	-1.0	
-1.0	-1	-1.0	WAULSORTIAN LMSTN	-1.0	-1.0	-1.0	
17.4	-1	11.3		-1.0	82.0	-1.0	
41.1	-1	6.1		25.4	54.5	-1.0	
18.2	-1	11.2	LIMESTONE & SANDST	10.4	32.7	-1.0	
79.0	203	-1.0	LIMESTONE	15.0	654.0	-1.0	
37.5	-1	8.8	DRIFT/?	-1.0	56.6	-1.0	
19.0	-1	18.0		8.5	109.0	-1.0	
2.0	-1	2.0	SHALE	0.3	55.0	-1.0	
41.0	-1	6.0	LMSTN	25.5	55.0	-1.0	
33.5	-1	-1.0		-1.0	-1.0	-1.0	
6.1	-1	-1.0		-1.0	-1.0	-1.0	

2013SWW010	21480	13527	TULLAMAINE	TI	069	-1.0	WS	D	P	-1.0	-1
2013SWW014	21159	13135	CADDLESTOWN HSE.	TI	069	-1.0	WB	D	P	48.7	-1
2013SWW013	20947	13509	ATTYKIT	TI	069	-1.0	WB	D	P	60.0	-1
2013SWW016	20808	13212	NEW INN	TI	069	-1.0	WB	D	P	67.0	-1
2013SWW002	20740	13108	UPPER GRAIGUE	TI	069	-1.0	WB	D	P	36.5	-1
2013SEW020	22097	13075	BAPTISTGRANGE	TI	070	-1.0	WS		G	-1.0	-1
2013SEW041	22245	13440	MULLENBAWN	TI	070	-1.0	WS	P	E	-1.0	-1
2013SEW030	22502	13325	KILUSTY	TI	070	-1.0	WS	D		-1.0	-1
2013SEW037	22102	13560	FETHARD	TI	070	-1.0	WB	I	P	97.5	-1
2013SEW034	22120	13139	BAPISTGRANGE	TI	070	-1.0	WD		G	4.3	-1
2013SEW033	21957	13182	JOSSETOWN	TI	070	-1.0	WB	D	P	45.7	-1
2013SEW002	21737	13480	BARRETSTOWN	TI	070	-1.0	WB	D	P	67.0	-1
2013SEW003	21782	13465	BARRETTSTOWN	TI	070	-1.0	WB	D	P	67.0	-1
2013SEW038	21955	13165	JOSSETOWN	TI	070	-1.0	WU			-1.0	-1
2013SEW011	21505	13525	FETHARD	TI	070	-1.0	WB	O	G	61.8	-1
2013SEW012	21505	13515	FETHARD	TI	070	-1.0	WB	O	P	92.3	152
2013SEW015	22075	13545	FETHARD	TI	070	-1.0	WB	D	P	74.1	152
2013SEW016	22153	13953	COOLMORE	TI	070	-1.0	WB	O	G	24.3	152
2013SEW017	22145	13960	FETHARD	TI	070	-1.0	WB	O		25.6	-1
2013SEW018	21970	13342	MARKET HILL	TI	070	-1.0	WB	D	P	44.8	-1
2013SEW019	22198	13275	DRUMDEEL	TI	070	-1.0	WU	D		-1.0	-1
2013SEW021	22445	13123	LOUGHCAPPLE	TI	070	-1.0	WU	D	P	8.5	-1
2013SEW022	21832	13145	GLENAGUILE	TI	070	-1.0	WB	D	P	32.9	-1
2013SEW023	22502	13336	KILLUSTY	TI	070	-1.0	WB	D	P	24.3	-1
2013SEW024	21687	13296	COLMAN	TI	070	-1.0	WB	D	P	37.7	-1
2013SEW025	22040	13837	COOLMORE	TI	070	-1.0	WB	O	P	-1.0	-1
2013SEW026	22240	13918	COOLMORE	TI	070	-1.0	WU	O	P	21.3	-1
2013SEW027	22195	13753	COOLMORE	TI	070	-1.0	WB	O		42.7	-1
2013SEW028	22534	13477	THE GREEN, FETHAR	TI	070	-1.0	WS	D		-1.0	-1
2013SEW029	22497	13314		TI	070	-1.0	WB		G	18.3	-1
2013SEW039	22036	13655	BALLYHOUGH	TI	070	-1.0	WS	D	P	0.8	-1
2013SEW004	22082	13557	FETHARD	TI	070	-1.0	WU	D	P	-1.0	-1

-1.0		-1.0	-1.0	-1.0	
14.6	LIMESTONE	19.2	27.2	-1.0	
12.2		-1.0	-1.0	-1.0	
18.2	CLAY+STONE/CRACK L	-1.0	32.7	-1.0	
0.6	GREY SHALE	20.0	74.1	-1.0	
-1.0		-1.0	-1.0	-1.0	
-1.0	LMSTN	-1.0	2273.0	-1.0	
-1.0		-1.0	-1.0	-1.0	
1.8	LIMESTONE	-1.0	174.4	-1.0	Y
-1.0	GRAVELS	-1.0	-1.0	-1.0	
915.0	GRIT & SHALE	930.5	60.9	-1.0	
18.0		34.0	64.5	-1.0	
4.0	LIMESTONE	14.5	82.0	-1.0	
-1.0	SHALES	-1.0	-1.0	-1.0	
-1.0	LIMESTONE	13.7	327.0	-1.0	Y
4.9	SHALE & LIMESTONE	48.8	218.0	-1.0	Y
10.7	LIMESTONE & SHALES	6.7	65.4	-1.0	Y
91.5	GRAVEL	6.7	392.4	-1.0	Y
-1.0		-1.0	-1.0	-1.0	
3.1	LIMESTONE	18.2	65.4	-1.0	
-1.0	LIMESTONE	-1.0	-1.0	-1.0	
-1.0		3.0	43.6	-1.0	
-1.0	BLACK LIMESTONE	3.7	32.7	-1.0	
-1.0		12.1	43.6	-1.0	
-1.0		12.8	32.7	-1.0	
0.6		-1.0	109.0	-1.0	
-1.0	GRAVEL	-1.0	109.0	-1.0	
6.1	SANDSTONE	-1.0	-1.0	-1.0	
1.8		-1.0	-1.0	-1.0	
2.4	BROWN ROCK	-1.0	-1.0	-1.0	
904.0	GRAVEL	-1.0	22.0	-1.0	
3.5	J. WALTON	3.5	59.0	-1.0	

2013SEW007	22032	13361	MARKET HILL	TI	070	-1.0	WB	D
2013SEW005	22220	13665	SAUCERSTOWN	TI	070	-1.0	WB	D
2013SEW010	22104	13210	LAKEFIELD	TI	070	-1.0	WB	D
2013SEW003	21782	13465	BARRETSTOWN	TI	070	-1.0	WB	D
2013SEW001	21725	13317	COLEMAN	TI	070	-1.0	WB	D
2313SWW022	32345	13185	BREANORMORE	TI	071	-1.0	WB	D
2313SWW027	23515	13255	WHITEHALL,9M.HSE	TI	071	-1.0	WB	D
2313SWW025	32345	13158	BREANORMORE,9MHS	TI	071	-1.0	WB	D
2313SWW024	32345	13169	BREANORMORE	TI	071	-1.0	WB	D
2313SWW041	32345	13177	BRANERMORE,9M HS	TI	071	-1.0	WB	D
2313SWW021	23500	13535	MULLINAHONE	TI	071	-1.0	WB	D
2313SWW020	23608	13635	BALLYDUGGAN	TI	071	-1.0	WD	
2313SWW019	23478	13622	BALLYDAVID	TI	071	-1.0	WB	D
2313SWW018	23394	13362	BALLINRUANE,9MHS	TI	071	-1.0	WB	D
2313SWW017	23607	13650	BALLYDUGGAN,9MHS	TI	071	-1.0	WB	D
2313SWW016	23477	13632	BALLYDAVID	TI	071	-1.0	WB	D
2313SWW015	23394	13374	BALLINRUAN,9M HS	TI	071	-1.0	WB	D
2313SWW014	23564	13361	GRANGEMOCKLER	TI	071	-1.0	WB	D
2313SWW013	23562	13372	GRANGEMOCKLER	TI	071	-1.0	WB	D
2313SWW012	23562	13384	GRANGEMOCKLER	TI	071	-1.0	WB	D
2313SWW011	23560	13397	GRANGEMOCKLER	TI	071	-1.0	WB	D
2313SWW009	23210	13319	GLENASKEAGH,9MHS	TI	071	247.0	WB	D
2313NWW029	23102	14425	KNOCKULTY	TI	071	-1.0	WB	D
2313SWW004	23634	13455	NINE-MILE-HOUSE	TI	071	-1.0	WB	D
2313SWW041	23588	13382	GRANGEMOCKLER	TI	071	-1.0	WB	D
2313SWW040	23585	13398	GRANGEMOCKLER	TI	071	-1.0	WB	D
2313SWW030	23660	13460	NINE-MILE-HOUSE	TI	071	-1.0	WB	D
2313SWW029	23655	13439	GRANGE	TI	071	-1.0	WB	D
2313SWW028	23635	13440	NINE-MILE-HOUSE	TI	071	-1.0	WB	D
2313SWW043	25871	13368	MULLINAHONE	TI	071	-1.0	WB	D
2013SEW043	22802	13338	CLORAN	TI	071	-1.0	WS	P
2313SWW042	23202	13055	TULLOHEA	TI	071	-1.0	WS	P

P	38.0	-1	1.0	LMSTN	12.0	64.5	-1.0	
P	36.5	-1	1.0	LMSTN	12.0	55.0	-1.0	
P	51.0	-1	-1.0		16.0	87.2	-1.0	
P	67.0	-1	4.0	CLAY/LMSTN	14.5	82.0	-1.0	
P	42.5	-1	15.0	DRIFT/LMSTN	17.0	54.5	-1.0	
P	28.9	-1	7.6	LIMESTONE	18.2	54.5	-1.0	
P	24.3	-1	21.6		13.7	141.7	-1.0	
P	12.1	-1	2.4		7.6	54.5	-1.0	
P	21.0	-1	6.1	LIMESTONE	7.6	54.5	-1.0	
P	30.5	-1	24.3		15.3	98.1	-1.0	
P	21.3	-1	9.1	LIMESTONE	-1.0	54.5	-1.0	
G	13.4	-1	913.4		-1.0	-1.0	-1.0	
P	18.2	-1	11.5	LIMESTONE & SANDST	13.7	54.5	-1.0	
P	18.2	-1	4.5		9.1	43.6	-1.0	
P	13.4	-1	7.6	LIMESTONE	-1.0	87.2	-1.0	
P	18.2	-1	11.5		10.1	54.5	-1.0	
P	20.7	-1	7.3		12.1	43.6	-1.0	
P	30.5	-1	28.9		8.5	32.7	-1.0	
P	13.7	-1	11.5	LIMESTONE	8.5	43.6	-1.0	
P	14.6	-1	4.5	LIMESTONE	7.6	65.4	-1.0	
P	14.6	-1	10.6		2.4	163.0	-1.0	
P	36.5	-1	3.0	LIMESTONE	18.2	43.6	-1.0	
P	21.3	-1	7.9		-1.0	13.1	-1.0	
P	37.4	-1	6.0	MUDSTONE & SANDSTO	6.0	65.4	-1.0	Y
P	12.1	-1	10.6		1.5	185.3	-1.0	
P	27.4	-1	4.6	SAND+CLAY/WHITE/RE	6.1	32.7	-1.0	Y
P	24.3	-1	3.9		4.5	114.5	-1.0	
P	30.4	-1	14.6		9.7	59.9	-1.0	
P	21.3	-1	2.4		10.3	54.5	-1.0	
P	19.8	-1	0.9		7.6	43.6	-1.0	
E	-1.0	-1	-1.0	KILTORCAN SSTN	-1.0	2509.0	-1.0	
G	-1.0	-1	-1.0	GREYWACKES??	-1.0	271.0	-1.0	

2313SWW046	23587	13368	MULLINAHONE	TI	071	-1.0	WB	D
2313NWW013	23436	14540	MOHBER,LISMALIN	TI	071	92.0	WB	D
2313NWW014	23462	14550	MOHBER,LISMALIN	TI	071	-1.0	WB	D
2313SWW023	23962	13172	CASTLEJOHN,AHENN	TI	072	360.0	WB	D
2313SWW043	23624	13283	GRANGEMOCKLER	TI	072	-1.0	WS	P
2313SWW044	23660	13120	BALLINVIR	TI	072	-1.0	WB	P
1711NEW003	19308	12730	ROSSIHEDRID	TI	074	-1.0	WB	P
2011NWW039	20660	12775	KEDRAH	TI	075	-1.0	WS	P
2011NWW024	20897	12857	RATHARD	TI	076	79.2	WB	D
2011NWW018	20898	12992	CHAMBERLAINSTOWN	TI	076	-1.0	WB	D
2011NWW019	21306	12822	CLONMORE,CLERIHA	TI	076	91.4	WB	D
2011NWW020	21270	12589	WOODROFF	TI	076	-1.0	WB	B
2011NWW022	20750	12616	SUTTONRATH	TI	076	-1.0	WB	D
2011NWW023	20769	12572	LOUGHAUN	TI	076	61.0	WB	D
2011NWW025	20810	12842	RATHARD	TI	076	82.3	WB	D
2011NWW015	20810	12900	WHITELANDS	TI	076	85.3	WB	D
2011NWW017	20917	12770	MORTLESTOWN	TI	076	82.3	WB	D
2011NWW016	20915	12783	MORTLESTOWN	TI	076	76.2	WB	D
2011NWW013	20657	12749	KEDRAH	TI	076	-1.0	WB	D
2011NWW014	21065	12640	HUSSEYTOWN	TI	076	-1.0	WB	D
2011NEW007	21657	12730	BALLYTARSNA	TI	076	-1.0	W	
2011NEW006	21990	12995	LISRONAGH,CLONME	TI	077	-1.0	WB	
2011NEW009	22451	12622	MULLINRANKA	TI	077	-1.0	WB	D
2011NEW010	21910	22525	CLASHINISKA	TI	077	-1.0	WB	B
2011NEW011	22331	12452	REDMONDSTOWN	TI	077	-1.0	WB	D
2011NEW012	22335	12452	REDMONDSTOWN	TI	077	-1.0	WB	I
2011E W013	22332	12482	REDMONSTOWN	TI	077	57.9	WB	I
2011NEW014	22560	12893	LISNATUBBRID	TI	077	48.8	WB	D
2011NEW015	22560	12872	LISNATUBRID	TI	077	-1.0	WB	
2011NEW016	22612	12856	KNOCKNACLASH	TI	077	-1.0	WB	D
2011NEW017	22312	12720	KILMORE	TI	077	-1.0	WB	D
2011NEW018	22612	12842	KNOCKANCLASH	TI	077	-1.0	WB	D

P	19.8	-1	0.9		7.6	43.6	-1.0
P	23.0	-1	-1.0	CLAY	-1.0	163.0	-1.0
P	15.0	-1	8.5		9.0	87.2	-1.0
G	54.0	-1	15.0	LIMESTONE	20.0	600.0	-1.0
	-1.0	-1	-1.0	GREYWACKES??	-1.0	-1.0	-1.0
P	-1.0	-1	-1.0	GREYWACKES??	-1.0	100.0	-1.0
E	-1.0	-1	-1.0	KILTORCAN SSTN	-1.0	2350.0	-1.0
E	-1.0	-1	-1.0	WAULSORTIAN LMSTN	-1.0	216000.	-1.0
P	22.8	-1	6.1		14.6	22.0	-1.0
P	22.5	-1	5.5		15.2	22.0	-1.0
P	37.8	-1	18.3	DRIFT/LIMESTONE	21.3	27.0	-1.0
P	30.5	-1	-1.0		18.9	109.0	-1.0
P	33.5	-1	3.6	DRIFT/LIMESTONE	15.2	33.0	-1.0
P	37.8	-1	3.7	DRIFT/LIMESTONE	21.6	22.0	-1.0
P	37.8	-1	3.7	DRIFT/LIMESTONE	18.6	27.0	-1.0
P	33.2	-1	6.1		17.4	33.0	-1.0
P	27.4	-1	6.1		14.0	33.0	-1.0
P	18.2	-1	11.3	DRIFT/LIMESTONE	1.8	33.0	-1.0
P	28.6	-1	3.1		15.2	33.0	-1.0
P	25.3	-1	25.3	DRIFT/LIMESTONE	8.5	22.0	-1.0
P	14.5	6	-1.0	DRIFT,LST. GRAVEL	-1.0	-1.0	-1.0
R	58.0	-1	-1.0	LST.	-1.0	-1.0	-1.0
P	22.9	-1	9.1		10.8	65.4	-1.0
P	59.1	-1	4.6	LST.	-1.0	65.4	-1.0
P	15.2	-1	6.1	LST.	7.3	65.4	-1.0
P	25.9	-1	7.0	LST.	5.5	65.4	-1.0
F	60.9	-1	-1.0		-1.0	2.7	-1.0
P	18.3	-1	6.1		9.1	43.6	-1.0
P	18.3	-1	4.9	LST.	-1.0	65.4	-1.0
P	19.8	-1	-1.0	JOHN CORCORAN	2.4	119.9	-1.0
P	37.5	-1	10.1		18.2	55.0	-1.0
P	19.8	-1	6.1		9.1	44.0	-1.0

2011NEW021	21561	12571	CHANCELLORSTOWN	TI	077	-1.0	WB	D
2011NEW025	22315	12740	KILMORE	TI	077	-1.0	WB	D
2011NEW026	21782	12450	KILTEGAN	TI	077	-1.0	WB	D
2011NEW027	22318	12572	BALLYVAUGHAN	TI	077	60.9	WB	D
2011NEW028	21987	12887	LISRONAGH	TI	077	-1.0	WB	D
2011NEW029	21746	12453	GARRYROE HSE.	TI	077	-1.0	WB	D
2011NEW031	21990	12876	LAKELANDS	TI	077	-1.0	WB	D
2011NEW032	22091	12695	FORTWILLIAM	TI	077	190.0	WD	D
2011NEW034	22180	12828	CARRIGWILLIAM	TI	077	53.5	WB	D
2311NWW025	23500	12770	BALLINACOONA HSE	TI	078	-1.0	WB	D
2311NWW024	23500	12987	HEATHVIEW	TI	078	-1.0	WB	D
2311NWW023	23400	12818	MAYLADSTOWN	TI	078	-1.0	WB	D
2311NWW022	23098	12677	BALLYPATRICK	TI	078	-1.0	WS	A
2313SWW031	23335	1300	TULLOHEA	TI	078	-1.0	WB	D
2011NEW036	22764	12545	BALLYGLASHEEN	TI	078	-1.0	WB	D
2313SWW042	23417	13187	BRENARMORE	TI	078	-1.0	WB	D
2311NWW027	23474	12875	BRITTAS	TI	078	-1.0	WB	D
2311NWW026	23474	12880	BRITTAS	TI	078	-1.0	WB	D
2313SWW044	23590	13355	GRANGEMOCKLER	TI	078	-1.0	WS	A
2313SWW045	23474	12885	BRITTAS	TI	078	-1.0	WB	D
2313SWW047	23590	13355	GRANGEMOCKLER	TI	078	-1.0	WS	A
2313SWW038	23969	13182	CASTLEJOHN	TI	079	-1.0	WB	D
2313SWW037	24160	13100	INCHNAGLUGH	TI	079	-1.0	WB	D
2313SWW034	24095	13065	CLASHNAMUTH	TI	079	121.9	WB	D
2313SWW035	24105	13065	CLASHNAMUTH	TI	079	-1.0	WB	D
2313SWW036	24125	13065	CLASHNASMUTH	TI	079	-1.0	WB	D
2313SWW033	23618	13045	CHEESEMOUNT	TI	079	152.4	WB	D
2311NWW028	24135	12940	AHENNY	TI	079	-1.0	WB	P
1711SEW002	19273	11715	COOLEGARRANROE	TI	080	106.0	WB	D
1711SEW005	18999	11720	SKEHEENARINKY	TI	080	-1.0	WB	D
1711SEW004	18996	11725	SKEHEENARINKY	TI	080	274.3	WB	D
1711SEW003	19273	11709	COOLAGARRANROE	TI	080	85.3	WB	D

P	54.8	-1	12.2	DRIFT/LMSTN	24.3	38.0	-1.0
P	42.7	-1	30.5		24.3	54.5	-1.0
P	25.9	-1	-1.0	LMSTN	-1.0	54.5	-1.0
P	39.0	-1	12.2	DRIFT/LMSTN	21.6	55.0	-1.0
P	42.8	-1	12.4		29.8	38.0	-1.0
P	48.8	-1	6.1	DRIFT/LMSTN	21.3	44.0	-1.0
P	58.7	-1	-1.0		-1.0	87.2	-1.0
P	5.0	-1	905.0		2.0	600.0	-1.0
P	21.2	-1	1.8	DRIFT/LMSTN	10.6	44.0	-1.0
P	33.5	-1	7.6		-1.0	65.0	-1.0
P	22.8	-1	14.0		12.1	65.0	-1.0
P	24.4	-1	-1.0		-1.0	55.0	-1.0
P	0.0	-1	0.0		-1.0	163.0	-1.0
P	18.3	-1	4.6	DRIFT/LMSTN	-1.0	65.0	-1.0
P	8.5	-1	2.1		2.1	-1.0	-1.0
P	12.2	-1	-1.0		5.2	196.0	-1.0
P	24.4	-1	1.8		10.7	65.0	-1.0
P	24.4	-1	4.5		12.2	49.0	-1.0
P	1.0	-1	-1.0		0.0	163.0	-1.0
P	24.2	-1	4.6	DRIFT/LMSTN	12.2	49.0	-1.0
P	1.0	-1	-1.0		0.0	163.0	-1.0
P	23.2	-1	-1.0	DRIFT/LMSTN	-1.0	65.0	-1.0
P	28.9	-1	12.8	DRIFT/SLATE	8.8	33.0	-1.0
P	37.4	-1	6.1	LMSTN	13.7	65.0	-1.0
P	27.4	-1	6.1		12.2	65.0	-1.0
P	30.5	-1	0.6	DRIFT/LMSTN	15.2	55.0	-1.0
P	27.4	-1	9.1	DRIFT/LMSTN	18.3	49.0	-1.0
P	-1.0	-1	-1.0	SLATES	-1.0	80.0	-1.0
P	32.0	-1	32.0	RED SANDSTONE	18.3	22.0	-1.0
P	50.2	-1	3.4	DRIFT/RED SANDSTON	-1.0	55.0	-1.0
P	25.9	-1	3.9	RED SANDSTONE	1.8	-1.0	-1.0
P	28.7	-1	6.1	RED SANDSTONE	19.2	27.0	-1.0

1SEW001	19548	11789	MONALOUGHRA	TI	080	-1.0	WB	D	P
1SEW008	19331	11285	BALLYPOREEN	TI	080	-1.0	WS	P	
3SWW001	24055	13480	WINDGAP	TI	080	-1.0	WB	D	P
1NWW039	20185	12025	PEAHILL	TI	081	-1.0	WB	D	P
1NWW036	20117	12190	WHITECHURCH	TI	081	-1.0	WB	D	P
1NWW029	20249	12051	SCARTANA	TI	081	-1.0	WB	D	P
1NWW032	20442	12275	KILCOMMON MORE,N	TI	081	70.1	WB	D	P
1NWW031	20736	12360	BALLYMACADAM WES	TI	081	91.4	WB	D	P
1NWW012	20105	12200	WHITECHURCH,CAHI	TI	081	-1.0	WB	D	P
1NWW011	20164	12153	GARRYROAN,CAHIR	TI	081	-1.0	WB	D	P
1NWW010	20251	12050	SCARTANA	TI	081	-1.0	WB	D	P
1NWW009	20413	12018	RUSKA,CAHIR	TI	081	-1.0	WB	D	P
1NWW008	20238	12222	GARRYCLOGHAN	TI	081	-1.0	WU	D	P
1NWW026	20040	12240	TINCURRY	TI	081	91.4	WB	D	P
1NEW001	19890	12185	KILCORAN	TI	081	61.0	WB	D	P
1NWW027	20087	12026	BURGES	TI	081	-1.0	WB	D	P
1NWW030	20242	12043	SCARTANA	TI	081	61.0	WB	D	P
11NWW033	20445	12179	KILCOMMON	TI	081	67.0	WB	D	P
11NWW034	20156	12165	GARRYROAN	TI	081	70.1	WB	D	P
11NWW035	20250	12221	GARRYCLOGHER	TI	081	70.1	WU	D	P
11NWW037	20012	12292	POULACULLEAR	TI	081	-1.0	WB	D	P
11SWW032	20640	11911	BALLYDRINAN	TI	081	-1.0	WS		
11SWW031	20088	11790	CURRAGHATOGHER	TI	081	61.0	WB	D	P
11SWW030	20055	11922	KNOCKANE	TI	081	62.1	WB	D	P
11SWW029	20365	11958	BALLYLEA	TI	081	60.9	WB	D	P
11SWW028	20365	11968	BALLYLEA	TI	081	61.0	WB	D	P
11SWW025	20502	11922	ROOSCA	TI	081	67.0	WB	D	P
11NEW004	19863	12178	KILCORAN	TI	081	-1.0	WB	P	
11NWW028	20892	12396	LOUGHLOHER,CAHIR	TI	082	91.4	WB	D	P
11NWW007	20852	12028	BALLYHICKEY	TI	082	48.7	WD		P
11NWW006	21487	12412	RATHKEEVAN LWR.	TI	082	60.9	WD	D	G
11NWW005	21320	12235	GARRANTEMPLE	TI	082	71.3	WB	D	G

45.7	-1	6.1	DRIFT/LIMESTONE	22.9	33.0	-1.0	Y
-1.0	-1	-1.0	WAULSORTIAN LMSTN	-1.0	-1.0	-1.0	
15.2	-1	1.0	DRIFT/SSTN	1.5	48.0	-1.0	
27.4	-1	27.4		18.3	27.0	-1.0	
38.1	-1	6.1	DRIFT/LIMESTONE	19.2	27.0	-1.0	
27.4	-1	27.4		15.2	44.0	-1.0	
33.5	-1	6.1	DRIFT/LIMESTONE	21.3	33.0	-1.0	
21.3	-1	12.2	DRIFT/LIMESTONE	16.5	27.0	-1.0	
38.1	-1	6.0	LIMESTONE	19.2	27.3	-1.0	
29.3	-1	3.0	LIMESTONE	18.8	32.7	-1.0	
27.4	-1	2.7		24.0	32.7	-1.0	
28.9	-1	6.0	LIMESTONE	18.2	27.2	-1.0	
6.0	-1	6.0	LIMESTONE	2.4	32.7	-1.0	
44.2	-1	39.6	DRIFT/RED SANDSTON	24.4	33.0	-1.0	
39.9	-1	6.4	DRIFT/LIMESTONE	28.3	27.2	-1.0	
34.1	-1	-1.0	LIMESTONE	9.1	22.0	-1.0	
27.4	-1	2.7	DRIFT/LIMESTONE	24.1	33.0	-1.0	
47.9	-1	6.1	DRIFT/LIMESTONE	19.9	33.0	-1.0	
29.3	-1	3.1	DRIFT/LIMESTONE	18.9	33.0	-1.0	
6.1	-1	6.1	DRIFT/LIMESTONE	2.4	33.0	-1.0	
28.0	-1	28.0	DRIFT/LIMESTONE	21.9	27.0	-1.0	
-1.0	-1	-1.0		-1.0	-1.0	-1.0	
37.8	-1	1.8	DRIFT/LIMESTONE	18.3	33.0	-1.0	
28.9	-1	28.9	DRIFT/LIMESTONE	16.2	22.0	-1.0	
24.6	-1	3.6	LIMESTONE	19.5	21.8	-1.0	
24.7	-1	3.7	DRIFT/LIMESTONE	19.5	22.0	-1.0	
28.9	-1	6.1	DRIFT/LIMESTONE	18.3	27.0	-1.0	
-1.0	-1	-1.0	KILTORCAN SSTN	-1.0	-1.0	-1.0	
43.3	-1	36.6	LIMESTONE	36.6	21.8	-1.0	
21.3	-1	-1.0	SAND	-1.0	-1.0	-1.0	
4.6	-1	-1.0	CLAY	-1.0	-1.0	-1.0	
38.4	-1	-1.0		-1.0	-1.0	-1.0	

2011NWW004	20947	12335	LOUGHLOHERY	TI	082	88.0	WB			91.4	254
2011NWW003	20846	12408	LOUGHLOHER,CAHIR	TI	082	-1.0	WB	D	G	26.8	-1
2011NWW002	20729	12148	GRANAVILLE	TI	082	-1.0	WB	D	P	36.5	-1
2011NWW001	20731	12155	GARNAVILLA	TI	082	64.6	WB	D		37.2	-1
2011SWW003	20669	11987	ROCHESTOWN	TI	082	60.9	WB	D	G	60.9	-1
2011SWW002	21394	11849	ROXBORO	TI	082	60.9	WD	D		15.2	-1
2011SWW001	20923	11915	MARLHILL	TI	082	-1.0	WB	D	P	28.7	-1
2011NWW038	21345	12225	GARRYTEMPLE	TI	082	60.9	WB	D	G	33.5	-1
2011SWW043	21339	11872	RATHWALTER	TI	082	-1.0	WB	D	P	20.6	-1
2011SWW033	21030	11762	CLOGHERDEEN	TI	082	-1.0	WB	D	P	24.4	-1
2011SWW026	21030	11788	CLOGHARDEEN	TI	082	51.8	WB	D	P	28.9	-1
2011SWW027	21030	11777	CLOGHARDEEN	TI	082	-1.0	WB	D	G	24.4	-1
2011NEW019	21835	12388	SUMMERHILL	TI	083	65.8	WB	D	P	28.9	-1
2011NEW020	21712	12420	BALLINGARRANE	TI	083	64.0	WB	D	P	36.5	-1
2011NEW022	22112	12246	CLONMEL	TI	083	-1.0	WB	D	P	16.7	-1
2011NEW023	22331	12430	REDMONDSTOWN	TI	083	-1.0	WB	D	P	15.2	-1
2011NEW024	22250	12332	GORTNAFLEUR	TI	083	61.0	WB	D	P	36.5	-1
2011NEW030	22072	12365	THE WILDERNESS	TI	083	-1.0	WB	D	P	61.8	200
2311NWW019	23877	12172	CARRICK-ON-SUIR	TI	085	-1.0	WB	D	P	-1.0	-1
2311NWW021	24121	12930	AHENNY	TI	085	-1.0	WB	D	P	18.2	-1
2311NWW020	24045	12175	CARRICK-ON-SUIR	TI	085	-1.0	WB		G	25.2	-1
2311NWW018	24165	12255		TI	085	-1.0	WB	D	P	30.5	-1
2311NWW017	23630	12278	BALLINDERRY	TI	085	35.1	WB	D	P	30.5	-1
2311NWW016	24200	12248	CARRICK-ON-SUIR	TI	085	-1.0	WB	D	P	50.0	-1
2311NWW015	23870	12350	BALLINAGRANA	TI	085	-1.0	WB	D	P	26.2	-1
2311NWW014	23669	12228	CARRICK-ON SUIR	TI	085	-1.0	W			55.7	-1
2313SWW039	23680	13355	NINE-MILE-HOUSE	TI	085	-1.0	WB			19.8	-1
2313SWW032	23370	13037	TULLOHEA	TI	085	-1.0	WB	D	P	18.3	-1
2011NEW037	22030	12280	CLONMEL	TI	085	-1.0	WB	D	P	15.2	-1
2313NWW032	23279	14425	THE ISLANDS	TI	085	-1.0	WB	D	P	24.3	-1
2311NWW029	23877	12146	COOLNAMUCK	TI	085	-1.0	WB	P	P	-1.0	-1
1711SEW023	19308	11085	GLENACUNNA	TI	086	-1.0	WB	D	P	27.4	-1

-1.0	LIMESTONE	-1.0	-1.0	-1.0	
26.8	LIMESTONE	14.3	-1.0	-1.0	
4.6	LIMESTONE	21.3	32.7	-1.0	
-1.0		-1.0	-1.0	-1.0	
-1.0	LIMESTONE	-1.0	-1.0	-1.0	
15.2	CLAY	-1.0	-1.0	-1.0	
28.7	LIMESTONE	18.9	33.0	-1.0	
4.6	LIMESTONE	28.9	-1.0	-1.0	
12.8	LIMESTONE	11.6	32.7	-1.0	
24.4		10.9	55.0	-1.0	
6.1	LIMESTONE	18.8	21.8	-1.0	
24.4		10.9	-1.0	-1.0	
6.1		22.8	52.3	-1.0	
4.5	DRIFT/LMSTN	21.3	66.0	-1.0	
16.7		3.0	81.7	-1.0	
15.2		4.6	16.3	-1.0	
3.0	DRIFT/LMSTN	15.2	66.0	-1.0	
14.0	CLAY/SAND/GRAVEL/L	3.6	196.0	-1.0	Y
-1.0		-1.0	-1.0	-1.0	
7.6		4.5	207.1	-1.0	
9.1	CLAY,LST.,DOLOMITI	-1.0	272.5	-1.0	Y
1.8		10.7	54.5	-1.0	
7.9	DRIFT/LST.	13.7	65.4	-1.0	
-1.0		-1.0	88.0	-1.0	
15.2		12.2	44.0	-1.0	
-1.0	CLAY/LST./SST.	14.6	174.4	-1.0	Y
12.2		0.6	156.9	-1.0	
5.5		10.7	185.3	-1.0	
14.0		6.1	131.0	-1.0	
-1.0		-1.0	33.8	-1.0	
-1.0	SNADS/GRAVEL	-1.0	-1.0	-1.0	
27.4	DRIFT/RED SST.	218.3	22.0	-1.0	

1711SEW021	19684	11128	KILLEATIN	TI	086	60.9	WB	G
1711SEW022	19509	11710	GARRANDILLON	TI	086	-1.0	WB	D
1711SEW018	19500	11710	SHANBALLY	TI	086	-1.0	WB	D
1711SEW020	19300	11085	GLENACUNNA	TI	086	-1.0	WB	D
1711SEW017	19188	11116	LYREFUNE	TI	086	-1.0	WB	D
1711SEW019	19394	11100	GORTEESHAL	TI	086	-1.0	WB	D
1711SEW024	19197	11116	LYREFUNE	TI	086	-1.0	WB	D
1711SEW014	19392	11700	CULLENAGH SOUTH	TI	086	-1.0	WB	D
1711SEW016	19323	11600	COOLANTALAGH	TI	086	91.4	WB	D
1711SEW028	19333	11463	DANGAN	TI	086	-1.0	WB	D
1711SEW025	19241	11379	NEWCASTLE	TI	086	-1.0	WB	D
1711SEW013	19625	11751	BALLYSHEEHAN	TI	086	-1.0	WU	D
1711SEW009	19292	11085	GLENACUNNA	TI	086	-1.0	WB	
1711SEW007	19385	11100	SHORTEESHAL	TI	086	-1.0	WB	
1711SEW015	19317	11600	COOLANTALLAGH	TI	086	91.4	WB	D
1711NEW002	29477	12220	BOOLAKENNEDY	TI	086	85.3	WB	D
1711SEW006	18954	11513	KILTANKIN	TI	086	-1.0	WB	D
1711SEW026	19315	11085	GLENACUNNA	TI	086	-1.0	WB	D
1711SEW027	19324	11085	GLENACUNNA	TI	086	152.4	WB	D
2011SWW040	20300	11760	TUBBRID	TI	087	60.9	WB	D
1711SEW010	19900	11770	KILROE	TI	087	-1.0	WB	D
1711SEW012	19700	11458	CARRIGMORE	TI	087	-1.0	WB	D
1711SEW011	19906	11772	KILROE	TI	087	73.7	WB	D
2011SWW019	20452	11735	SCART (TUBRID)	TI	087	60.1	WD	
2011SWW008	20455	11748	SCART	TI	087	85.4	WB	D
2011SWW009	20429	11508	BALLINAHALLE	TI	087	-1.0	WB	D
2011SWW010	20170	11545	BALLYBOY	TI	087	60.9	WB	D
2011SWW011	20558	11772	BALLYLAFFIN	TI	087	-1.0	WB	D
2011SWW012	20555	11761	BALLYLAFFIN	TI	087	61.0	WB	D
2011SWW013	20505	11635	BALLYHIST	TI	087	60.1	WB	D
2011SWW014	20335	11402	BOHERNAGORE	TI	087	-1.0	WB	D
2011SWW016	20540	11160	GURTACULLEN	TI	087	-1.0	WB	D

P	36.5	-1	12.5	DRIFT/RED SST. AND	34.4	44.0	-1.0
P	85.9	-1	17.0	DRIFT/ROCK	25.9	109.0	-1.0
P	43.9	-1	1.5	CLAY/ROCK	28.6	22.0	-1.0
P	13.7	-1	6.1		3.0	109.0	-1.0
P	16.2	-1	16.2		2.7	33.0	-1.0
P	15.3	-1	4.3	DRIFT/RED SST.	6.4	22.0	-1.0
P	16.2	-1	16.2	DRIFT/RED SST.	2.7	33.0	-1.0
P	14.0	-1	14.0	DRIFT/LMST	4.2	27.0	-1.0
P	18.2	-1	18.3	DRIFT/LMSTN	8.2	11.0	-1.0
P	22.3	-1	26.2	DRIFT/LST.	23.2	27.0	-1.0
P	32.0	-1	8.3	DRIFT/LST	18.3	22.0	-1.0
P	14.9	-1	12.2	DRIFT/LMSTN	8.8	22.0	-1.0
	-1.0	-1	90.0	RED SST.	60.0	200.0	-1.0
	50.0	-1	14.0	RED SST.	21.0	250.0	-1.0
P	18.3	-1	16.2	DRIFT/LMST	4.8	22.0	-1.0
P	20.1	-1	3.7	DRIFT/RED SANDSTON	4.6	38.0	-1.0
P	19.5	-1	6.1	DRIFT/RED SANDSTON	-1.0	22.0	-1.0
P	26.2	-1	10.9		13.7	27.0	-1.0
P	24.3	-1	6.1	DRIFT/ RED SST.	13.7	55.0	-1.0
P	25.6	-1	6.1	DRIFT/LIMESTONE	8.8	22.0	-1.0
P	33.5	-1	30.5		19.8	55.0	-1.0
P	65.8	-1	50.3		24.4	33.0	-1.0
P	25.9	-1	3.5	LMSTN.	18.2	44.0	-1.0
G	25.9	-1	-1.0	LMSTN.	-1.0	-1.0	-1.0
P	29.3	-1	29.3	DRIFT/RED SSTN	25.3	22.0	-1.0
P	25.9	-1	3.1		22.9	22.0	-1.0
P	25.6	-1	15.5	DRIFT/LMSTN	15.3	87.0	-1.0
P	36.6	-1	3.1	JAMES LONG	21.3	27.0	-1.0
P	36.3	-1	3.1	DRIFT/LMSTN	21.3	22.0	-1.0
P	32.6	-1	10.4	DRIFT/LMSTN	10.9	78.0	-1.0
P	-1.0	-1	-1.0		6.1	109.0	-1.0
P	7.0	-1	6.1		4.5	33.0	-1.0

2011SWW018	20832	11523	CASTLEGRACE	TI	087	-1.0	WB	D
2011SWW038	20940	11410	LODGE, ARDFINNAN	TI	088	45.7	WB	D
2011SWW042	21395	11840	ROXBORO	TI	088	-1.0	WB	D
2011SWW041	20969	11660	NEDDANS HSE	TI	088	-1.0	WB	D
2011SWW037	20814	11132	KNOCKBALLINIARY	TI	088	-1.0	WB	D
2011SWW036	21155	11670	MONECREA	TI	088	-1.0	WB	D
2011SWW034	21289	11534	BURGESSLAND	TI	088	-1.0	WB	D
2011SEW025	21815	11317	DEERPARK	TI	088	-1.0	WB	D
2011SWW024	20891	11519	CROUGHTA	TI	088	45.7	WB	D
2011SWW023	20900	11445	LISHEENPOWER	TI	088	42.6	WB	D
2011SWW022	21310	11340	NEWCASTLE	TI	088	30.5	WB	D
2011SWW021	21102	11462	KILMANEEN	TI	088	91.4	WB	
2011SWW020	21100	11475	KILMANEEN	TI	088	-1.0	WB	D
2011SWW015	20879	11349	GOATENBRIDGE	TI	088	36.5	WD	D
2011SWW059	20767	11650	CLOCULLY	TI	088	36.5	WB	D
2011SWW058	20767	11660	MONMORE	TI	088	-1.0	WB	D
1713NEW022	18960	14616	GREENFIELDS	TI	088	-1.0	WB	D
1713NEW023	19860	14610	GREENFIELDS	TI	088	-1.0	WB	D
2009NWW017	21300	11067	MIDDLEQUATER	TI	088	54.9	WB	D
1709NEW013	19391	10712	BARNAHOWN	TI	089	-1.0	WB	D
1709NEW012	19391	10726	BARNAHOWN	TI	090	-1.0	WB	D
2011NEW033	22585	12895	LISNATUBRID	TI	091	-1.0	WB	D
2009NEW035	21620	10940	AUGHAVOLIMANE	TI	091	-1.0	WB	D
2009NEW034	21620	10950	AUGHAVALOMAUN	TI	091	243.8	WB	D
2009NEW036	21655	20785	PRIESTOWN	TI	091	-1.0	WB	D
2011SWW017	20081	11802		TI	081	60.9	WB	
2011SWW018	20832	11523	CASTLEGRACE	TI	087	-1.0	WB	D
2011SWW016	20540	11160	GURTBACULLEN	TI	087	-1.0	WB	D
2011SWW014	20335	11402	BOHERNACORGE	TI	087	-1.0	WD	D
2011SWW013	20505	11635	BALLYHIST	TI	087	60.1	W	D
2011SWW012	20555	11761	BALLYLAFFIN	TI	087	61.0	WB	D
2011SWW011	20558	11772	BALLYLAFFIN	TI	087	-1.0	WB	D

P	8.8	-1	6.1	LMSTN	6.1	22.0	-1.0
P	14.6	-1	5.2	DRIFT/LIMESTONE	10.1	27.0	-1.0
P	24.9	-1	6.1	LIMESTONE	18.3	27.0	-1.0
P	18.8	-1	4.6		6.4	27.0	-1.0
P	21.3	-1	6.1	DRIFT/LIMESTONE	14.0	22.0	-1.0
P	51.8	-1	5.4	RED SANDSTONE/LIME	21.6	33.0	-1.0
P	35.4	-1	16.4		18.9	33.0	-1.0
P	28.9	-1	3.6	DRIFT/SST.	18.2	55.0	-1.0
P	20.7	-1	0.9		9.1	76.0	-1.0
P	21.9	-1	6.7	DRIFT/LST./SSTN.	11.9	22.0	-1.0
P	18.3	-1	12.2	DRIFT/RED RED SST.	5.8	33.0	-1.0
	15.8	-1	6.7	DRIFT/LST.	6.1	33.0	-1.0
P	22.5	-1	6.1		10.7	27.0	-1.0
P	2.7	-1	902.7	GRAVEL	-1.0	-1.0	-1.0
P	14.3	-1	7.6	DRIFT/LMSTN	2.7	22.0	-1.0
P	101.8	-1	12.2	LMSTN	32.9	122.0	-1.0
P	3.6	-1	-1.0		1.5	-1.0	-1.0
P	5.2	-1	-1.0		3.6	22.0	-1.0
P	17.6	-1	-1.0	DRIFT/RED SSTN	11.6	22.0	-1.0
P	21.3	-1	1.8		0.9	33.0	-1.0
P	39.6	-1	7.6		28.0	44.0	-1.0
P	18.3	-1	6.1	DRIFT/LMSTN	7.6	55.0	-1.0
P	21.3	-1	1.8	DRIFT/RED SSTN	18.2	11.0	-1.0
P	24.4	-1	4.6	DRIFT/RED SSTN	4.8	16.0	-1.0
P	26.2	-1	2.4	DRIFT/RED SSTN	-1.0	22.0	-1.0
	37.7	-1	-1.0		18.2	32.7	-1.0
P	8.1	-1	6.1	LMSTN.	6.1	22.0	-1.0
P	7.0	-1	6.1		4.6	33.0	-1.0
P	-1.0	-1	-1.0	P. KEATING	6.1	109.0	-1.0
P	32.6	-1	-1.0	DRIFT/LMSTN.	11.0	78.0	-1.0
P	36.3	-1	3.1	DRIFT/LST.	21.3	22.0	-1.0
P	36.6	-1	3.1		21.3	27.0	-1.0

2011SWW010	20170	11545	BALLYBOY	TI	087	60.9	WB	D	P	25.6	-1	15.5	DRIFT/LST.	15.2	87.0	-1.0
2011SWW008	20455	11748	SCART	TI	087	85.4	WB	D	P	29.3	-1	29.3	DRIFT/RED SST.	25.2	22.0	-1.0
2011SWW015	20879	11349	GOATENBRIDGE	TI	088	36.5	WD	D	G	2.7	-1	902.7	GRAVEL	-1.0	-1.0	-1.0

APPENDIX B.5

DRY WEATHER FLOW MEASUREMENTS AROUND SOME SOURCE AREAS

Groundwater Division,
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of Ireland

PERIODIC WELL MEASUREMENTS

Multeen River – upstream from BH 2 Ironhills

River Profile

dist from right bank (m)	total depth (m).				
0.5	0.17				
1.0	0.23				
1.5	0.291				
2.0	0.375				
2.5	0.432				
3.0	0.465				
3.5	0.475				
4.0	0.495				
4.5	0.51				
5.0	0.495				
5.5	0.49				
6.0	0.413				
6.5	0.46				
7.0	0.51				
7.5	0.387				
7.6	Left	Bank			

1918192

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PERIODIC WELL MEASUREMENTS

Multeen River - upstream from BH#2 IRONMILLS.

Dist from left bank (m)	Total Depth	dist from surface	# of revs/s n	Velocity	Comments
0.5	0.17	0.12	13,12,12 / 12.3	0.0743	
1.0	0.23	0.18	39,39,41 / 39.6	0.208	
		0.08	46,46 / 46	0.239	
1.5	0.291	0.241	19,19,22, / 20	0.112	
		0.141	41,44 / 42.5	0.222	
2.0	0.375	0.325	47,50,48 / 48.3	0.250	
		0.225	57,57 / 57	0.293	
		0.075	56,58 / 57	0.293	
2.5	0.432	0.382	51,48,55 / 51.3	0.265	
	—	0.282	66,65 / 65.5	0.337	
		0.132	61,62 / 61.5	0.317	
		0.032	59,57 / 58	0.299	
3.0	0.465	0.415	52,51,50 / 51	0.264	
		0.315	61,66,63 / 63.3	0.326	
		0.165	63,64 / 63.5	0.327	
		0.065	56,57 / 56.5	0.291	
3.5	0.475	0.425	52,51,53 / 52	0.269	
		0.325	63,69,65 / 65.6	0.338	
		0.175	69,69,70 / 69.3	0.357	
		0.075	54,58 / 56	0.288	
4.0	0.495	0.445	56,55,56 / 55.6	0.286	
		0.345	67,70 / 68.5	0.353	
		0.195	72,70 / 71	0.365	
		0.095	67,68 / 67.5	0.347	

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19/8/92

PERIODIC WELL MEASUREMENTS

Multeen River – upstream from RH#2 TRONHILLS

Dist from Left bank	Total Depth	dist from surface	# of revs/s n	Velocity	Comment
4.5	0.51	0.46	24, 24, 27 / 25	0.136	
		0.36	47, 47 / 47	0.244	
		0.21	66, 65 / 65.5	0.337	
		0.11	70, 66, 71 / 69	0.355	
5.0	0.495	0.445	50, 46, 46 / 47.3	0.246	
		0.345	58, 53, 57 / 56	0.288	
		0.195	62, 61 / 61.5	0.317	
		0.095	~~60~~, 61 / 61	0.314	
5.5	0.49	0.44	20, 18, 21 / 19.6	0.110	
	—	0.34	41, 42 / 41.5	0.217	
		0.19	48, 51 / 49.5	0.256	
		0.09	59, 59 / 59	0.304	
6.0	0.413	0.363	30, 29, 30 / 29.6	0.159	
		0.263	41, 44 / 42.5	0.222	
		0.113	50, 50 / 50	0.259	
6.5	0.46	0.41	22, 23 / 22.5	0.124	
		0.31	35, 35 / 35	0.185	
		0.16	33, 34 / 33.5	0.178	
		0.06	44, 47, 45 / 45.3N	0.236	
7.0	0.51	0.46	14, 14 / 14	0.082	
		0.36	27, 22, 24 / 24.3	0.133	
		0.21	35, 34 / 34.5	0.183	
		0.11	41, 40 / 40.5	0.212	
7.5 →					→

				Vel
7.5	0.387	0.337	20, 20 / 20	0.112
		0.237	19, 20 / 19.5	0.109
		0.087	20, 21 / 20.5	0.114

Dye Dilution Method

Groundwater Division,
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27/8/92

PERIODIC WELL MEASUREMENTS

Coolmore – Johnstown [Kilkenny Bog Hole]

Run	conc 1 C_p	conc 2 $C_o \rightarrow C_s$	Flow rate q	$Q = \frac{C_p \times q}{C_s - C_o}$	Discharge Q l/s
Run 1	65,000	420→436 16	0.045 ml/s	$\frac{0.045 \times 65,000}{16}$	= 182.8 l/s
Run 2	65,000	420→436 16	0.045 ml/s	$\frac{0.045 \times 65,000}{16}$	= 182.8 l/s
Run 3	65,000	422→436 14	0.045 ml/s	$\frac{0.045 \times 65,000}{14}$	= 208.9 l/s
			Average	191.5 l/s	

Johnstown Castle Bridge

Run	conc 1	conc 2	Flow rate	Q	Discharge
Run 1	66,500	435→446 11	0.045	$\frac{0.045 \times 66,500}{11}$	= 272.0 l/s
Run 2	66,500	437→449 12	0.045	$\frac{0.045 \times 66,500}{12}$	= 249.3 l/s
Run 3	69,000	418→426 8	0.045	$\frac{0.045 \times 69,000}{8}$	= 388.1 l/s omitted
Run 4	69,000	436→448 12	0.045	$\frac{0.045 \times 69,000}{12}$	= 258.9 l/s
			Average	260 l/s	

Dye Dilution Method. 28/8/92.

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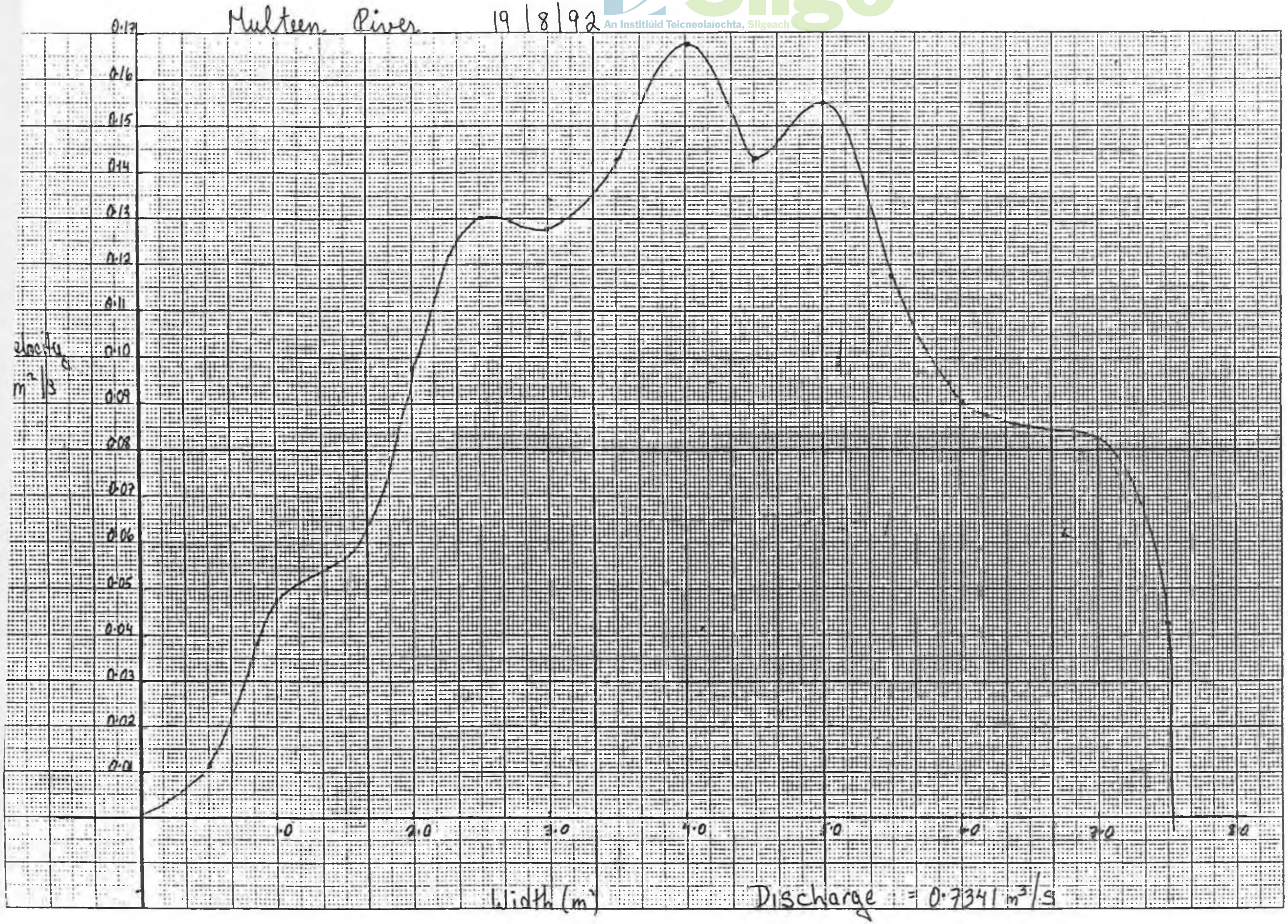
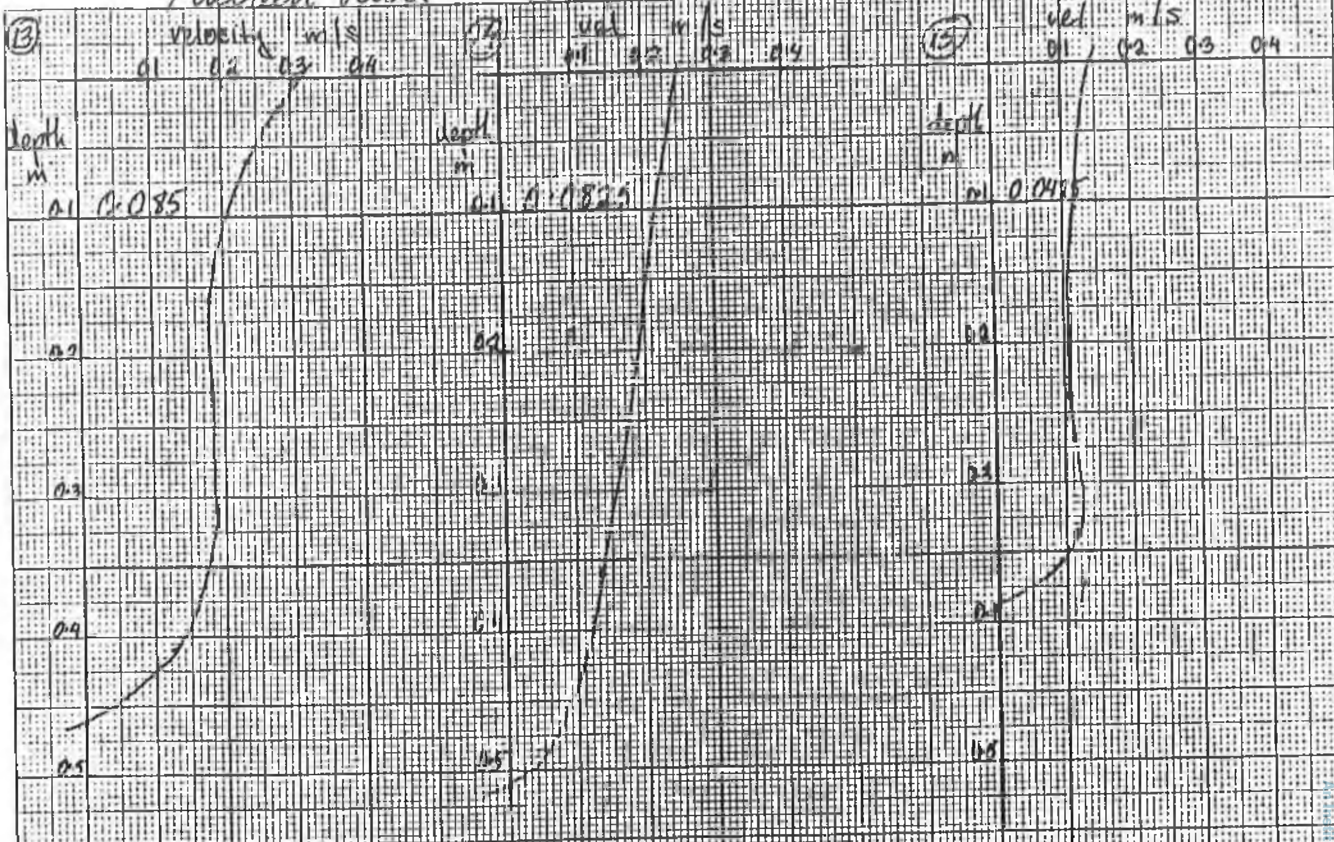
PERIODIC WELL
MEASUREMENTS

(3). Kiltinan Castle - Roaring Spring

Run 1.	Cp Conc 1	Co → Es conc 2	q. Flow rate	Q = (Cp x q)/(Cs - Co)	Discharge
	76,000 µS	600→621 µS	0.045 m/s	0.045 x 76,000 / 21	= 162.8 l/s
		21			
Run 2.	76,000 µS	612→634 µS	0.045 m/s	0.045 x 76,000 / 22.	= 155.4 l/s
		22.			
			Average	159.1 l/s	
Temperature	11°C				
Conductivity	675 µS.				

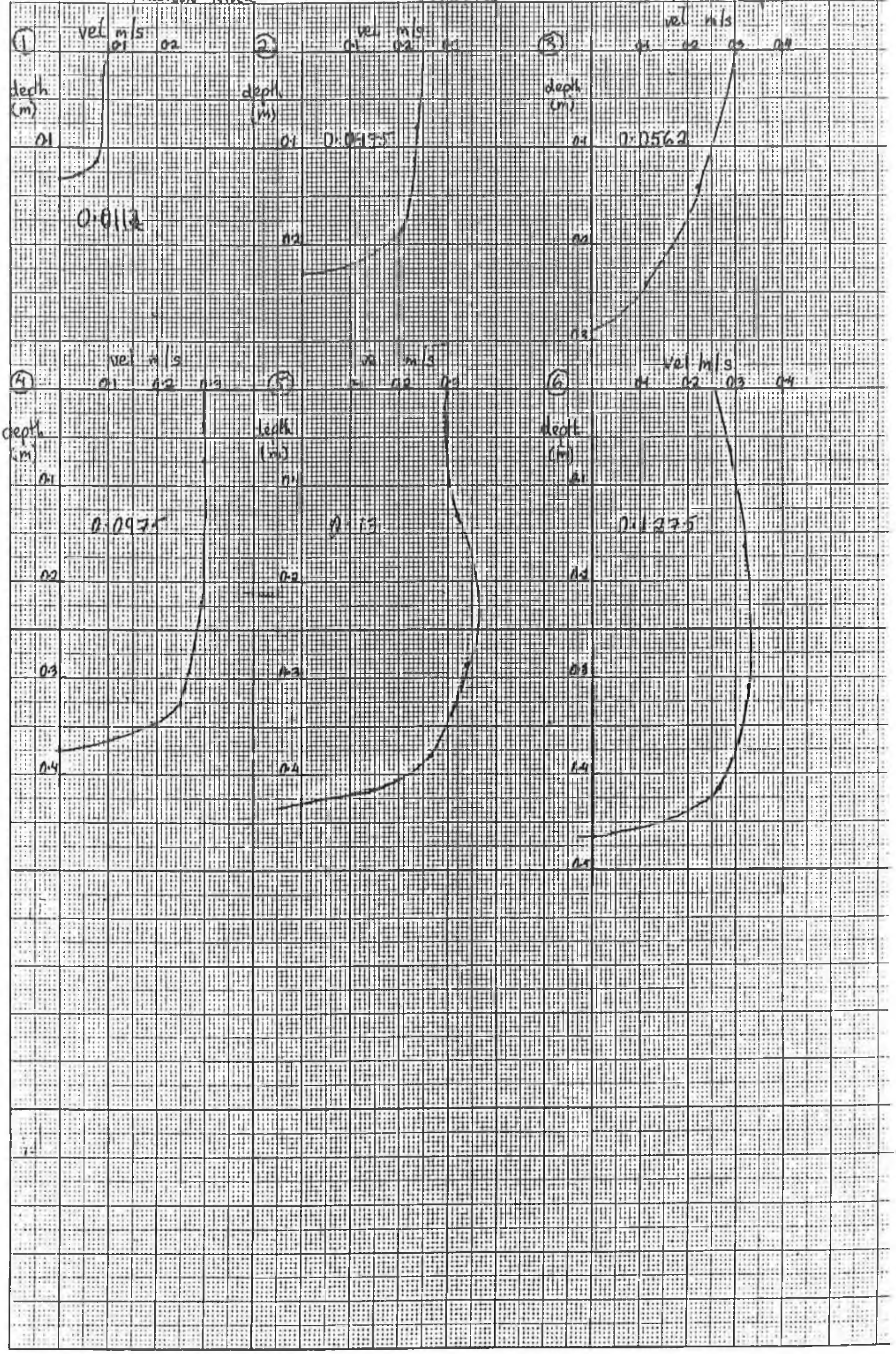

Multeen River 19/8/92
Velocity m²/s
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Width (m)
Discharge = 0.7341 m³/s

Multeen River 19/8/92 Velocity vs Depth

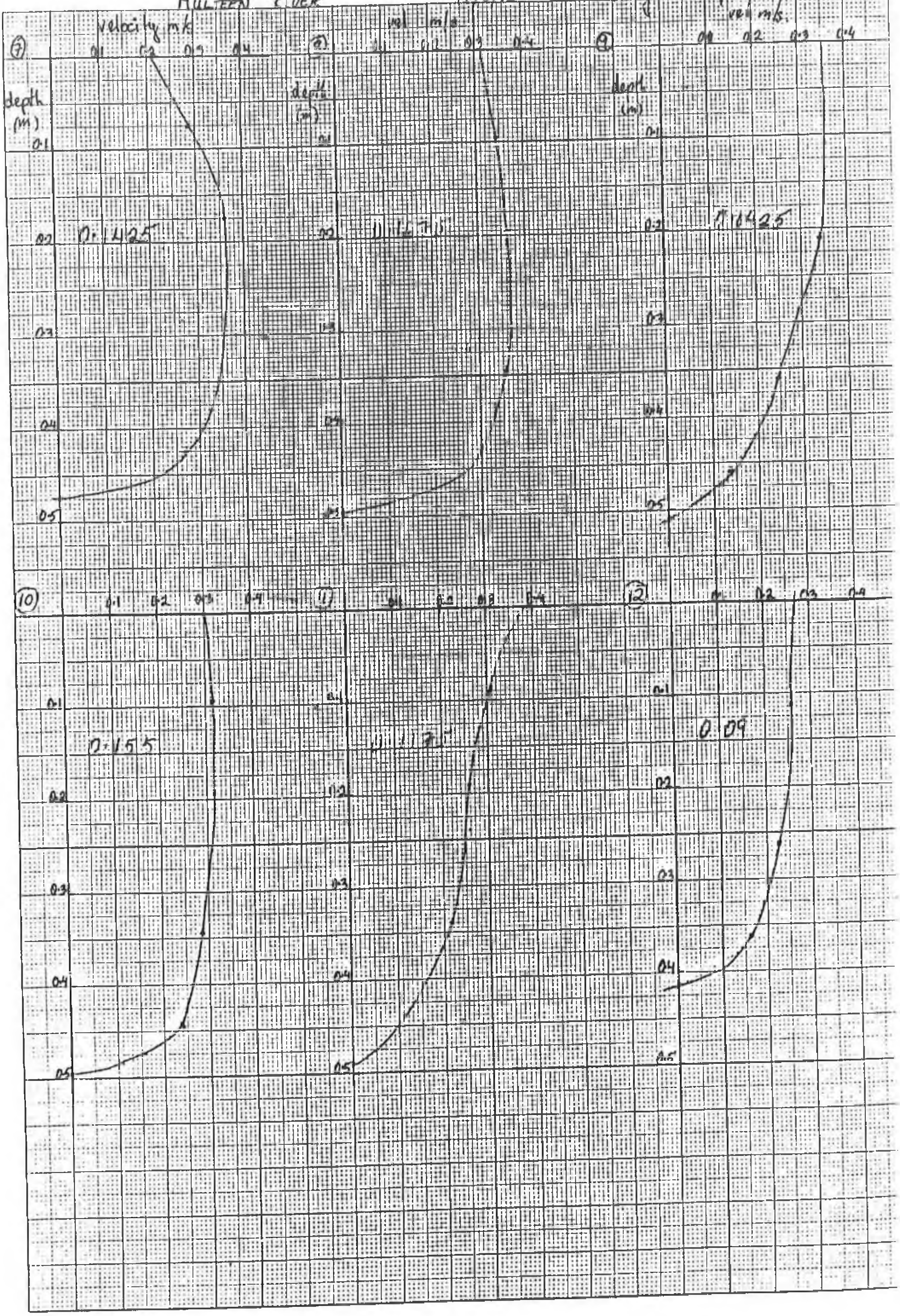


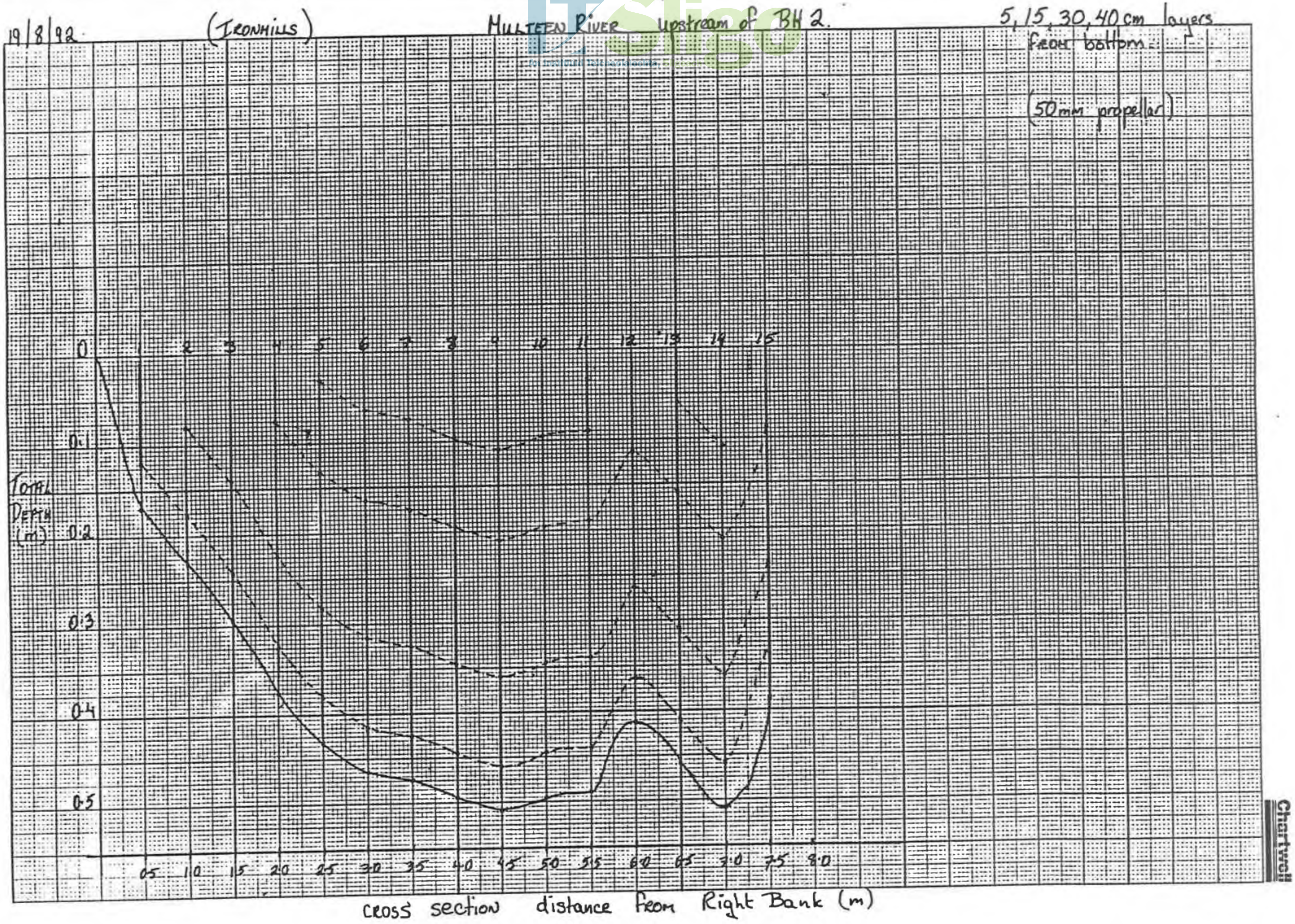
Chartwell

Multeen River — 19/8/92 — Velocity vs Depth



MULTEEN RIVER 19/8/92 Velocity vs depth





19/8/92
(IRONHILLS)
MULTEEN RIVER upstream of BH 2.
5, 15, 30, 40 cm layers from bottom.
(50mm propellar)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0
0.1
0.2
0.3
0.4
0.5
TOTAL DEPTH (m)
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0
CROSS section distance from Right Bank (m)

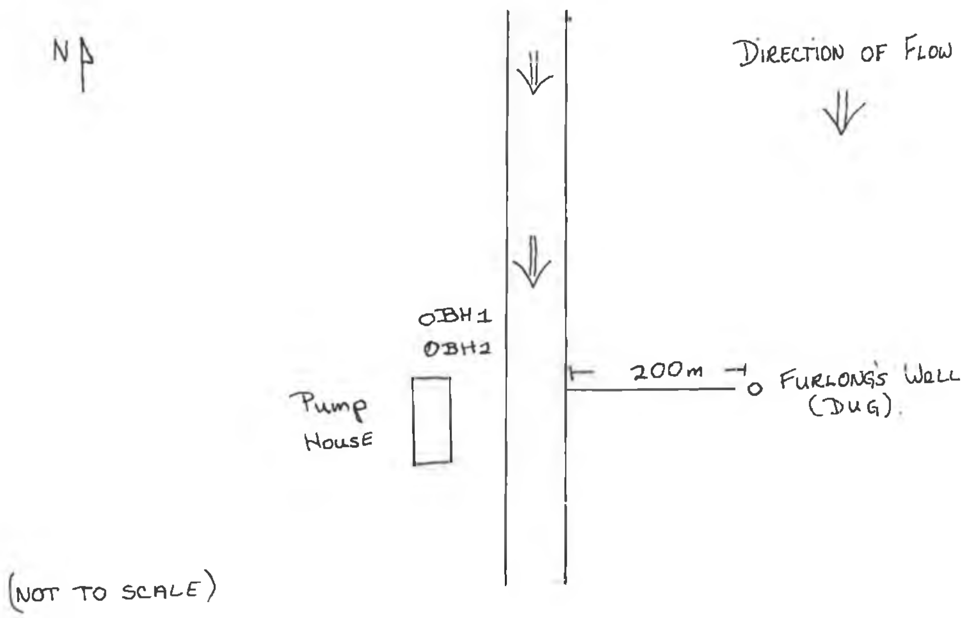
APPENDIX B.6

RESULTS OF A PUMPING TEST AT IRONMILLS, CAPPAGHWHITE, CO. TIPPERARY

RESULTS OF PUMP TEST AT IRONMILLS, CAPPAWHITE, CO. TIPPERARY.

A thirty six hours pump test was carried out on a Co Co borehole # 2 (BH 2) at Ironmills. The monitoring of this test was carried out by M. Keegan and K. Forde on request of Tipperary SR Co Co -Sanitary Section.

BH 2 commenced pumping at 8:00hrs on the 17/08/92, and continued pumping at a constant rate of 28,000gph until 20:00hrs on the 18/08/92. During this time the pumping well BH 2 and the observation well BH 1 were monitored by M.Keegan and K. Forde (GSI). A nearby (approx. 200m) shallow dug well (Furlong's) was monitored by Tipperary SR Co Co.



The analysis of the pump test data has been undertaken by M. Keegan GSI/Sligo RTC. The raw data plus the semi-log time drawdown for both BH 1 and BH 2 follow.

The transmissivities of the pumping well BH 2 and the observation well BH 1 decreases with time.

BH 2 $T = 1862 m^2/d$

$T = 859.3 m^2/d$

BH 1 $T = 1471.6 m^2/d$

$T = 980 m^2/d$

The graphs (observation and pumped) show that the transmissivity is decreasing with time until it reaches a "barrier" ie: an area of less permeable material with time.

If the river was a source of recharge to the borehole the graph would quickly level out or even increase. This is not so, the cone of influence may spread futher than originally thought.

The water level in the well (Furlong's) drop from Wednesday 7:30 hrs to Thursday 20:00 hrs by 8 cms .

The temperature and the conductivity of both the pumped borehole and the adjacent river were measured , this was undertaken to examine if they are in hydraulic continuity. There was a slight increase in the conductivity and the temperature of the borehole during the pump test.

Temperature	**Conductivity**
10 - 10.5 °C	5 - 5.2 *u*S

The increase is insignificant at this scale and therefore suggests that the borehole does not receive recharge from the river. This implies that the borehole and the river are not in hydraulic continuity.

This agrees with the information from the pump test. The extent of the cone of influence is not known because there is insufficent water levels from Furlong's well during the pump test.

The information to hand implies that there was a decrease of 0.08m in water level in Furlong's well during the thirty-six hour pump test of Borehole 2 at Ironmills.

Geological Survey of Ireland **MEASUREMENTS**

Temperature and Conductivity

	GMT	Temp °C	Conductivity µS x10^{-3} 25°	Borehole	River	Comments
192.				Placed into Borehole		
	8·45	10·5	5·2	✓		
	9·00.	10·5	5·2	✓		
	9·55.	10·5°	5·2	✓		
	11·25	10·5°	5·2.	✓		
				Placed into River.		
	13.50.	13·8°	2.18		✓	
	14.22.	14°	2.18		✓	
	15·24	12.75°	2·6.		✓	
	15·47	14.97°	2·6		✓	
	16.52.	13°	2.63		✓	

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PERIODIC WELL MEASUREMENTS

Temperature + Conductivity & Measurements

GMT	Temp °C	Conductivity $\times 10^2 \mu S$	Borehole	River	
	10°	5 μS	✓		
11.05	10°	5.00	✓		
11.10	10.5°	5.05	✓		
11.27	10.3°	5.07	✓		
			Placed into river at 11.40		
11.45	11.2°	2.1		✓	30m upstr from BH2
11.55	11.4°	2.1		✓	
12.15	11.6	2.1		✓	
12.35	12.0	2.1		✓	
12.45	12.2.	2.1		✓	
			Placed in Borehole at 12.50		
13.03	10.2°	5.09	✓		
13.30	10.2°	5.09	✓		
13.45	10.2°	5.09	✓		
14.00	10.2°	5.09	✓		
			Placed into River at 14.0		
14.45	13.2°	2.1		✓	
			Placed into Borehole 15.3		

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AQUIFER TESTS
WATER LEVEL
MEASUREMENTS

Page...1...

Borehole name. IRONHILLS...... No...1...

County...TI............ 6" sheet No...51....

Date...18/8/92...

Weather...Fair...

Drawdown [✓]

Recovery [ ]

Pumping well [ ]

Observation well [✓]

Distance from pumping well...2 m...m

Test conducted by...MK + KF...

Time GMT/ BST	Elapsed time Mins/ Hours	Days	MINS	Water level M	Draw-down M	Meter reading	Q	Remarks (i.e. pump behaviour, water temp, water quality etc)
Tues 8·00	0	0·0		4·205				
	½ min	3·47 x 10^{-4}						
8·01	1	6·95		5·16	0·955			
	1½	1·04 x 10^{-3}						
8·02	2	1·39		5·325	1·12			
8·02½	2½	1·74		5·375	1·17			
8·03	3	2·08		5·41	1·205			
8·03½	3½	2·43		5·44	1·235			
8·04	4	2·78		5·465	1·245			
8·04½	4½	3·13		5·485	1·28			
8·05	5	3·47		5·505	1·3			
8·06	6	4·17		5·52	1·315			
8·07	7	4·86		5·55	1·345			
8·08	8	5·56		5·565	1·36			
8·09	9	6·25		5·58	1·375			
8·10	10	6·94		5·59	1·385			
	13	8·33						
8·14	14	9·72		5·62	1·415			
8·16	16	1·11 x 10^{-2}		5·645	1·44			
	18	1·25						
8·20	20	1·39		5·67	1·465			
	22	1·53						
8·24	24	1·67		5·70	1·495			
8·26	26	1·81		5·71	1·505			
	28	1·94						
8·30	30	2·08		5·725	1·52			
	35	2·43						
8·40	40	2·78		5·75	1·545			
	45	3·13						
8·50	50	3·47		5·78	1·575			
	55	3·82						
9·00	1 hour	4·17	60	5·81	1·605			
9·15	1¼	5·21	75	5·855	1·65			
9·30	1½	6·25	90	5·88	1·675			
9·45	1¾	7·29	105	5·905	1·7			
10·00	2	8·83	120	5·93	1·725			

Groundwater Division,
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of Ireland

AQUIFER TESTS
WATER LEVEL
MEASUREMENTS

page 2

Borehole name IRONHILLS No. 1 County ...... 6" sheet no 51

Time GMT/BST	Elapsed time Mins/Hours	Days	MINS	Water level M	Draw-down M	Meter reading	Q	Remarks (i.e. pump behaviour, water temp, water quality etc)
10:36	~~2½~~	—	156	5.965	1.745 (*) change to river			10.11 → 5.42
11:00	3	1.25	180	5.985	1.78			10.17 → 5.975
11:30	3½	1.46	210	6.07	1.865			10.45 → 5.97
12:00	4	1.67	240	6.09	1.885			changed pump to
13:00	5	2.08	300	6.13	1.925			river.
14:00	6	2.5	360	6.18	1.975			11.13 → 6.06
15:00	7	2.92	420	6.2	1.995			11.24 → 6.06
16:00	8	3.33	480	6.23	(*) 2.025			changing pumping rate
17:00	9	3.75	540		change	back to		when switch to river
18:00	10	4.17	600			reservoir.		2.115
20:00	12	5.0	720	6.36	2.155		720 mins	(*) 21.00 → 6.32 change to river.
22:00	14	5.83	840					
24:00	16	6.67	960					
02:00	18	7.5	1080					Pump to Reservoir
5:00	21	8.75	1260					
8:06	24	1.0 x 10^0	1446	6.54	2.335			(*) 9.00 → 6.545 2.34
12:00	~~27~~ 28	~~1.125~~	1680	5.6.	*1.395 pump off for 2 mins			1560 10.00 → 6.58 2.375
14:00	30	1.25	1800					29 1380 13.40 → 6.61 2.405
20:00	36	1.5	2160	6.7	2.1495			30 1832 14.32 → 6.25 2.045
	42	1.75						31 1885 15.25 → 6.63 2.425
	48	2.0						33 2032 17.52 → 6.66 2.45
	54	2.25						35 2105 19.05 → 6.67 2.465 (night)
	60	2.5						
	66	2.75						
	72	3.0						Pump turned off by
		3.5						workman for 2 mins
		4.0						– recovery of at
		4.5						least 1m
		5.0						
		6.0						
		7.0						
		8.0						
		9.0						
		10.0						

Other remarks River level Wed 11am 0.665 down from peg
" 8:05pm 0.683 " " "
Thurs 9am 0.685 " " "

Furlong's Well Tues 7:30am 03.95m
Wed 10am 3.99, 7.55pm – 4.03
Thurs 9am 4.03

Groundwater Division,
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AQUIFER TESTS
WATER LEVEL
MEASUREMENTS

Page 1

Borehole name FRONHILLS No. 2

County TI 6" sheet No. 51

Date 18/8/92

Weather FINE

Drawdown ☑ Recovery ☐

Pumping well ☑ Observation well ☐

Distance from pumping well 0 m

Test conducted by MC + KF

Time GMT/BST	Elapsed time Mins/Hours	Days	MINS	Water level M	Draw-down M	Meter reading	Q	Remarks (i.e. pump behaviour, water temp, water quality etc)
8·00	0	0·0		4·225				
	½ min	$3{\cdot}47 \times 10^{-4}$						
	1	6·95						
	1½	$1{\cdot}04 \times 10^{-3}$						
	2	1·39						
	2½	1·74						
	3	2·08						
	3½	2·43						
	4	2·78	—					
	4½	3·13						
	5	3·47						
	6	4·17						
	7	4·86						
	8	5·56						
	9	6·25						
	10	6·94						
8·12	12	~~8·33~~	12	6·65	2·425			
	14	9·72						
	16	$1{\cdot}11 \times 10^{-2}$						
	18	1·25	18	6·70	2·475			
	20	1·39						
	22	1·53	22	6·77	2·545			
	24	1·67						
	26	1·81						
	28	1·94	28	6·70	2·475			difficult to get
	30	2·08						accurate readings
	35	2·43	35	6·79	2·565			because noise
	40	2·78						was continuous
	45	3·13	45	6·805	2·58			
	50	3·47						
	55	3·82	55	6·81	2·585			
9·05	~~1 hour~~	~~4·17~~	65	6·86	2·635			
9·20	~~1¼~~	~~5·21~~	80	6·90	2·675			
9·35	~~1½~~	~~6·25~~	95	6·91	2·685			
9·50	~~1¾~~	~~7·29~~	110	6·94	2·715			
10·50	—	~~[illegible]~~	170	6·96	2·735			

Groundwater Division,
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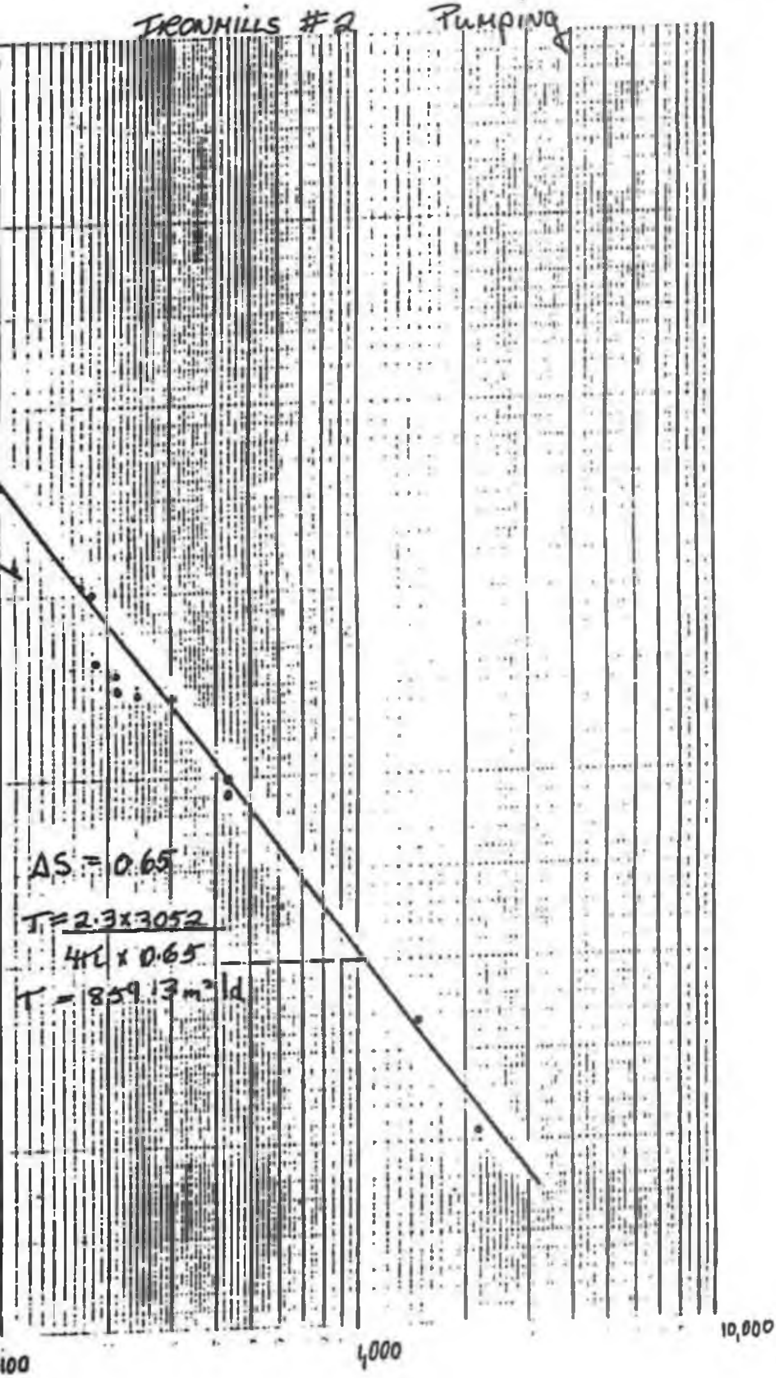
AQUIFER TESTS
WATER LEVEL
MEASUREMENTS

Pumping.

Borehole name..IRONHILLS............ No....2..... County....T.L.............. 6" sheet no..51....

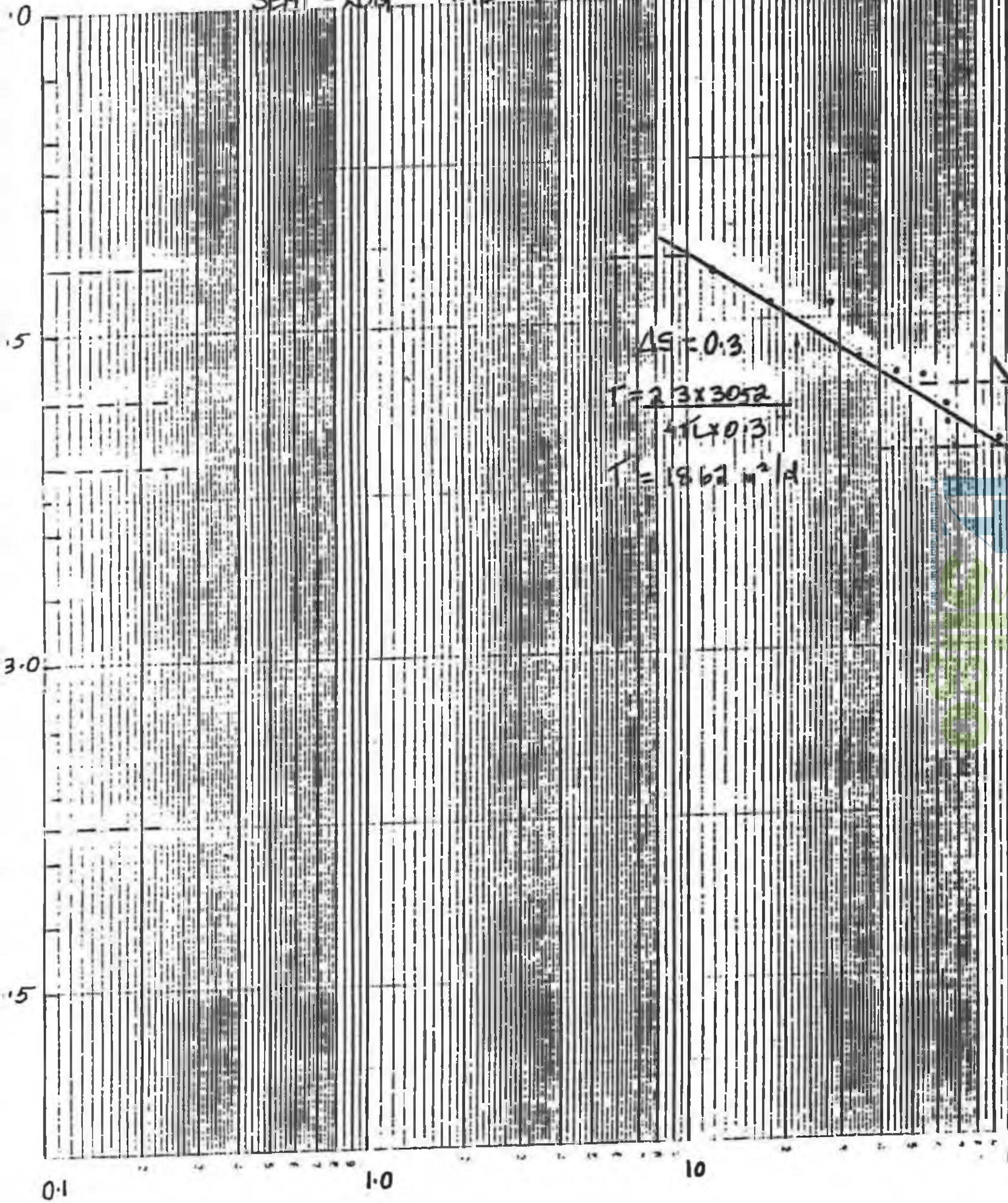
Time GMT/BST	Elapsed time Mins/Hours	Days		Water level M	Draw-down M	Meter reading	Q	Remarks (i.e. pump behaviour, water temp, water quality etc)
10·58	~~2½~~	——	178	6·98	2·755			
11·05	~~3~~	1·25 +5	185	7·11	2·885			Change pumping
11·35	3½	1·46 +5	215	7·12	2·895			rate to steady 28,000
12·05	4	1·67 +5	245	7·16	2·935			11·25 → 7·2 ↘ 2·975
13·05	5	2·08 +5	305	7·21	2·985			
14·05	6	2·5 +5	365					
15·05	7	2·92 +5	425	7·25	3·025			
16·05	8	3·33 +5	485	7·28	3·055			
	9	3·75 +5						
	10	4·17+5						DRAWDOWN
20·25	12	5·0 +5	745	7·26.	3·035			21·00 → 7·20. 2·975.
	14	5·83						(750)
	16	6·67						
	18	7·5						
	21	8·75	——					
8·10	24	1·0 x 10⁰	1450	7·57	3·335		(1505)	9·05 → 7·565. 3·34
	27	1·125					(1562)	10·02 → 7·59 3·365
14·05	30	1·25	1810				(1835)	14·25 → 7·73? ↗ 3·505
20·05	36	1·5	2165	7·72	3·495		(1885)	15·25 → 7·73 [illegible]
	42	1·75					(2036)	17·56 → 7·74 3·515 [illegible]
	48	2·0					(2104)	19·04 → 7·75. 3·525.
	54	2·25.						
	60	2·5						
	66	2·75						
	72	3·0						
		3·5						
		4·0						
		4·5						
		5·0						
		6·0						
		7·0						
		8·0						
		9·0						
		10·0						

Other remarks

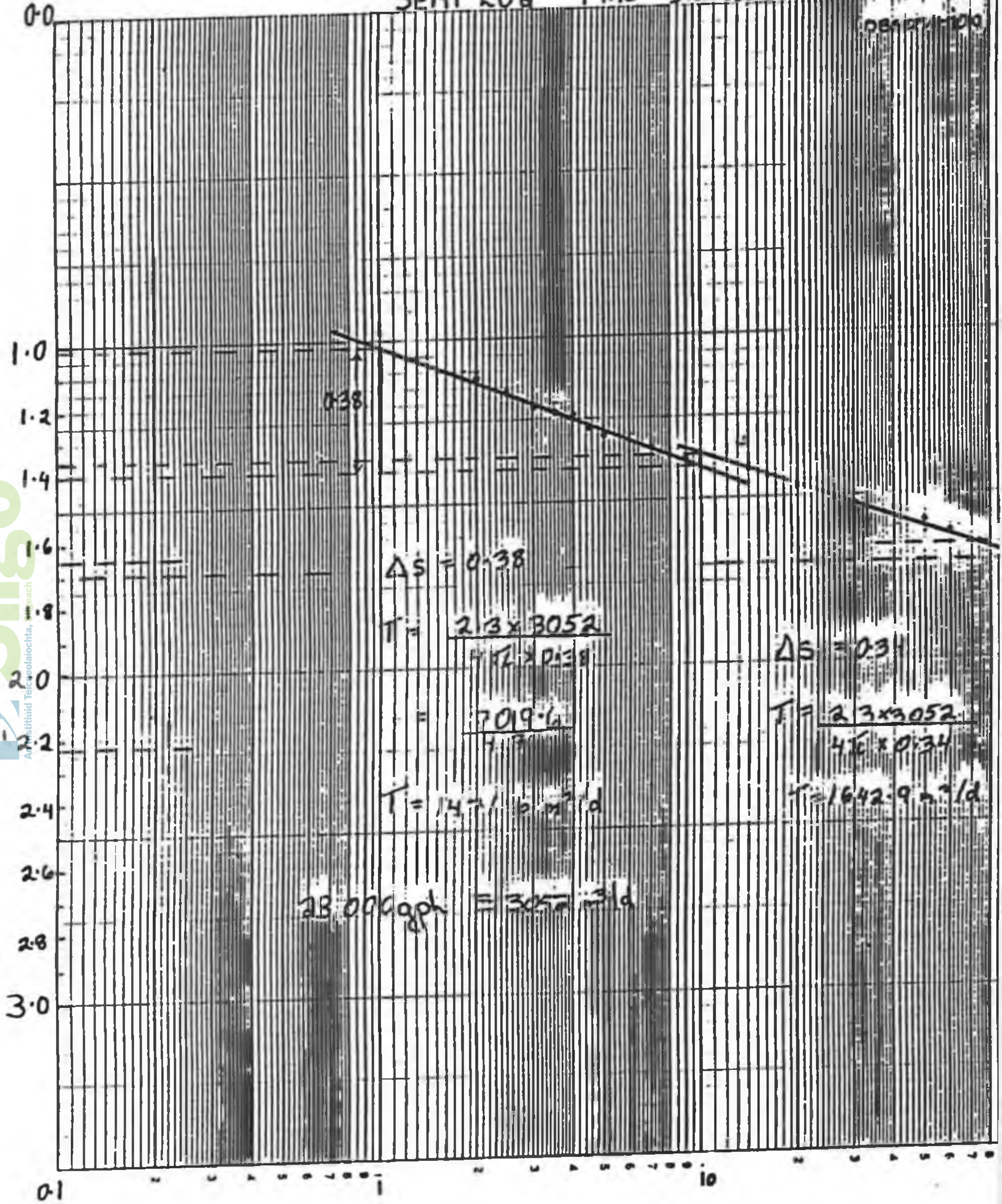


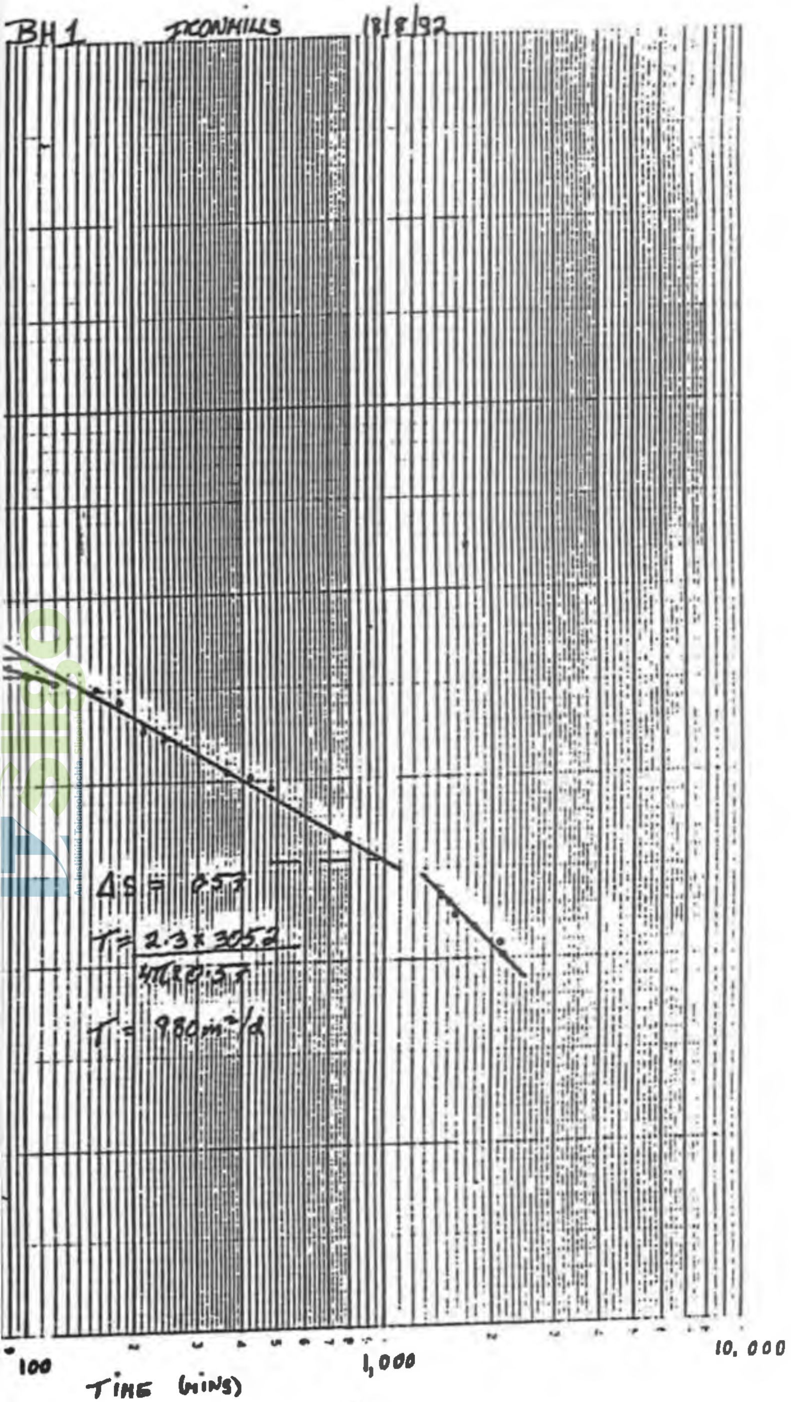
IRONHILLS #2 Pumping
ΔS = 0.65
T = 2.3x3052 / 4π x 0.65
T = 859.13 m²/d
100
1,000
10,000

SEMI-LOG TIME DRAWDOWN CURVE FOR BH2



SEMI LOG TIME DRAWDOWN CURVE FOR





BH1
18/8/92
Δs = 0.57
T = 2.3 x 305.2
T = 980 m²/d
100
1,000
10,000
TIME (MINS)

APPENDIX C

HYDROCHEMISTRY/WATER QUALITY

APPENDIX C.1

CHEMICAL ANALYSIS FOR A SAMPLING EVENT FROM 3/5/1993 TO 10/5/1993.

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Site id number		1711NEW1023	1711NEW1024	1713NEW1003
Sample number		1	1	26
Sample date		19930503	19930503	19930503
Date of analysis		19930621	19930621	19930620
Analytical laboratory		R.W.L.	R.W.L.	R.W.L.
Calcium	(mg/L Ca)	2.0	2.0	7.0
Calcium hardness	(mg/L)	5^_	5^_	17^_
Chloride	(mg/L)	8.00	18.00	14.00
Color	(mg/L Pt)	10^X	15^X	5^X
E. COLI	(/100 mL)			
Fluoride	(mg/L)			
Ion-balance error	(%)	-1.91	-19.99^_	-4.41
Iron (total)	(mg/L)	0.005	0.005	0.005
magnesium	(mg/L Mg)	4.0000	9.0000	22.0000
Manganese	(mg/L)	0.006	0.005	0.005
Methyl orange alkalinity	(mg/L)	31.00	60.00	116.00
Nitrate as nitrogen	(mg/L)	0.200	0.300	1.800
Temperature	(C)			
TOTAL COLIFORMS	(/100ML)	2.0^^	0.0	0.0
TOTAL HARDNESS (CaCO3)	(MG/L)	19.0^_	40.0^_	110.0^_
Zinc	(mg/L)	0.0760	0.0050	0.0140
Ammonia as nitrogen	(mg/L)	0.010	0.010	0.010
BIOCHEMICAL OXYGEN DEMAND	(MG/L)			
Copper	(mg/L)	0.002	0.720^X	0.008
Electrical conductivity	(µS/cm)	86.000	165.000	270.000
pH	(pH unit)	6.90	6.30^Y	7.10
Potassium	(mg/L)	0.90	0.80	1.00
Sulphate	(mg/L)	1.00	1.00	1.00
SUSPENDED SOLIDS	(MG/L)	0.00	0.00	0.00
Σ Cations	(meq/L)	0.848	1.167	2.622
TOC	(mg/L O2)	7.60^^	13.60^^	33.60^^
Dry Residues	(mg/L)	42.0^^	72.0^^	130.0^^
Faecal Coliforms	(100/ml)	0.00	0.00	0.00
Lead	(mg/L)	0.001	0.007	0.002
Nitrate as NO3	(mg/L NO3)	0.90^^	1.30^^	8.00^^
Nitrite as nitrogen	(mg/L)	0.001	0.001	0.001
Odor	(TON)	1^X	1^X	1^X
Ortho phosphorous	(mg/L P)	0.007^^	0.003^^	0.004^^
Sodium	(mg/L)	9.00^_	7.00^_	10.00^_
Σ Anions	(meq/L)	0.881	1.750	2.864
Carbonate	(mg/L)	0	0	0
Magnesium hardness	(mg/L)	16	37	91
TOTAL BACTERIA	(/100ML)			
Sulphide	(mg/L S)	0.00	0.00	0.00
Aluminum	(mg/L)	0.060^X	0.020	0.010

Selected standard : EEC drinking water
^^ = Exceeds max acceptable value ^Y = Below min guideline value
^X = Exceeds max guideline value ^_ = Below min acceptable value
< = Below detection limit

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Site id number		1713SEW1023	1715SEW1002	1715SEW1002
Sample number		1	4	3
Sample date		19930503	19930503	19930503
Date of analysis		19930621	19930621	19930621
Analytical laboratory		R.W.L.	R.W.L.	PAW
Calcium	(mg/L Ca)	102.0^X	64.0	
Calcium hardness	(mg/L)	255^^	160	
Chloride	(mg/L)	18.00	17.00	
Color	(mg/L Pt)	5^X	10^X	
E. COLI	(/100 mL)			16^^
Fluoride	(mg/L)		0.0000	
Ion-balance error	(%)	-9.53^Y	-5.71^Y	
Iron (total)	(mg/L)	0.005	0.027	
magnesium	(mg/L Mg)	4.0000	14.0000	
Manganese	(mg/L)	0.006	0.005	
Methyl orange alkalinity	(mg/L)	305.00	232.00	
Nitrate as nitrogen	(mg/L)	2.100	2.300	
Temperature	(C)			
TOTAL COLIFORMS	(/100ML)	0.0	7.0^^	16.0^^
TOTAL HARDNESS (CaCO3)	(MG/L)	269.0	217.0	
Zinc	(mg/L)	0.0050	0.0050	
Ammonia as nitrogen	(mg/L)	0.010	0.010	
BIOCHEMICAL OXYGEN DEMAND	(MG/L)			
Copper	(mg/L)	0.001	0.068	
Electrical conductivity	(µS/cm)	534.000^^	452.000^X	
pH	(pH unit)	7.30	7.20	
Potassium	(mg/L)	0.20	1.40	
Sulphate	(mg/L)	1.00	1.00	
SUSPENDED SOLIDS	(MG/L)	0.00	0.00	
Σ Cations	(meq/L)	5.599	4.732	
TOC	(mg/L O2)	74.80^^	62.00^^	
Dry Residues	(mg/L)	318.0^^	252.0^^	
Faecal Coliforms	(100/ml)	0.00	4.00^^	
Lead	(mg/L)	0.001	0.001	
Nitrate as NO3	(mg/L NO3)	9.30^^	10.20^^	
Nitrite as nitrogen	(mg/L)	0.001	0.001	
Odor	(TON)	1^X	1^X	
Ortho phosphorous	(mg/L P)	0.011^^	0.004^^	
Sodium	(mg/L)	4.00^_	8.00^_	
Σ Anions	(meq/L)	6.778	5.305	
Carbonate	(mg/L)	0	0	0
Magnesium hardness	(mg/L)	16	58	
TOTAL BACTERIA	(/100ML)			
Sulphide	(mg/L S)	0.00	0.00	
Aluminum	(mg/L)	0.010	0.010	

Selected standard : EEC drinking water
^^ = Exceeds max acceptable value ^Y = Below min guideline value
^X = Exceeds max guideline value ^_ = Below min acceptable value
< = Below detection limit

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Site id number		2011SWW1030	2011SWW1031	2013NEW1007
Sample number		6	6	1
Sample date		19930503	19930503	19930504
Date of analysis		19930621	19930621	19930621
Analytical laboratory		R.W.L.	R.W.L.	R.W.L.
Calcium	(mg/L Ca)	65.0		88.0
Calcium hardness	(mg/L)	162		220^^
Chloride	(mg/L)	16.00	16.00	20.00
Color	(mg/L Pt)	10^X	10^X	10^X
E. COLI	(/100 mL)			
Fluoride	(mg/L)			
Ion-balance error	(%)	-5.03^Y	-99.81^_	1.48
Iron (total)	(mg/L)	0.005	0.026	
magnesium	(mg/L Mg)	9.0000		23.0000
Manganese	(mg/L)	0.005	0.002	
Methyl orange alkalinity	(mg/L)	199.00	219.00	274.00
Nitrate as nitrogen	(mg/L)	3.300	3.600	4.400
Temperature	(C)			
TOTAL COLIFORMS	(/100ML)	7.0^^	7.0^^	7.2^^
TOTAL HARDNESS (CaCO3)	(MG/L)	199.0	207.0	315.0
Zinc	(mg/L)	0.0050	0.0170	0.0050
Ammonia as nitrogen	(mg/L)	0.010	0.010	0.150^X
BIOCHEMICAL OXYGEN DEMAND	(MG/L)			
Copper	(mg/L)	0.006	0.005	0.011
Electrical conductivity	(µS/cm)	415.000^X	428.000^X	625.000^^
pH	(pH unit)	7.30	7.30	7.20
Potassium	(mg/L)	0.90		4.20
Sulphate	(mg/L)	5.00	7.00	15.00
SUSPENDED SOLIDS	(MG/L)	0.00	0.00	0.00
Σ Cations	(meq/L)	4.314	0.005	6.872
TOC	(mg/L O2)	53.00^^	54.50^^	56.20^^
Dry Residues	(mg/L)	236.0^^		344.0^^
Faecal Coliforms	(100/ml)	4.00^^	1.00^^	0.00
Lead	(mg/L)	0.001	0.003	0.001
Nitrate as NO3	(mg/L NO3)	14.60^^	15.90^^	19.50^^
Nitrite as nitrogen	(mg/L)	0.001	0.001	0.004
Odor	(TON)	1^X	1^X	1^X
Ortho phosphorous	(mg/L P)	0.005^^	0.005^^	0.004^^
Sodium	(mg/L)	7.00^_		11.00^_
Σ Anions	(meq/L)	4.771	5.234	6.671
Carbonate	(mg/L)	0	0	0
Magnesium hardness	(mg/L)	37		95
TOTAL BACTERIA	(/100ML)			
Sulphide	(mg/L S)	0.00	0.00	0.00
Aluminum	(mg/L)	0.030	0.050	0.030

Selected standard : EEC drinking water
^^ = Exceeds max acceptable value ^Y = Below min guideline value
^X = Exceeds max guideline value ^_ = Below min acceptable value
< = Below detection limit

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Site id number		2013NEW1009	2013NWW1033	2013SEW1019
Sample number		5	1	14
Sample date		19930510	19930504	19930510
Date of analysis		19930713	19930621	19930713
Analytical laboratory		R.W.L.	R.W.L.	R.W.L.
Calcium	(mg/L Ca)	18.0	96.0	5.0
Calcium hardness	(mg/L)	45^_	240^^	12^_
Chloride	(mg/L)	16.00	27.00^X	11.00
Color	(mg/L Pt)	10^X	10^X	5^X
E. COLI	(/100 mL)			
Fluoride	(mg/L)			
Ion-balance error	(%)	3.80	-5.50^Y	38.86^^
Iron (total)	(mg/L)	0.055^X	0.007	0.026
magnesium	(mg/L Mg)	38.0000^X	30.0000	3.0000
Manganese	(mg/L)	0.034^X	0.005	0.007
Methyl orange alkalinity	(mg/L)	208.00	364.00	8.00
Nitrate as nitrogen	(mg/L)	1.000	7.100^X	0.100
Temperature	(C)			
TOTAL COLIFORMS	(/100ML)	0.0	30.0^^	0.0
TOTAL HARDNESS (CaCO3)	(MG/L)	204.0	363.0	10.0^_
Zinc	(mg/L)	0.0150	0.0050	0.0420
Ammonia as nitrogen	(mg/L)	0.010	0.220^X	0.010
BIOCHEMICAL OXYGEN DEMAND	(MG/L)			
Copper	(mg/L)		0.001	
Electrical conductivity	(µS/cm)	403.000^X	695.000^^	44.000
pH	(pH unit)	7.10	7.10	6.30^Y
Potassium	(mg/L)	2.80	0.80	0.80
Sulphate	(mg/L)	8.00	1.00	1.00
SUSPENDED SOLIDS	(MG/L)	0.00	0.00	0.00
Σ Cations	(meq/L)	5.232	7.675	1.131
TOC	(mg/L O2)	48.20^^	0.90^^	0.70^^
Dry Residues	(mg/L)	236.0^^	410.0^^	34.0^^
Faecal Coliforms	(100/ml)	0.00	1.00^^	0.00
Lead	(mg/L)		0.001	
Nitrate as NO3	(mg/L NO3)	4.40^^	31.40^^	0.40^^
Nitrite as nitrogen	(mg/L)	0.001	0.002	0.001
Odor	(TON)	1^X	1^X	2^X
Ortho phosphorous	(mg/L P)	0.010^^	0.009^^	0.010^^
Sodium	(mg/L)	26.00^_	9.00^_	14.00^_
Σ Anions	(meq/L)	4.849	8.569	0.498
Carbonate	(mg/L)	0	0	0
Magnesium hardness	(mg/L)	156	124	12
TOTAL BACTERIA	(/100ML)			
Sulphide	(mg/L S)	0.00	0.00	0.00
Aluminum	(mg/L)	0.010	0.040	0.060^X

Selected standard : EEC drinking water
^^ = Exceeds max acceptable value ^Y = Below min guideline value
^X = Exceeds max guideline value ^_ = Below min acceptable value
< = Below detection limit

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Site id number		2013SEW1020	2013SEW1032	2013SWW1021
Sample number		16	1	9
Sample date		19930504	19930504	19930504
Date of analysis		19930620	19930621	19930621
Analytical laboratory		R.W.L.	R.W.L.	R.W.L
Calcium	(mg/L Ca)	113.0^X	91.0	123.0^X
Calcium hardness	(mg/L)	282^^	227^^	307^^
Chloride	(mg/L)	20.00	20.00	23.00
Color	(mg/L Pt)	5^X	5^X	5^X
E. COLI	(/100 mL)			
Fluoride	(mg/L)			0.0000
Ion-balance error	(%)	-3.33	-4.99	-5.23^Y
Iron (total)	(mg/L)	0.005	0.005	0.005
magnesium	(mg/L Mg)	11.0000	22.0000	13.0000
Manganese	(mg/L)	0.007	0.005	0.005
Methyl orange alkalinity	(mg/L)	340.00	334.00	365.00
Nitrate as nitrogen	(mg/L)	3.600	2.800	5.600
Temperature	(C)			
TOTAL COLIFORMS	(/100ML)	11.0^^	20.0^^	0.0
TOTAL HARDNESS (CaCO3)	(MG/L)	326.0	318.0	361.0
Zinc	(mg/L)	0.0050	0.0050	0.0050
Ammonia as nitrogen	(mg/L)	0.010	0.010	0.240^X
BIOCHEMICAL OXYGEN DEMAND	(MG/L)			
Copper	(mg/L)	0.001	0.003	0.001
Electrical conductivity	(µS/cm)	620.000^^	606.000^^	673.000^^
pH	(pH unit)	7.20	7.10	7.20
Potassium	(mg/L)	4.80	1.60	0.90
Sulphate	(mg/L)	1.00	1.00	1.00
SUSPENDED SOLIDS	(MG/L)	0.00		0.00
Σ Cations	(meq/L)	7.149	6.755	7.537
TOC	(mg/L O2)	64.20^^	71.40^^	45.60^^
Dry Residues	(mg/L)	377.0^^	353.0^^	409.0^^
Faecal Coliforms	(100/ml)	11.00^^	14.00^^	0.00
Lead	(mg/L)	0.010	0.001	0.010
Nitrate as NO3	(mg/L NO3)	15.90^^	12.40^^	24.80^^
Nitrite as nitrogen	(mg/L)	0.002	0.002	0.001
Odor	(TON)	1^X	1^X	1^X
Ortho phosphorous	(mg/L P)	0.008^^	0.033^^	0.002^^
Sodium	(mg/L)	11.00^_	8.00^_	7.00^_
Σ Anions	(meq/L)	7.642	7.465	8.369
Carbonate	(mg/L)	0	0	0
Magnesium hardness	(mg/L)	45	91	54
TOTAL BACTERIA	(/100ML)			
Sulphide	(mg/L S)	0.00	0.00	0.00
Aluminum	(mg/L)	0.040	0.190^X	0.020

Selected standard : EEC drinking water
^^ = Exceeds max acceptable value ^Y = Below min guideline value
^X = Exceeds max guideline value ^_ = Below min acceptable value
< = Below detection limit

* HydroBase * Chemistry Report * Date printed : 26 February 1994
Generated for : TIPPERARY SOUTH RIDING Page 6

Site id number		2015SEW1008	2311NWW1017	2311NWW1027
Sample number		11	11	1
Sample date		19930504	19930504	19930510
Date of analysis		19930621	19930621	19930713
Analytical laboratory		R.W.L.	R.W.L.	R.W.L.
Calcium	(mg/L Ca)	52.0	35.0	5.0
Calcium hardness	(mg/L)	130	87	12^_
Chloride	(mg/L)	17.00	15.00	12.00
Color	(mg/L Pt)	5^X	5^X	15^X
E. COLI	(/100 mL)			
Fluoride	(mg/L)			
Ion-balance error	(%)	-2.03	-1.73	42.02^^
Iron (total)	(mg/L)		0.032	0.056^X
magnesium	(mg/L Mg)	14.0000	17.0000	3.0000
Manganese	(mg/L)		0.015	0.033^X
Methyl orange alkalinity	(mg/L)	181.00	152.00	7.00
Nitrate as nitrogen	(mg/L)	0.700	3.100	0.200
Temperature	(C)			
TOTAL COLIFORMS	(/100ML)	0.0	0.0	0.0
TOTAL HARDNESS (CaCO3)	(MG/L)	189.0	159.0	10.0^_
Zinc	(mg/L)	0.0050	0.0050	0.1040^X
Ammonia as nitrogen	(mg/L)	0.200^X	0.010	0.010
BIOCHEMICAL OXYGEN DEMAND	(MG/L)			
Copper	(mg/L)	0.017	0.006	
Electrical conductivity	(µS/cm)	411.000^X	353.000	54.000
pH	(pH unit)	7.40	7.00	5.50^Y
Potassium	(mg/L)	3.20	1.50	0.60
Sulphate	(mg/L)	12.00	1.00	1.00
SUSPENDED SOLIDS	(MG/L)	0.00	0.00	0.00
Σ Cations	(meq/L)	4.224	3.579	1.259
TOC	(mg/L O2)	0.90^^	33.20^^	0.10^^
Dry Residues	(mg/L)	219.0^^	180.0^^	35.0^^
Faecal Coliforms	(100/ml)	0.00	0.00	0.00
Lead	(mg/L)	0.001	0.001	
Nitrate as NO3	(mg/L NO3)	3.10^^	13.70^^	0.90^^
Nitrite as nitrogen	(mg/L)	0.006	0.003	0.001
Odor	(TON)	1^X	1^X	1^X
Ortho phosphorous	(mg/L P)	0.006^^	0.020^^	0.010^^
Sodium	(mg/L)	9.00^_	9.00^_	17.00^_
Σ Anions	(meq/L)	4.399	3.705	0.514
Carbonate	(mg/L)	0	0	0
Magnesium hardness	(mg/L)	58	70	12
TOTAL BACTERIA	(/100ML)			
Sulphide	(mg/L S)	0.00	0.00	0.00
Aluminum	(mg/L)	0.050	0.030	0.060^X

Selected standard : EEC drinking water
^^ = Exceeds max acceptable value ^Y = Below min guideline value
^X = Exceeds max guideline value ^_ = Below min acceptable value
< = Below detection limit

* HydroBase * Chemistry Report * Date printed : 26 February 1994
Generated for : TIPPERARY SOUTH RIDING Page 7

Site id number		2311NWW1028	2313SWW1018
Sample number		1	9
Sample date		19930510	19930510
Date of analysis		19930621	19930713
Analytical laboratory		R.W.L.	R.W.L.
Calcium	(mg/L Ca)	91.0	8.0
Calcium hardness	(mg/L)	227^^	20^_
Chloride	(mg/L)	17.00	12.00
Color	(mg/L Pt)	5^X	10^X
E. COLI	(/100 mL)		
Fluoride	(mg/L)		
Ion-balance error	(%)	-3.22	2.24
Iron (total)	(mg/L)	0.065^X	0.036
magnesium	(mg/L Mg)	5.0000	9.0000
Manganese	(mg/L)	0.005	
Methyl orange alkalinity	(mg/L)	250.00	64.00
Nitrate as nitrogen	(mg/L)	1.800	1.200
Temperature	(C)		
TOTAL COLIFORMS	(/100ML)	0.0	0.0
TOTAL HARDNESS (CaCO3)	(MG/L)	247.0	56.0^_
Zinc	(mg/L)	0.0230	0.1180^X
Ammonia as nitrogen	(mg/L)	0.010	0.010
BIOCHEMICAL OXYGEN DEMAND	(MG/L)		
Copper	(mg/L)	0.007	
Electrical conductivity	(µS/cm)	492.000^X	169.000
pH	(pH unit)	7.70	6.90
Potassium	(mg/L)	0.60	1.20
Sulphate	(mg/L)	1.00	2.00
SUSPENDED SOLIDS	(MG/L)	0.00	0.00
Σ Cations	(meq/L)	5.278	1.826
TOC	(mg/L O2)	57.80^^	17.40^^
Dry Residues	(mg/L)	277.0^^	91.0^^
Faecal Coliforms	(100/ml)	0.00	0.00
Lead	(mg/L)	0.001	
Nitrate as NO3	(mg/L NO3)	8.00^^	5.30^^
Nitrite as nitrogen	(mg/L)	0.002	0.001
Odor	(TON)	1^X	1^X
Ortho phosphorous	(mg/L P)	0.006^^	0.020^^
Sodium	(mg/L)	7.00^_	15.00^_
Σ Anions	(meq/L)	5.629	1.746
Carbonate	(mg/L)	1	0
Magnesium hardness	(mg/L)	21	37
TOTAL BACTERIA	(/100ML)		
Sulphide	(mg/L S)	0.00	0.00
Aluminum	(mg/L)	0.050	0.020

Selected standard : EEC drinking water
^^ = Exceeds max acceptable value ^Y = Below min guideline value
^X = Exceeds max guideline value ^_ = Below min acceptable value
< = Below detection limit

APPENDIX D

GROUNDWATER LEGISLATION

APPENDIX D.1

INTEGRATION OF THE GROUNDWATER PROTECTION PLAN INTO THE COUNTY DEVELOPMENT PLAN

INTEGRATION OF THE GROUNDWATER PROTECTION PLAN INTO THE COUNTY DEVELOPMENT PLAN

Points of interest from the protection of groundwater from pollution are as follows;

PART ONE A

Section 1

1.1 It will encourage the exploitation of gravel and other mineral deposits, and assist where possible the farming organisations in promoting the more intensive use of the land.

Section 2

1.11 Since the land is the main resource in the County the development of agriculture must be seen as a major priority. Teagasc's proposals for its development together with future state aid will increase farm output, but the problems of the processing sector are more difficult of solution, and will require to be dealt with at a national and EC level.

Section 4

1.20 The Council will generally refuse permission for new dwellings in areas defined in this Plan as areas of high amenity and in other areas, will not allow buildings in conspicuous colours or of bad design or sited where they would obtrude interactive views, or where inadequate service exists.

Section 5

1.25 The Council will insist on industrial effluent being fully treated to appropriate standards before being discharged.

1.27 The Council recognises that many agricultural buildings are exempt from planning permission. This exemption has resulted in a number of unfortunate developments, giving rise to the spoliation of pleasant views, the creation of nuisance, and the pollution of watercourses.

Wherever such agricultural buildings are not exempt, the Council in granting Planning Permission, will attach appropriate planning conditions to ensure that these buildings are appropriately designed and sited to avoid spoiling a pleasant view or causing pollution or giving rise to a traffic hazard.

Section 8

1.36 To increase the number of tourists visiting the County the Council recognises that it must adopt measures to protect what the tourist comes to see, to prevent spoliation of the countryside, to eliminate pollution and to increase public access to the areas where tourists wish to visit, such as the scenic areas, the forests, the hills and the riverbanks.

Section 9

1.58 The Council is satisfied that it is possible to promote the industrial development of the County without at the same time, degrading the environment or polluting streams and rivers. It will, therefore, utilise its powers to fall under the Water Pollution Act, 1977, to ensure that new industrial activities or expansion of existing ones do not pose any pollution threat to **streams or rivers.** In addition, the Council will utilise its powers to the full to ensure that existing sources of pollution are rapidly eliminated.

In relation to the River Suir, a Water Quality Management Plan has been prepared by An Foras Forbartha and the Council and formally adopted. The recommendations listed in this Plan, are being implemented.

Section 10

1.65 The County possesses large deposits of a hugh quality gravel and considerable resources of anthracite. The Council will grant planning permission for the exploiting of these resources subject to suitable conditions. These conditions will relate to, inter alia, safe access, the rehabilitation of the land following the working out of the deposits, the protection of any archaeological, scientific or historic areas, the giving of security to endure compliance with conditions towards the necessary road improvements and increased maintenance charges arising from the traffic generated by such development.

1.67 The River Suir and its tributaries is a resource of great potential in relation to the establishment of wet industries. The Council will facilitate the exploiting of this resource as and when demand arises, subject to stringent conditions in relation to the siting of such industries, planting and landscaping, pollution control and the protection of those areas of scenic importance referred to in this Development Plan.

PART ONE B

1.69 In amenity areas, uses and structures will not be permitted which conflict with the preservation of the amenity.

The Council will not grant permission for any development that is likely to have injurious effects on places of archaeological, architectural, historical or scientific interest.

1.74 Permission will not be granted if the development proposed is likely to cause pollution or to overload the sewers or sewage treatment plants so as to danger public health.

1.77 a) Areas of High Amenity; Development control policy will consider primarily the effect of any proposed development on the amenity of the area and development will not be permitted which would be injurious to the area or any part of it.

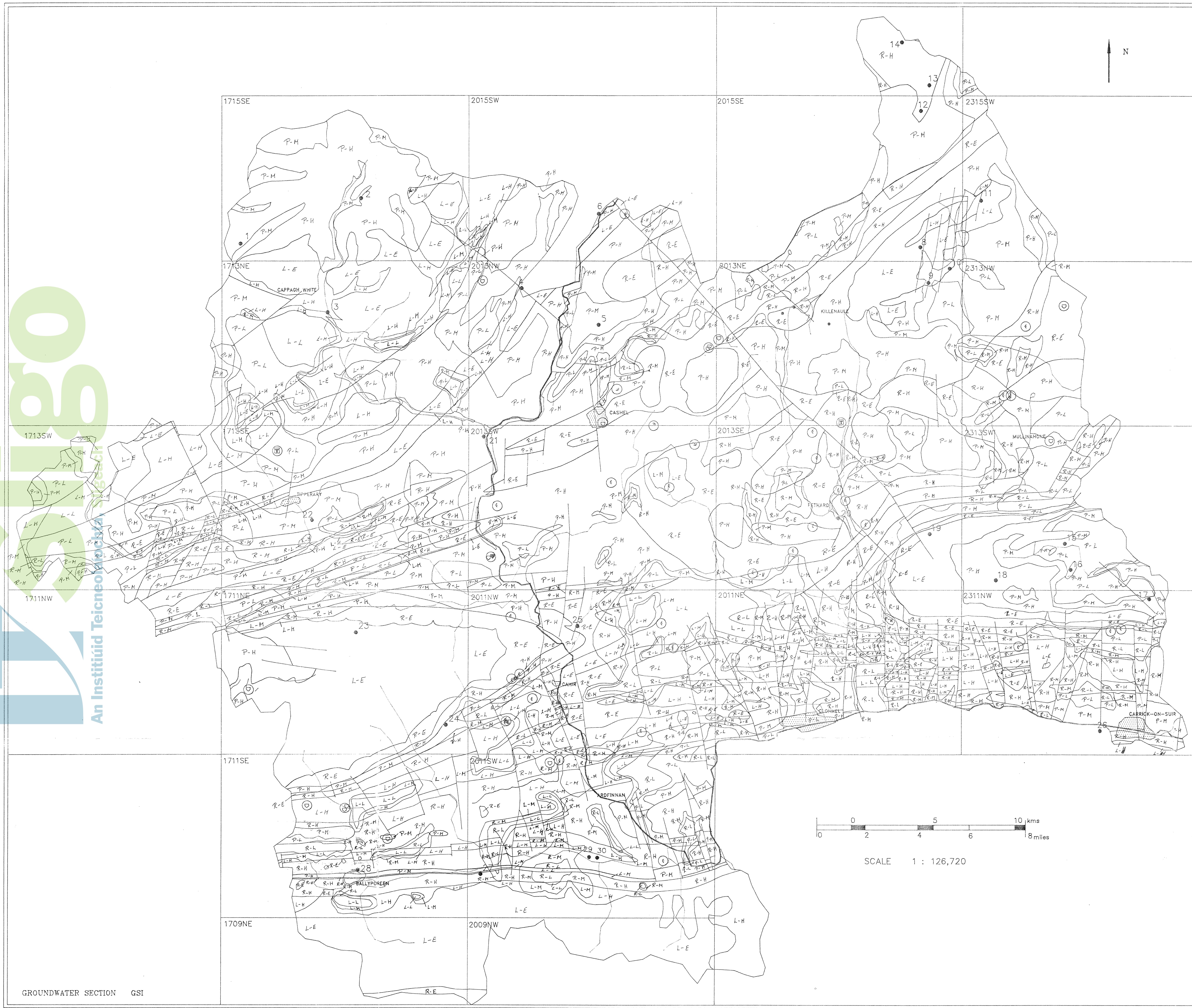
b) Areas of Scenic Importance; In those areas of scenic importance shown on map 3, development may be permitted which will not obtrude on the skyline, materially alter the visual character of the area or any part of it, or hinder the development of its recreational potential.

PART TWO

2.9 The water quality of 24 rivers within the County is monitored annually by taking analysis of 1250 samples at 114 stations. Information gained from each year's results is used to prepare a programme of action for water quality improvement in the subsequent year.

It will be Council policy to prevent new polluting discharges, to eliminate existing illegal discharges, and to ensure that conditions attached to discharge licences are adhered to.

2.11 It will be Council policy to preserve places of archaeological, architectural, historic and scientific interest. It is an objective of this Development Plan to preserve and protect the places listed in Table #'s 10,11,11a, and 12 shown on Map #'s 4 and 4A.



GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY (SOUTH RIDING) IRELAND.

GROUNDWATER PROTECTION

LEGEND

FETHARD — TOWNS

RIVERS

COUNTY BOUNDARY

1 — PUBLIC SUPPLY SOURCES (Groundwater)

KARST FEATURE

1A / 1B — SOURCE PROTECTION AREAS (radii of 300m and 1km)

		VULNERABILITY	EXTREME	HIGH	MODERATE	LOW
	SOURCE	Zone 1A	1A – E	1A – H	1A – M	1A – L
	SOURCE	Zone 1B	1B – E	1B – H	1B – M	1B – L
RESOURCE	REGIONALLY IMPORTANT AQUIFERS		R – E	R – H	R – M	R – L
RESOURCE	LOCALLY IMPORTANT AQUIFERS		L – E	L – H	L – M	L – L
RESOURCE	POOR AQUIFERS		P – E	P – H	P – M	P – L

WARNING: THIS IS AN INTERPRETED MAP AND IS NOT SITE SPECIFIC

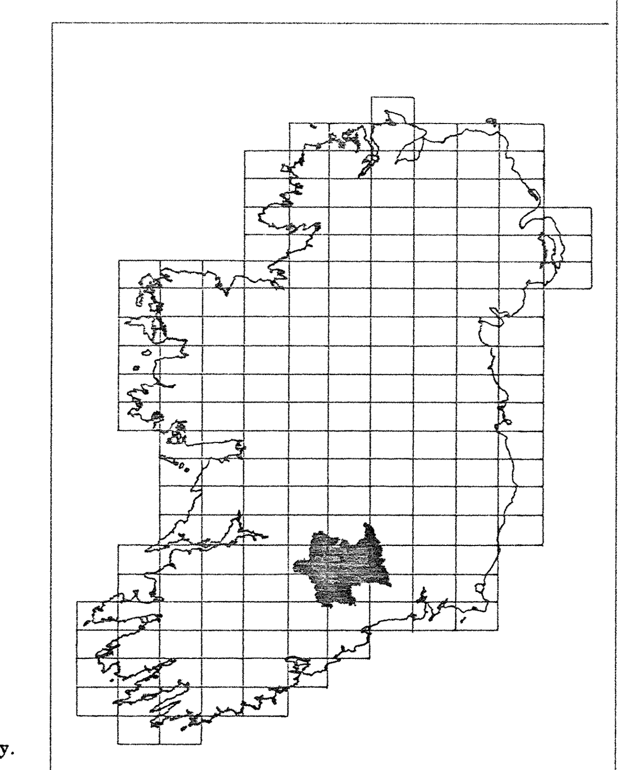
Sources of Information

1 : 126,720 Ordnance Survey Map

Map 6. Aquifers

Map 8. Vulnerability

Source Protection Areas



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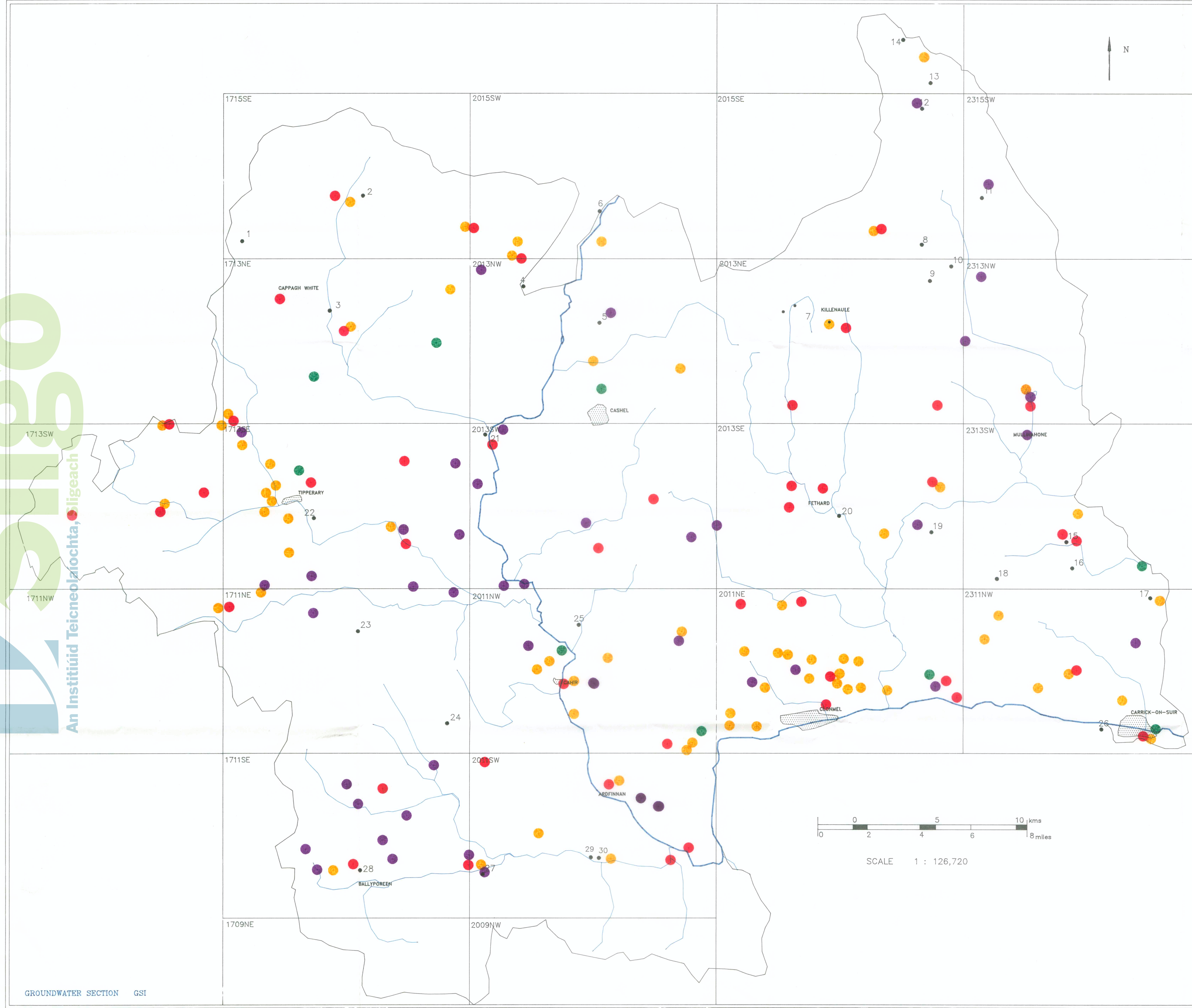


GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY (SOUTH RIDING) IRELAND.

POTENTIAL POLLUTION THREATS TO GROUNDWATER

LEGEND

FETHARD	TOWNS
	RIVERS
	COUNTY BOUNDARY
• 1	PUBLIC SUPPLY SOURCES (Groundwater)
●	WASTE DISPOSAL SITES
●	BURIAL GROUNDS
●	INTENSIVE ANIMAL REARING UNITS
●	CONCENTRATION OF SEPTIC TANKS

0 5 10 kms
0 2 4 6 8 miles

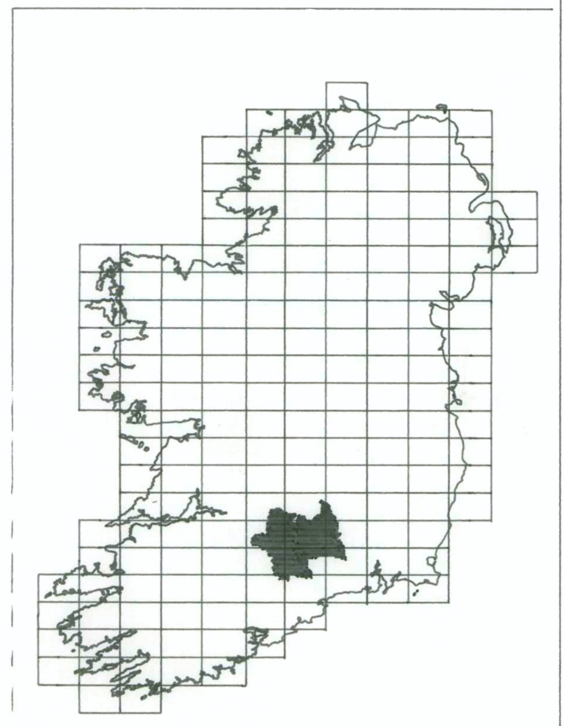
SCALE 1 : 126,720

Sources of Information

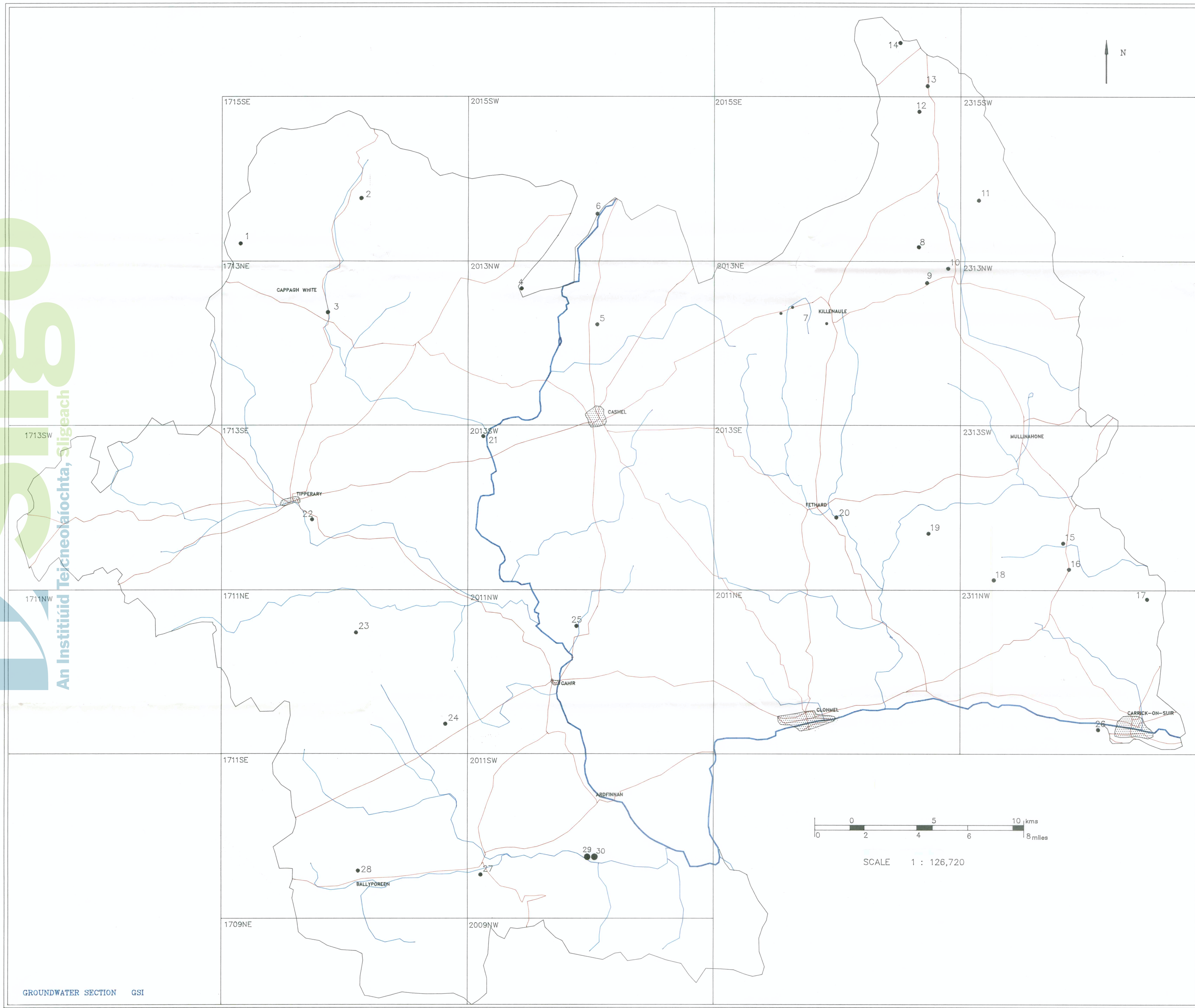
1 : 126,720 Ordnance Survey Map

Environment Section,
Tipperary SR County Council

Compiled and digitised by Margaret Keegan, GSI/SLIGO RTC for Tipperary South Riding County Council under the supervision of Mr. Eugene Daly, Dr. Richard Thorn and Mr. Donal Daly.



MAP NUMBER 1



GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY

(SOUTH RIDING) IRELAND.

LOCATIONAL MAP

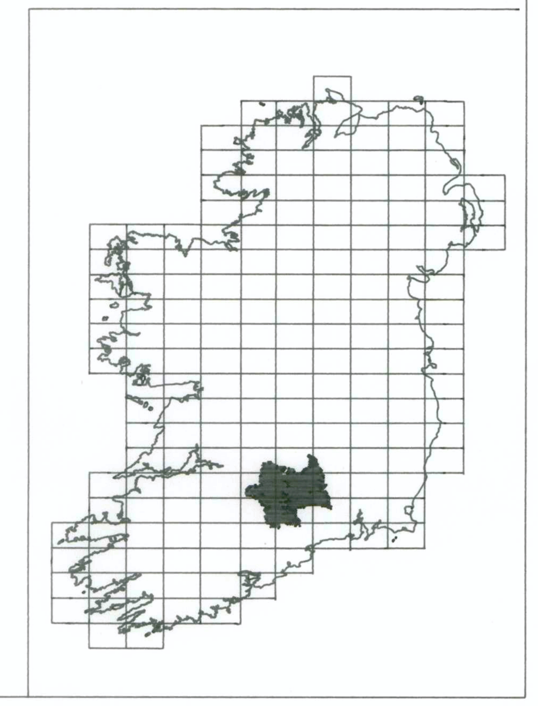
LEGEND

FETHARD	TOWNS
	RIVERS
	COUNTY BOUNDARY
● 1	PUBLIC SUPPLY SOURCES (Groundwater)
	MAIN ROADS

● 1	GLENGAR	● 16	BALLINVIR
● 2	HOLLYFORD	● 17	AHENNY
● 3	IRONMILLS	● 18	TULLOHEA
● 4	GOOLDS' CROSS	● 19	CLORAN
● 5	SYNONE	● 20	MULLENBAWN
● 6	HOLYCROSS	● 21	SPRINGMOUNT
● 7	LAFFANSBRIDGE	● 22	FAWNAGOWAN
● 8	COALBROOK	● 23	ROSSIDREHID
● 9	BALLINCURRY	● 24	KILCORAN
● 10	GORTEEN	● 25	KEDRAH
● 11	COMMONS	● 26	COOLNAMUCK
● 12	RATHBEG	● 27	CLOGHEEN
● 13	TRIANDRA	● 28	BALLYPOREEN
● 14	INCHIROURKE	● 29	POULATAR
● 15	GRANGEMOCKLER	● 30	POULALEE

Sources of Information

1 : 126,720 Ordnance Survey Map



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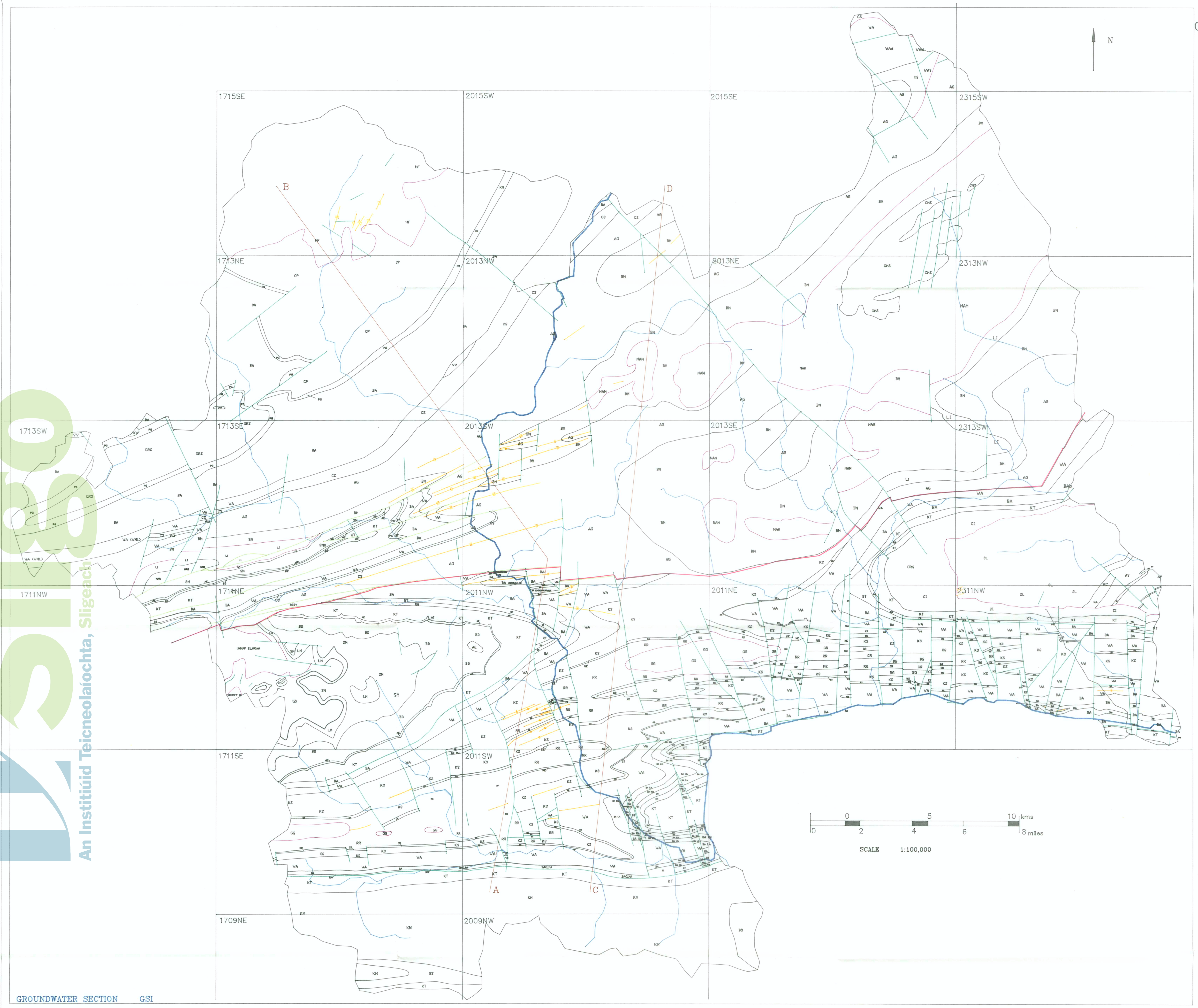
GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY (SOUTH RIDING) IRELAND

BEDROCK GEOLOGY



LEGEND

CLONMEL — TOWNS

RIVERS

COUNTY BOUNDARY

ARBITARY NORTH–SOUTH DIVIDE

STRATIGRAPHIC COLUMN

290 Mya

CARBONIFEROUS	NORTHERN REGION	SOUTHERN SYNCLINES
UPPER	Coal Measures CMS ? m	
UPPER	Namurian NAM ? m	Giant's Grave Formation GG ? m
unconformity		
BRIGANTIAN	Lismalin Formation LI ? m	
ASBIAN	Ballyadams Formation BM c. 90–300 m	Croane Formation CR 300m
ASBIAN		Rathronan Formation RR 300m / Ballyglasheen Formation BG 300m
ASBIAN		Kilee Formation KE 100 m
HOLKERIAN		
ARUNDIAN	Aghmacart Formation AG 140m	Kilsheelan Formation KS 600 m
CHADIAN	Crosspatrick Formation CS 70 m	Silverspring Formation SS 10–100m
	Waulsortian Mudbank Complex WA	Waulsortian Mudbank Complex WA 400m
COURCEYAN	Ballysteen Formation BA 200 m	Ballysteen Formation BA 500 m
COURCEYAN	Ballymartin Formation BT 50 m	
COURCEYAN	Porter's Gate Formation PG 50 m	Ringmoylan Formation RM 10 m

345 Mya

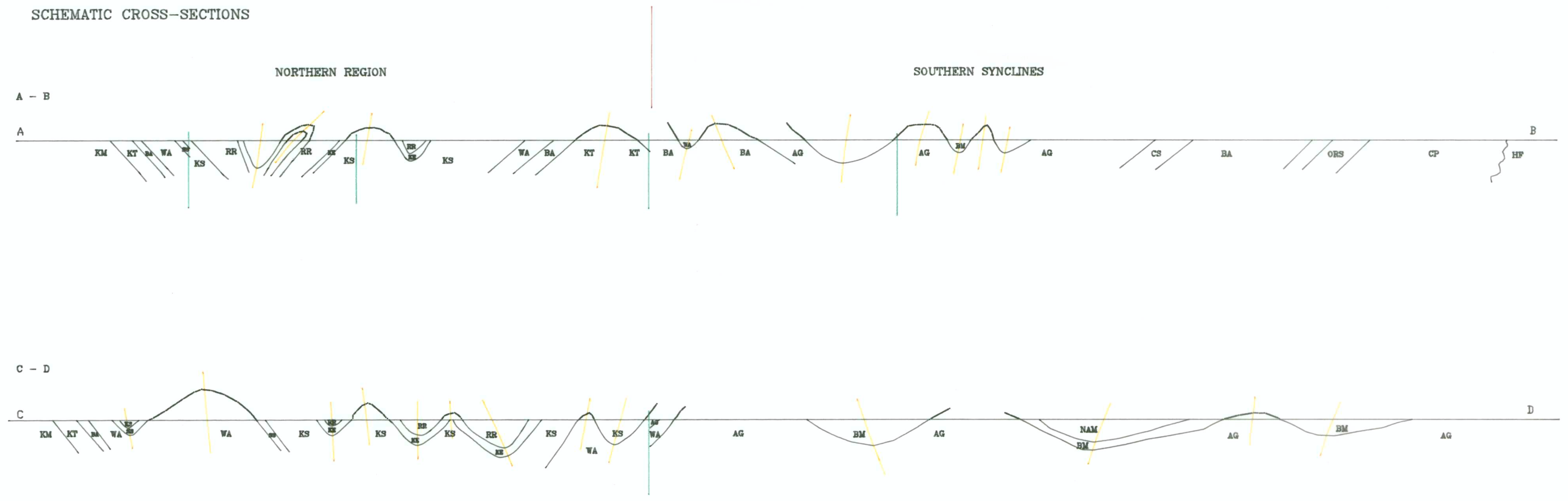
NORTH — SOUTH

DEVONIAN / SILURIAN	SLIEVE PHELIM	GALTEES	SLIEVENAMON	KNOCKMEALDOWNS
UPPER		Kiltorcan Formation KT 300m	Kiltorcan Formation KT 300m	Kiltorcan Formation KT 300m
MIDDLE	Cappagh White Formation CP 300m	Ardane Formation AE 70m; Ballydavid Formation BD 470m	Carrigmaclea Formation CI 460m	Knockmealdown Formation KM ....m
LOWER		Slievenamuck Formation SM 600m; Lough Muskry Formation LM 328m; Galtymore Formation GS 200m		Ballytarsna Formation BS ....m
395 Mya unconformity				
PREDOLI			South Lodge Formation SL > 3000m	
LUDLOW	Hollyford Formation HF > 1000m	Ballygeana Formation BG 1275m		
WENLOCK			Rathclarish Formation RC 340m; Ahenny Formation AY >1075m	
LLANDOVERY				

435 Mya

VOLCANICS

SCHEMATIC CROSS–SECTIONS



STRUCTURAL FEATURES

GEOLOGICAL BOUNDARY

UNCONFORMITY

FAULT

THRUST

FOLD AXIS (ANTICLINE AND SYNCLINE)

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SOURCES OF INFORMATION

GEOLOGICAL SURVEY OF IRELAND

Contract Mapping / PhD Theses – Doran, J.P (1970), Colthurst, J.R.J (1973), Keeley, M (1980), Carruthers, R.A (1985), Shearley, E (1988).

1:25,000 Published Sheets – 2009 NE, 2011 NE, 2011 SW, 2311 NW, 2313 SW

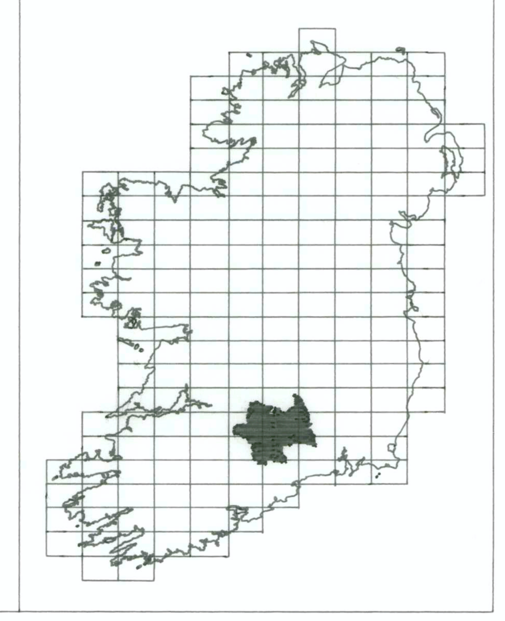
Original Geological Field Sheets

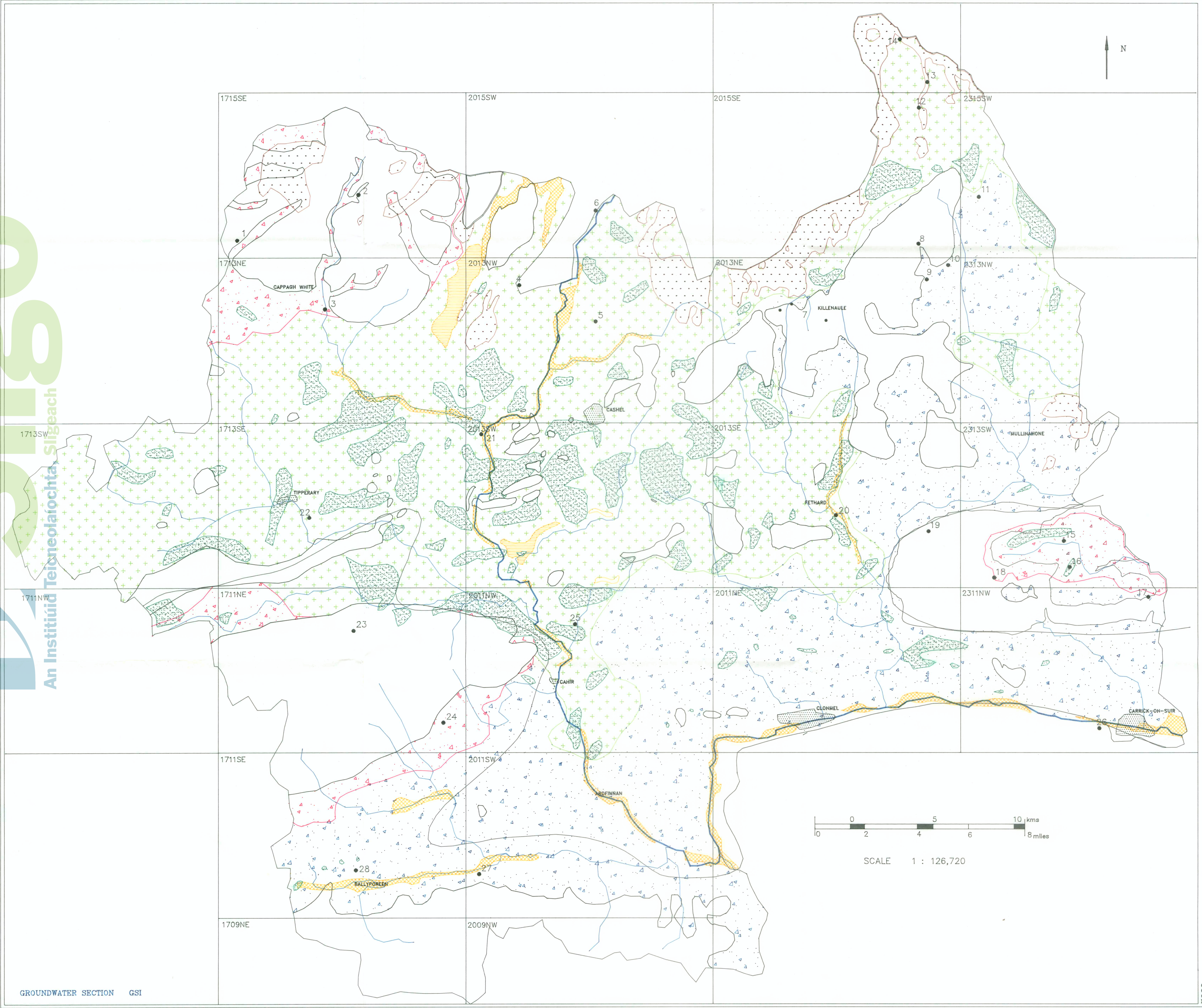
Internal Reports by Howes, M (1990), Daly, E.P (1986), Jones, G. Ll (1977)

Mineral Resources Division, Prospecting Licencing Reports

OTHERS

Hitzman, M. W. (1993) Bedrock Geology Map of the Carboniferous of Central Ireland (1:100,000 scale, O.S. Sheets 12,13,15,16,18 and 19)
GEOLOGICAL SURVEY OF IRELAND





GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY (SOUTH RIDING) IRELAND.

SUBSOIL GEOLOGY

LEGEND

- FETHARD — TOWNS
- RIVERS
- COUNTY BOUNDARY
- ● 1 — PUBLIC SUPPLY SOURCES (Groundwater)
- PEAT
- MARL
- ALLUVIUM
- PREDOMINANTLY LIMESTONE GRAVEL
- TILL WITH GRAVEL
- PREDOMINANTLY OLD RED SANDSTONE TILL
- PREDOMINANTLY LIMESTONE TILL
- ROCK CLOSE TO SURFACE
- SOUTHERN IRELAND ICE LIMIT (FINCH, SYNGE)

WARNING: THIS IS AN INTERPRETED MAP AND IS NOT SITE SPECIFIC

Sources of Information

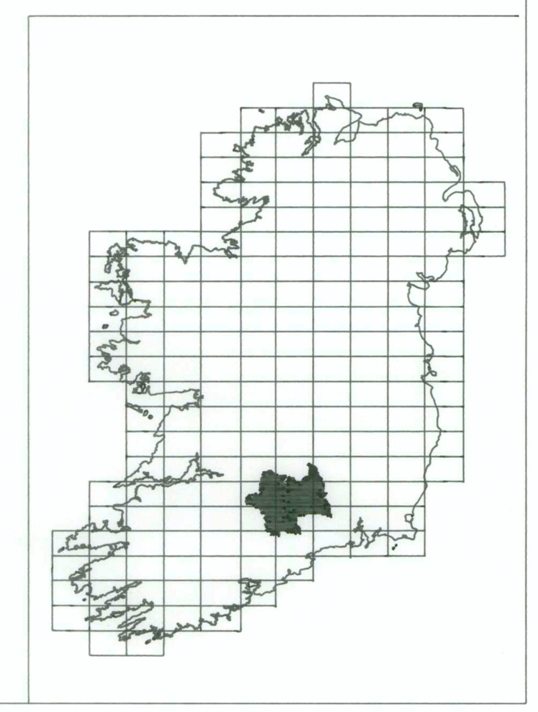
1 : 126,720 Ordnance Survey Map

1 : 10,560 GSI Geology Maps including subsoil descriptions.

1 : 63,360 GSI Geology Maps indicating areas of no "drift" cover.

Gas Pipeline Sections

Borehole and Well logs (GSI and Mineral Exploration data)



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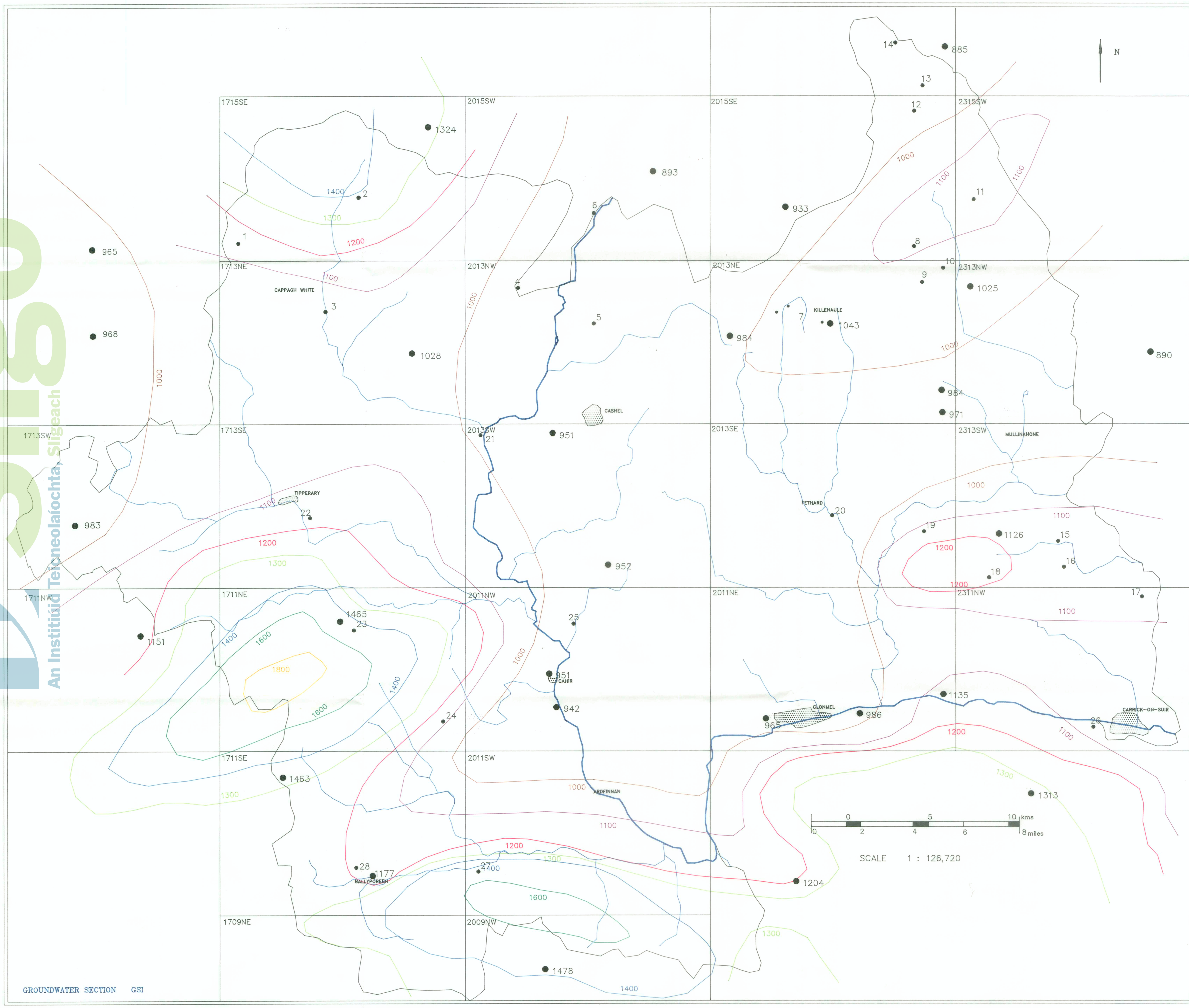
MAP NUMBER 4

GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY

(SOUTH RIDING) IRELAND.



MEAN ANNUAL RAINFALL DATA MAP (1951 – 1980)

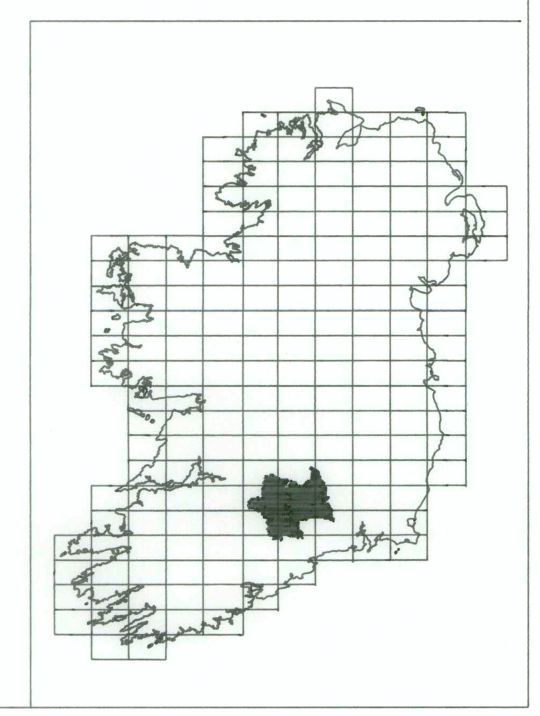
LEGEND

- FETHARD — TOWNS
- RIVERS
- COUNTY BOUNDARY
- • 1 — PUBLIC SUPPLY SOURCES (Groundwater)
- ● 890 — RAIN GAUGE STATION (value in mm)
- 1000 mm CONTOUR
- 1100 mm CONTOUR
- 1200 mm CONTOUR
- 1300 mm CONTOUR
- 1400 mm CONTOUR
- 1600 mm CONTOUR
- 1800 mm CONTOUR

Sources of Information

1 : 126,720 Ordnance Survey Map

Meterological Service, Glasnevin



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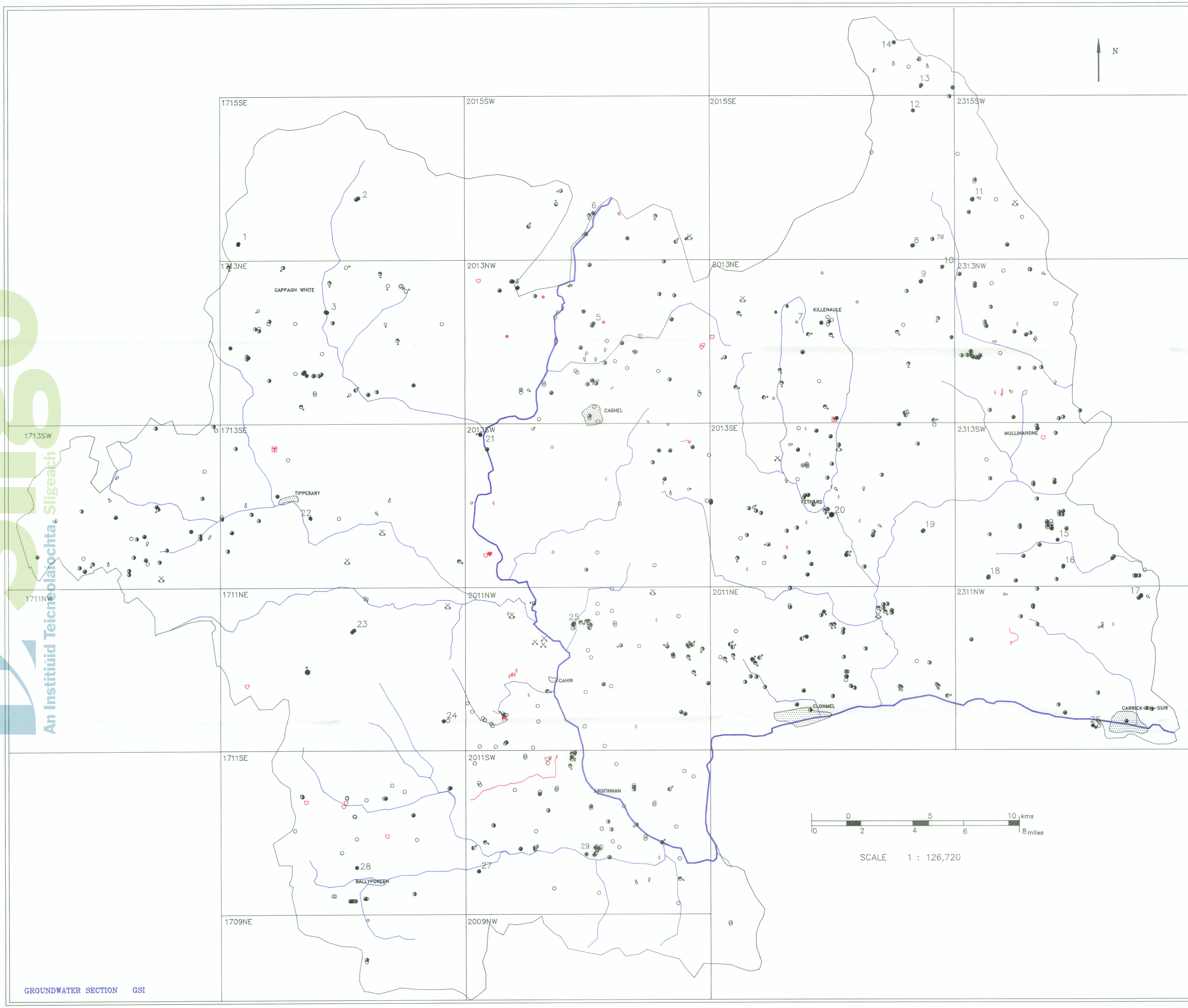
GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY (SOUTH RIDING) IRELAND.



HYDROGEOLOGICAL FEATURES

LEGEND

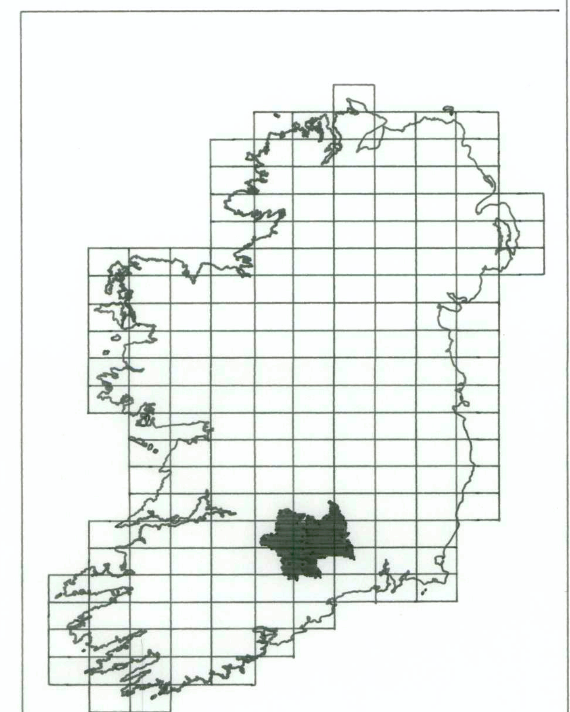
FETHARD	TOWNS
	RIVERS
	COUNTY BOUNDARY
1	PUBLIC SUPPLY SOURCES (Groundwater)
	Springs (Less Important, Important, More Important)
	Wells [failed (0 m3/d), poor (< 43.6 m3/d), reasonable (43.6–109 m3/d), good (109–436 m3/d), execellent (> 436 m3/d)]
	Swallow Holes
	Turlough
	Losing Streams
	Caves
	Quarry (used and disused)

Sources of Information

1 : 126,720 Ordnance Survey Map

1 : 10,560 GSI Geology Sheets

Groundwater Section Well Database



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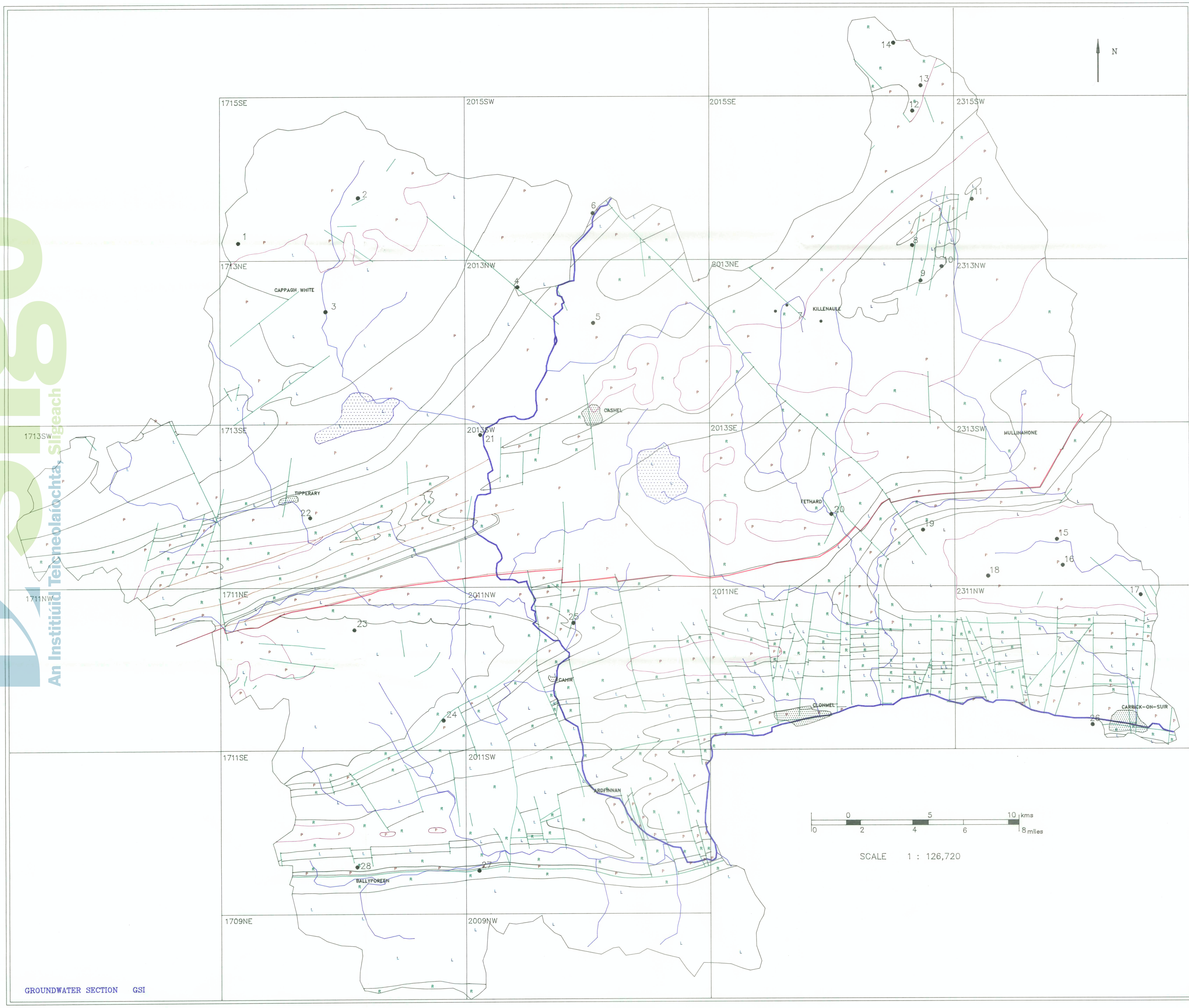
MAP NUMBER 6

GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY (SOUTH RIDING) IRELAND.

AQUIFERS



LEGEND

FETHARD — TOWNS

RIVERS

COUNTY BOUNDARY

● 1 — PUBLIC SUPPLY SOURCES (Groundwater)

REGIONALLY IMPORTANT AQUIFER

LOCALLY IMPORTANT AQUIFER

LOCALLY IMPORTANT AQUIFER (INTERGRANULAR)

POOR AQUIFER / AQUITARD

FAULT

THRUST

UNCONFORMITY

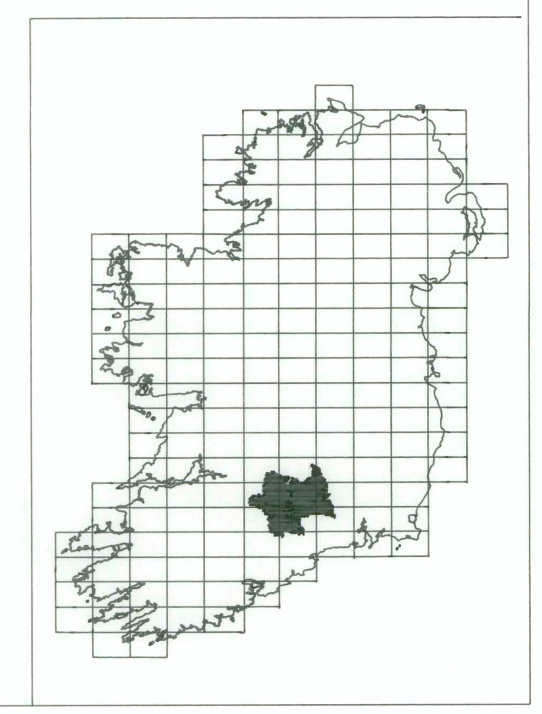
ARBITARY NORTH SOUTH DIVIDE

Sources of Information

1 : 126,720 Ordnance Survey Map

E P DALY (1992)

G WRIGHT (1979)



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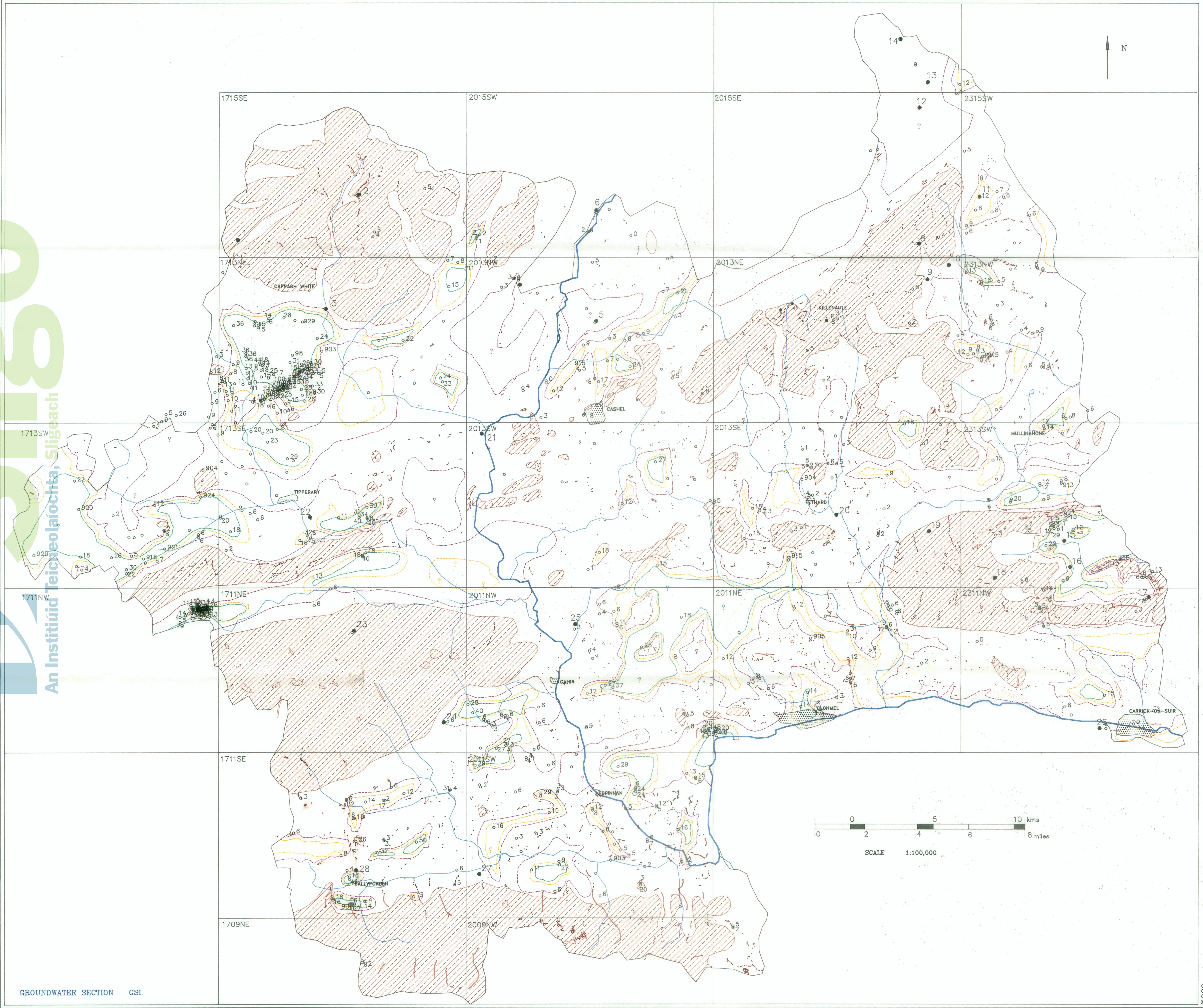
MAP NUMBER 7

GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY (SOUTH RIDING) IRELAND.

DEPTH TO BEDROCK



LEGEND

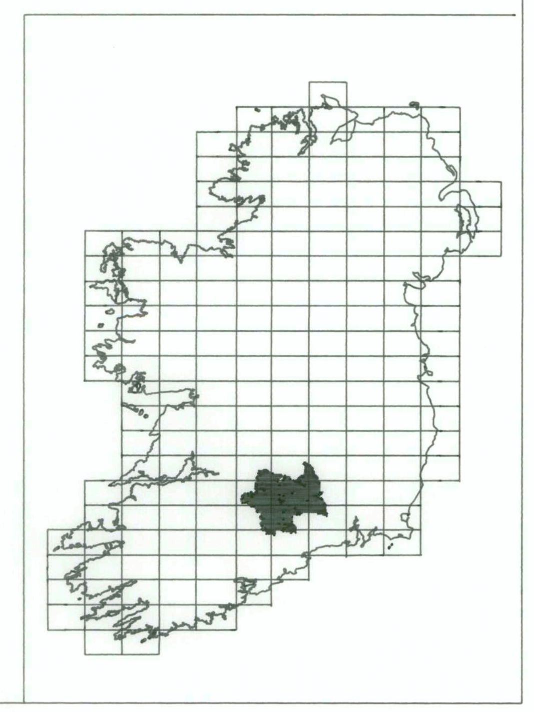
FETHARD	TOWNS
	RIVERS
	COUNTY BOUNDARY
● 1	PUBLIC SUPPLY SOURCES (Groundwater)
	Inferred 5 m (approximate) Contour
	Inferred 10 m (approximate) Contour
	Inferred 15 m (approximate) Contour
	Rock Close to Surface (< 1 m)
○ 12	Depth to Bedrock Value (m)
	Outcrop

WARNING: THIS IS AN INTERPRETED MAP AND IS NOT SITE SPECIFIC

Sources of Information

1 : 126,720 Ordnance Survey Map

GSI Dataflex Database – Borehole and Well Records



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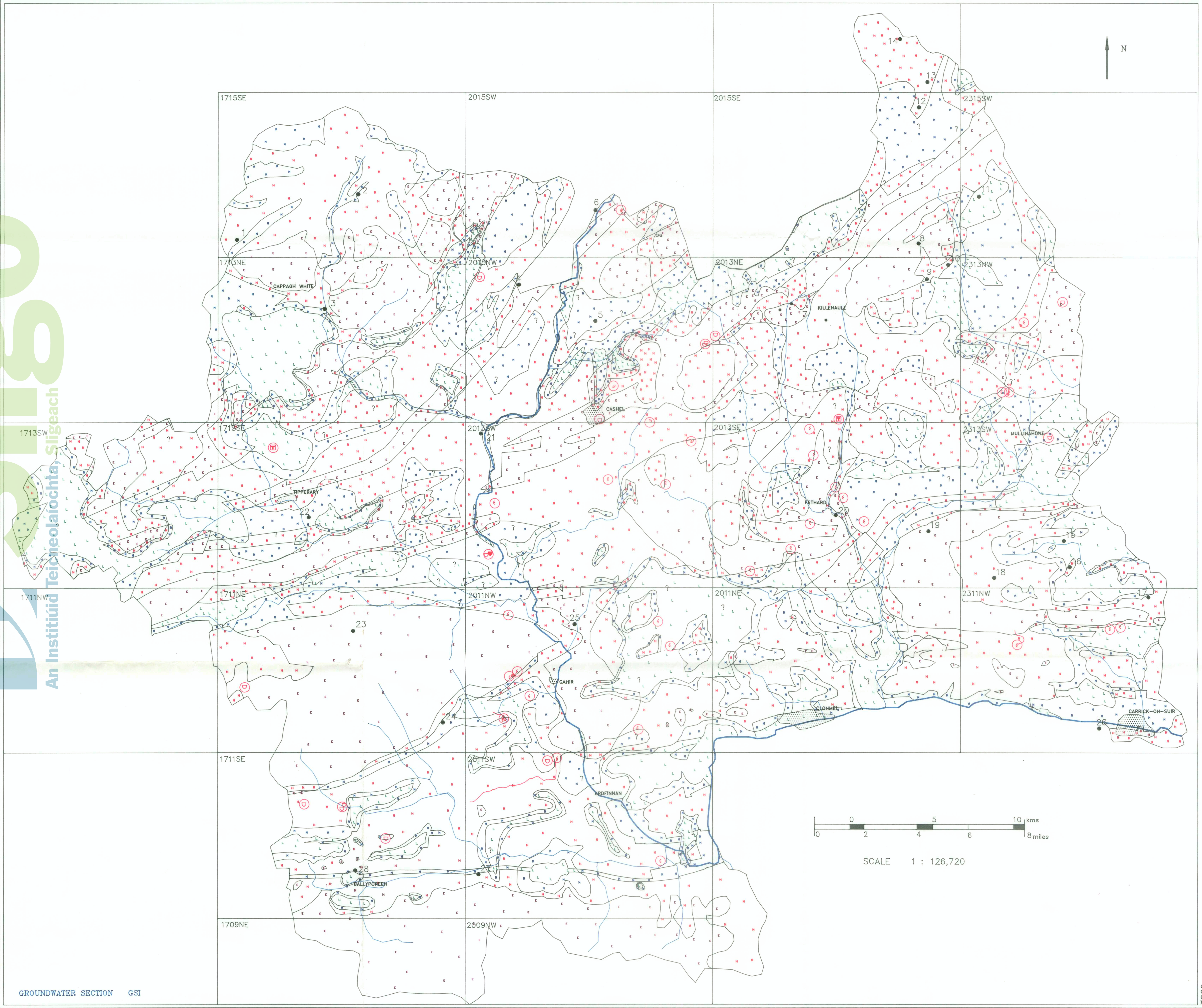
MAP NUMBER 8

GROUNDWATER VULNERABILITY AND PROTECTION IN COUNTY TIPPERARY (SOUTH RIDING) IRELAND.

VULNERABILITY



LEGEND

FETHARD TOWNS

RIVERS

COUNTY BOUNDARY

PUBLIC SUPPLY SOURCES (Groundwater)

EXTREME

HIGH

MODERATE

LOW

KARST FEATURE

INFERRED BOUNDARY

WARNING: THIS IS AN INTERPRETED MAP AND IS NOT SITE SPECIFIC

Sources of Information

1 : 126,720 Ordnance Survey Map

Map 3. Subsoils

Map 4. Depth to Bedrock

Map 5. Aquifer

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