Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Mountmellick Water Supply Scheme

Derrygile Borehole

April 2010

Prepared by:
Coran Kelly TOBIN

With contributions from:
Dr. Robert Meehan, Consultant Geologist; Jenny Deakin TCD

And with assistance from:
Laois County Council

Geological Survey of Ireland
Suirbhéireacht Gheolaíochta Éireann

PROJECT DESCRIPTION

Since the 1980's, the Geological Survey of Ireland (GSI) has undertaken a considerable amount of work developing Groundwater Protection Schemes throughout the country. Groundwater Source Protection Zones are the surface and subsurface areas surrounding a groundwater source, *i.e.* a well, wellfield or spring, in which water and contaminants may enter groundwater and move towards the source. Knowledge of where the water is coming from is critical when trying to interpret water quality data at the groundwater source. The Source Protection Zone also provides an area in which to focus further investigation and is an area where protective measures can be introduced to maintain or improve the quality of groundwater.

The project "Establishment of Groundwater Source Protection Zones", led by the Environmental Protection Agency (EPA), represents a continuation of the GSI's work. A CDM/TOBIN/OCM project team has been retained by the EPA to establish Groundwater Source Protection Zones at monitoring points in the EPA's National Groundwater Quality Network.

A suite of maps and digital GIS layers accompany this report and the reports and maps are hosted on the EPA and GSI websites (www.epa.ie; www.gsi.ie).

TABLE OF CONTENTS

FIGURES and TABLES

1 Introduction

Groundwater Source Protection Zones are delineated for the Mountmellick Water Supply Scheme (Derrygile Borehole) according to the principles and methodologies set out in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999) and in the GSI/EPA/IGI Training course on Groundwater Source Protection Zone Delineation.

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the area surrounding the source.
- To delineate source protection zones for the borehole.
- To assist the Environmental Protection Agency and Laois County Council in protecting the water supply from contamination.

Groundwater protection zones are delineated to help prioritise the area around the source in terms of pollution risk to groundwater. This prioritisation is intended as a guide in evaluating the likely suitability of an area for a proposed activity prior to site investigations. The delineation and use of groundwater protection zones is further outlined in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

The maps produced are based largely on the readily available information in the area, a field walkover, test pumping, water levels and on mapping techniques which use inferences and judgements based on experience at other sites. As such, the maps cannot claim to be definitively accurate across the whole area covered, and should not be used as the sole basis for site-specific decisions, which will usually require the collection of additional site-specific data.

2 Methodology

Site visits (including interviews on 8th July 2010 with caretaker), site walk-overs, test pumping on 23rd September 2010, field mapping (including mapping of drainage indicators and logging of bedrock outcrops and subsoil exposures), and ordnance levelling of the borehole (August 2010) were conducted.

3 Location, site description and well head protection

The Derrygile Borehole is located 2 km south of Mountmellick, in the townland of Derrygile, as shown in Figure 1 and Figure 2. The borehole is contained within a concrete chamber adjacent to the road, which can be seen in Photographs 1–4. The borehole is finished below ground level. There is a pumphouse alongside the concrete borehole chamber. The water is pumped to a reservoir at Wood Hill which is mixed with surface water and distributed through the network. The borehole annulus is not grouted, though the concrete base of the chamber is set against the outer casing. The site is not fenced off. The concrete lip around the chamber is above road level and it reportedly does not flood along the road.

4 Summary of borehole details

Details on the borehole are sparse and are based on interviews with the caretaker and the County Laois Groundwater Protection Scheme (Deakin *et al*., 2000). The borehole is 46 m deep, comprising an 8" PVC liner asymmetrically installed inside 10" steel casing. Details are given in Table 4-1.

Table 4-1 Summary details of Derrygile Borehole

	Derrygile (Mountmellick WS)
EU Reporting Code	IE_SE_G_107_11_009
GSI Code	2319NEW151
Grid reference	E245145 N205809
Townland	Derrygile
Source type	Borehole
Owner	Laois County Council
Elevation of the top of casing	78.87 m OD (Surveyed by Tobin)
Top of casing below ground level	1.06 m
Ground level at borehole	79.93 m OD
Borehole Depth	46 m (Laois GWPS)
Construction	8inch PVC liner asymmetrically installed inside 10 inch steel casing
Depth to rock	14 m
Static water level (below top of casing)	0.54 m on 23rd September 2010
Pumping water level (below top of casing)	17.35 m on 23rd September 2010 18.17 m on 8th July 2010
Yield (GSI records)	545 m^3/day
Current abstraction rate (Co Co records)	14.55 m^3/hour / 350 m^3/day (2010)
Specific Capacity	18–20 m^3/d/m




Photographs 1-4 of Chamber, Borehole and Pumphouse at Derrygile

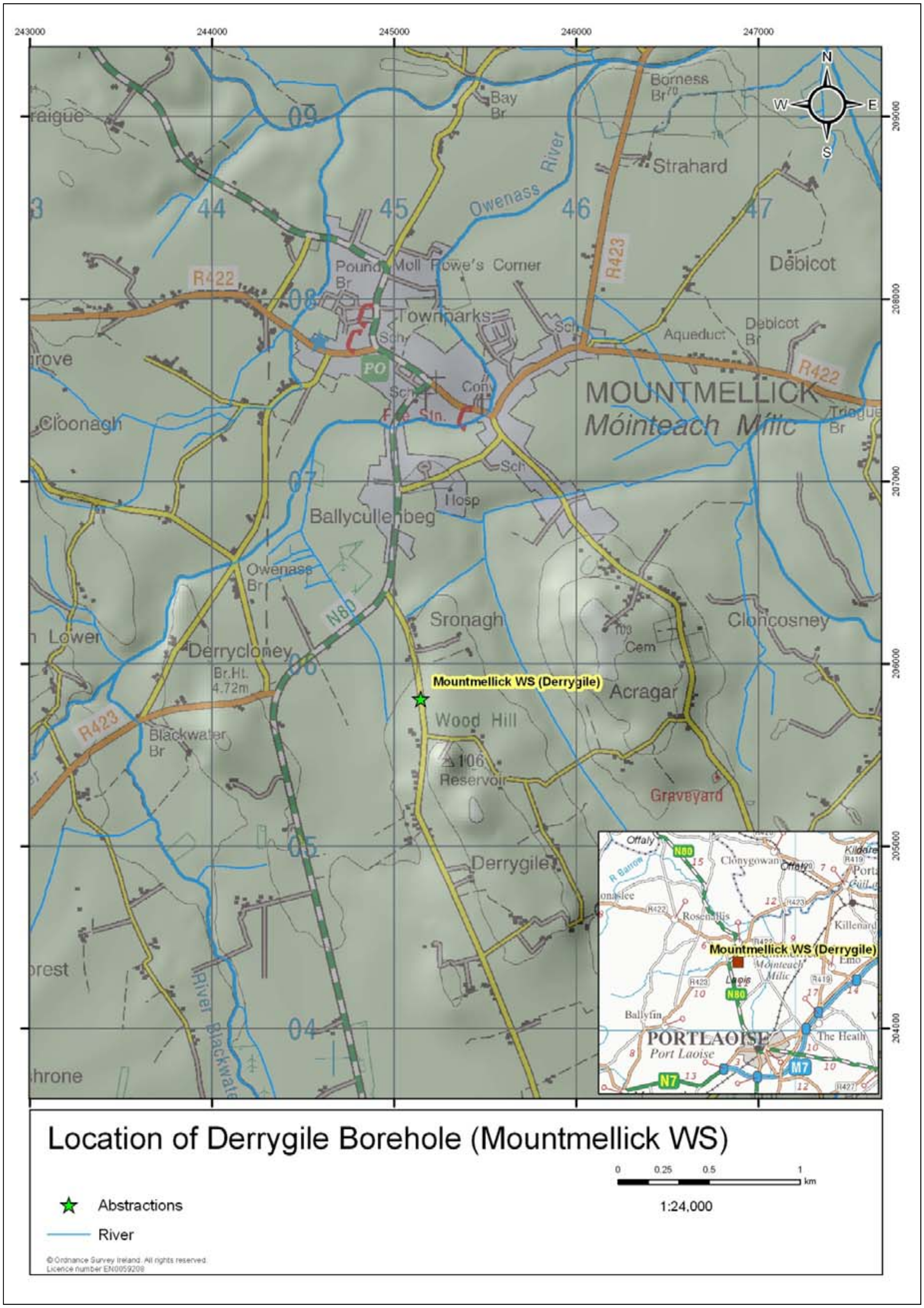

Figure 1 Location of Derrygile Borehole

Figure 2 Aerial View of Site around Derrgile, showing land use

5 Topography, surface hydrology and landuse

The regional topography around Derrgile and Mountmellick is relatively flat, gently sloping to the north and east, set at approximately 70–80 m OD. The exceptions to this are three elongated ridges, orientated southeast-northwest, located at Wood Hill to the southeast of the source, at Acragar to the east, and 1 km west of Wood Hill, adjacent to the Blackwater River (Figure 1). The ridges are approximately 1.5 km by 800 m, with the first two having an amplitude of approximately 20 m, and the westernmost one near the river being much lower, approximately 10 m high. Derrygile borehole is located close to the base of the northerly facing slope of Wood Hill (Figure 1) on which the topographic slope is approximately 7%.The regional topographic slope is approximately 0.6%.

Springs originate at the base of the two higher ridges of Wood Hill and Acragar, and are seen on the OSI six inch sheets discharging to unnamed streams flowing generally southeast-northwest before, joining the Blackwater, shown on Figure 4. The Blackwater then joins the Owenass, which in turn joins the Triogue, ultimately meeting the River Barrow, north of Mountmellick (inset in Figure 1). Numerous drainage ditches occur on the flat areas around the source. The fields on the slopes of Wood Hill are free draining.

Landuse in the vicinity of the borehole comprises pasture as shown in Figure 2. There are several houses with individual on-site wastewater treatment systems, as well as several farm yards and a garden centre along the road up to Wood Hill.

6 Hydro-meteorology

Establishing groundwater source protection zones requires an understanding of general meteorological patterns across the area of interest. The data source is Met Eiréann.

Annual rainfall: 900 mm. The contoured data map of rainfall in Ireland (Met Éireann; 1961–1990 dataset) shows that the source is located between the 800–1000 mm annual rainfall isohyets, and 900 mm is taken for the purposes of this report.

Annual evapotranspiration losses: 428 mm. Potential evapotranspiration (P.E.) is estimated to be 450 mm/yr (based on data from Met Éireann). Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits giving an Actual Evapotranspiration of 428 mm.

Annual Effective Rainfall: 472 mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore, 472 mm/year. See also Section 8.6 on Recharge which estimates the proportion of effective rainfall that enters the aquifer.

7 Geology

This section briefly describes the relevant characteristics of the geological materials that underlie the Derrygile Borehole. It provides a framework for the assessment of groundwater flow and source protection zones. The geological information is based on:

- the bedrock geological map of Galway and Offaly, Sheet 15, 1:100,000 Series (Geological Survey of Ireland and accompanying memoir (Gatley *et al.*, 2003),
- the GSI Well, Borehole and Karst Databases,
- EPA Soils and Subsoils Maps (Teagasc, 2006a and 2006b), and on,
- bedrock outcrops and subsoil exposures encountered and mapped during site visits.

7.1 Bedrock

The Ballysteen Limestones (Dinantian Lower Impure Limestones) occupy the area beneath the source and are generally described as dark muddy limestones (Figure 3). A major northeast-southwest trending fault crosses 650 m south of the borehole. There are few outcrops, thus the mapped fault trace is an inferred boundary and may lie closer to the borehole. A major fracture zone feeds the borehole at depth.

7.2 Soils and subsoils

'Wet' Soils (cutover peat, alluvium and poorly drained mineral soils) occupy the lowest areas of the landscape, including the lower fringes of the elevated ridges, whilst 'Dry' soils (deep, well drained mineral soils and shallow mineral soils) occupy the elevated areas (Figure 4). Alluvium is mapped along the stream course northwest of the borehole, along the Owenass River.

The subsoils principally comprise cutover peat and till derived from limestones (TLs). The cutover peat occupies the lowest areas and the till occupies the elevated ridges as shown in Figure 5.

On the Acragar ridge to the east of the borehole, bedrock outcrop and rock close to the surface are mapped along the northern flank. A small area of sand and gravel is mapped 1.6 km southeast of the source. Depth to rock at the Derrygile Borehole is recorded to be 14 m, and on the neighbouring ridge, "rock close to surface / at surface" is mapped (Teagasc, 2006). It is assumed that Wood Hill is similarly rock cored and that the subsoil thickness decreases toward the top of the hill.

8 Groundwater vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. In this area where the target is in the bedrock, this means that vulnerability relates to the permeability and thickness of the subsoil. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DELG/EPA/GSI, 1999) and in the draft GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination (Fitzsimons *et al.*, 2003).

A groundwater vulnerability map for the area has been prepared for County Laois by the GSI and in the vicinity of Derrygile, the groundwater vulnerability is mapped predominantly as '**High**', with areas of '**Moderate**' and '**Low**' vulnerability further south, shown in Figure 6. This was based on assumption that the depth to bedrock is less than 10 m in the area and that the subsoil permeability is '**moderate**'. However, the depth to bedrock is 14 m at the borehole, and subsoil permeability in the area is considered to be '**Moderate'** based on the assessments completed for the Laois Groundwater Protection Scheme. As well as this, the slopes in the area are free draining, with large fields. Therefore at the source, the groundwater vulnerability is classed as '**Moderate**'. Following from this, an amendment to the vulnerability map for the area is proposed which is shown in Figure 7.

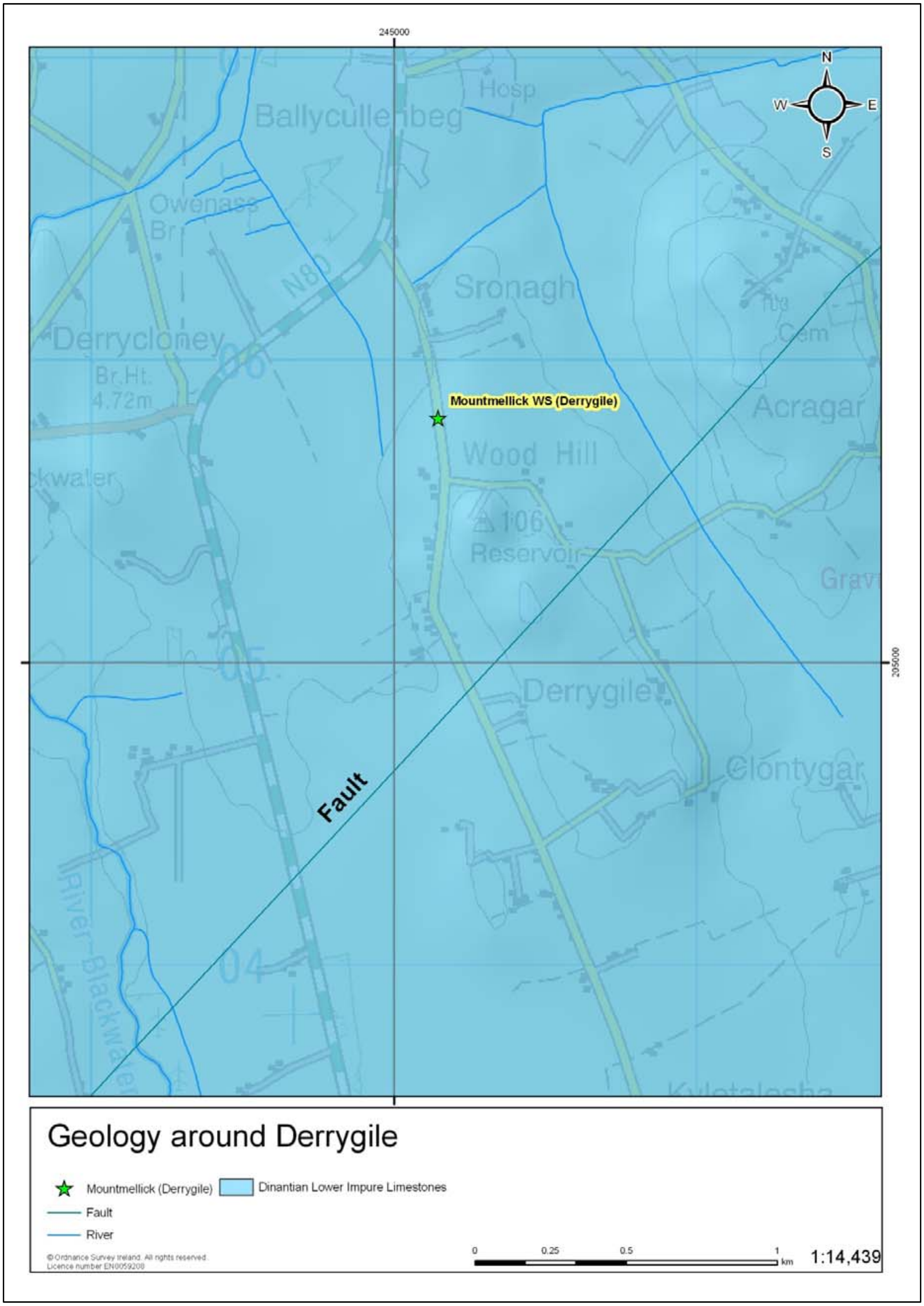

Figure 3 Geology in the vicinity of Derrygile (mapped fault trace, may be closer to the borehole)

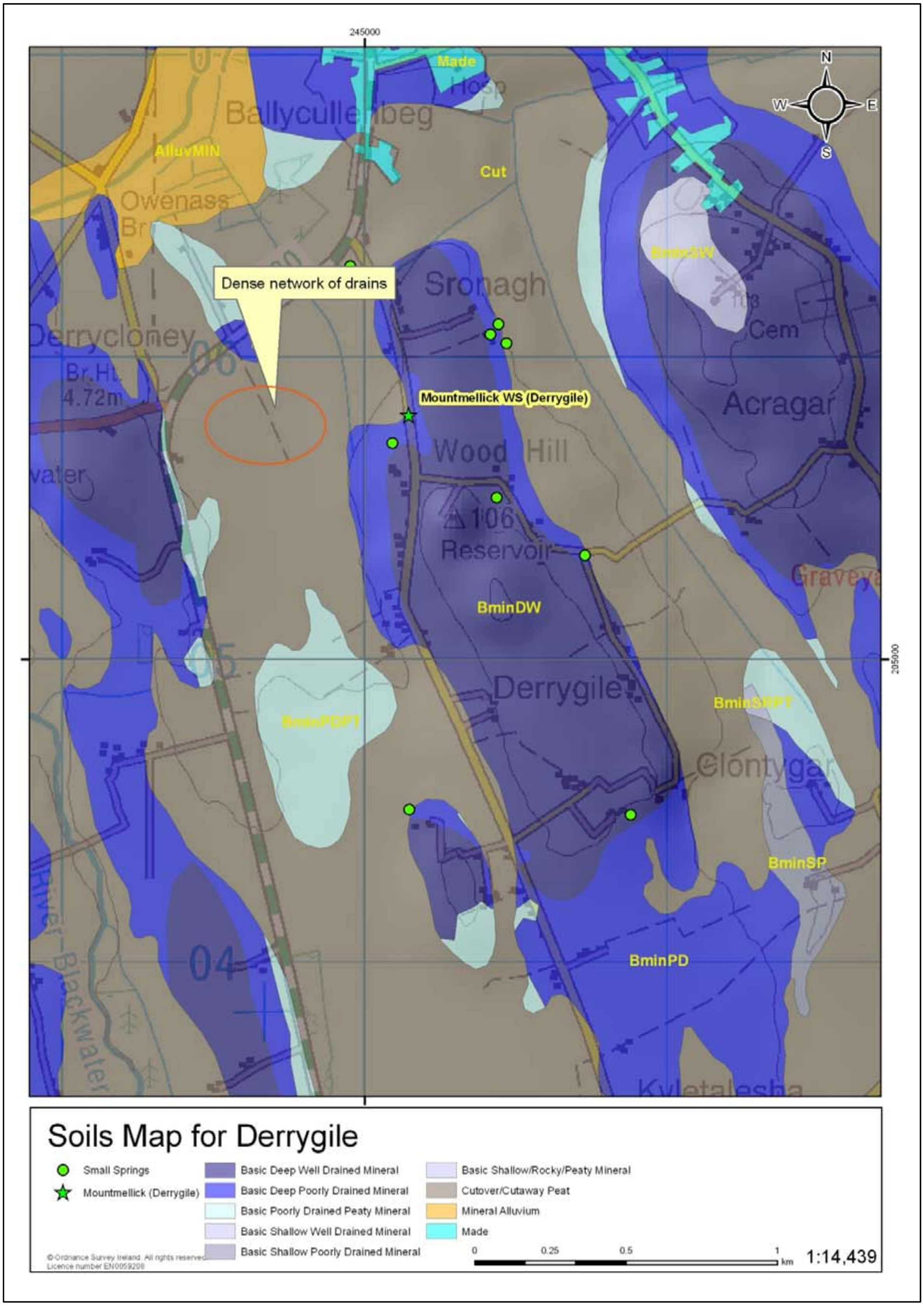

Figure 4 Soils in the vicinity of Derrygile (Teagasc 2006)

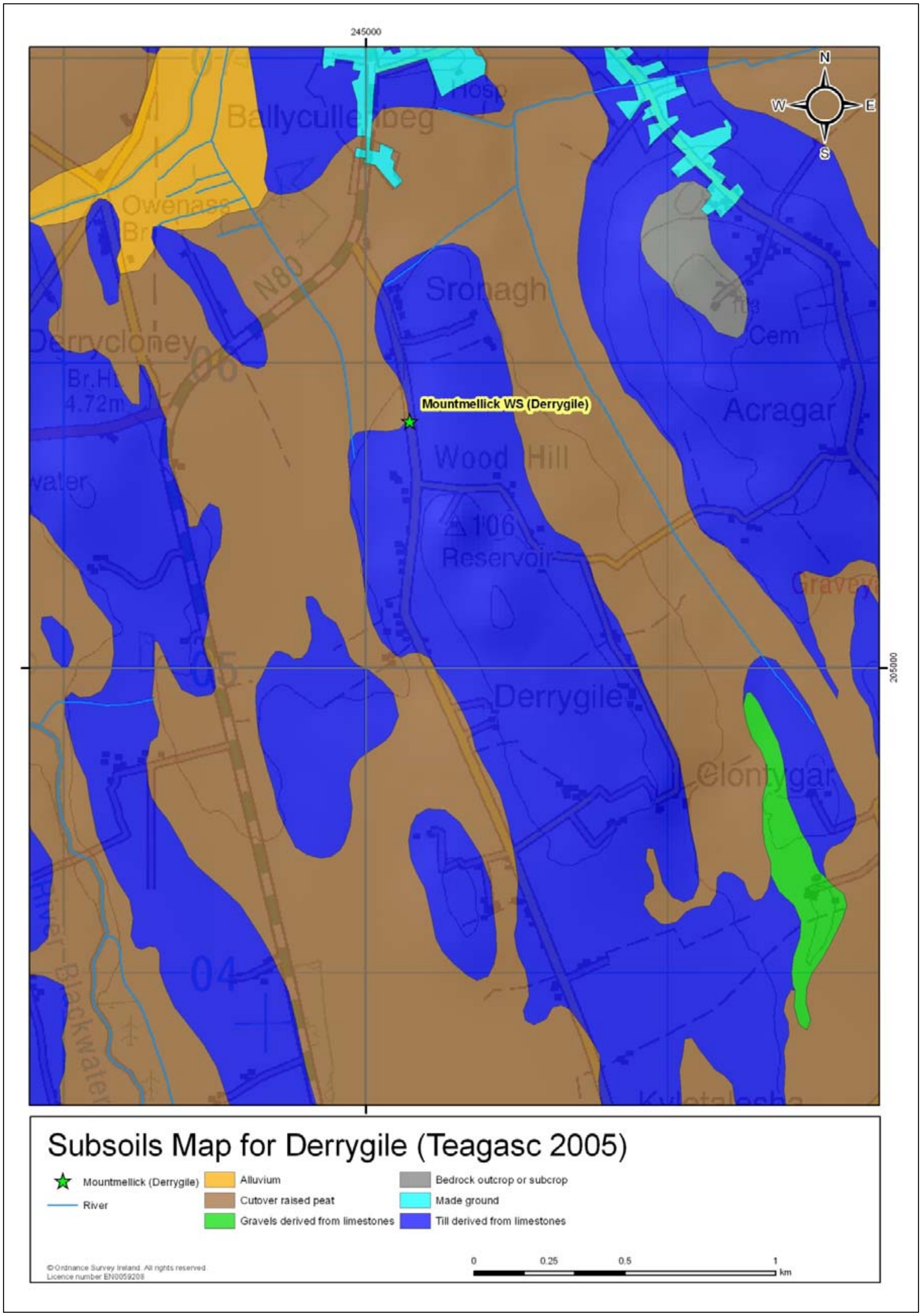

Figure 5 Subsoils in the vicinity of Derrygile

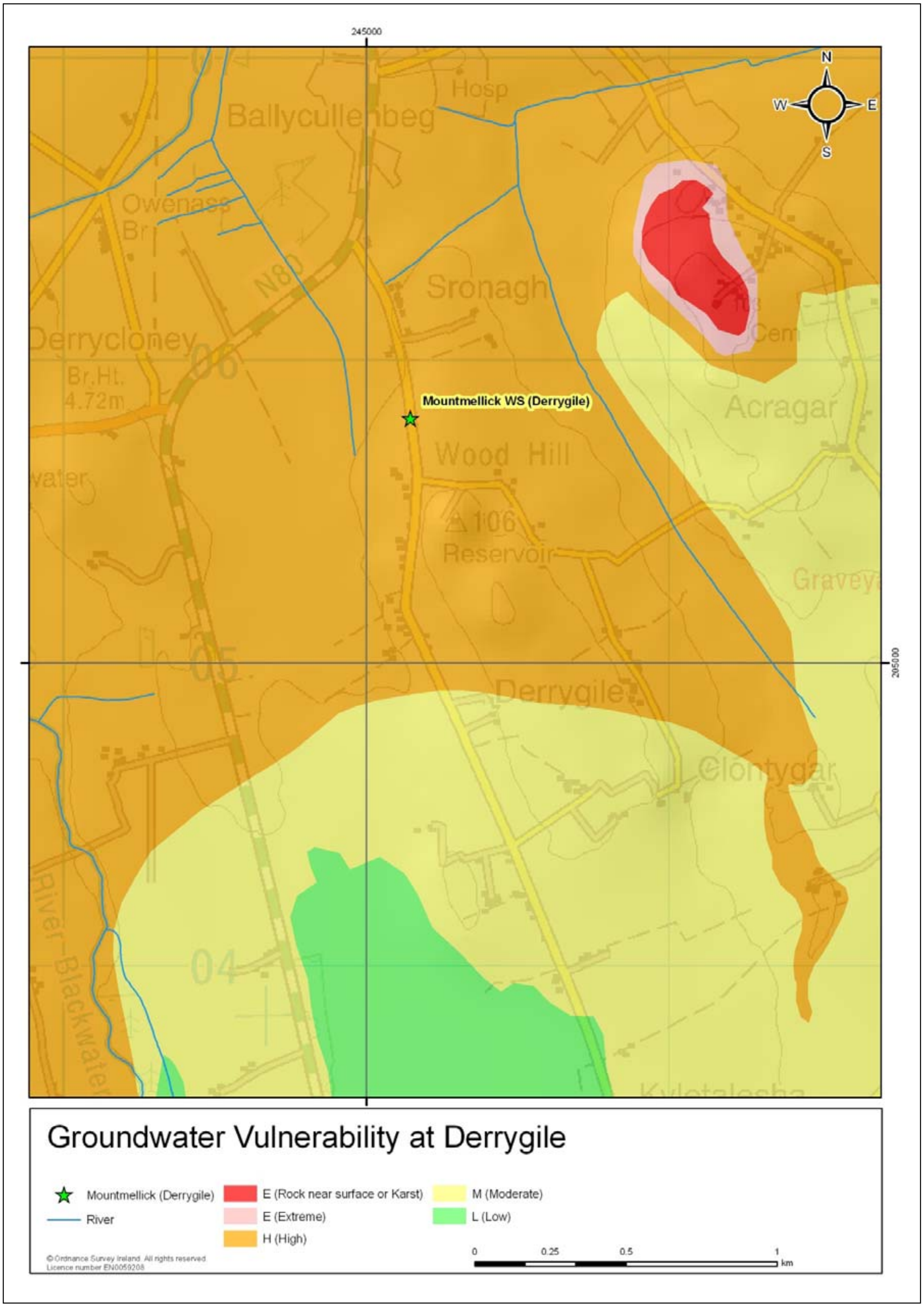

Figure 6 Groundwater Vulnerability in the vicinity of Derrygile

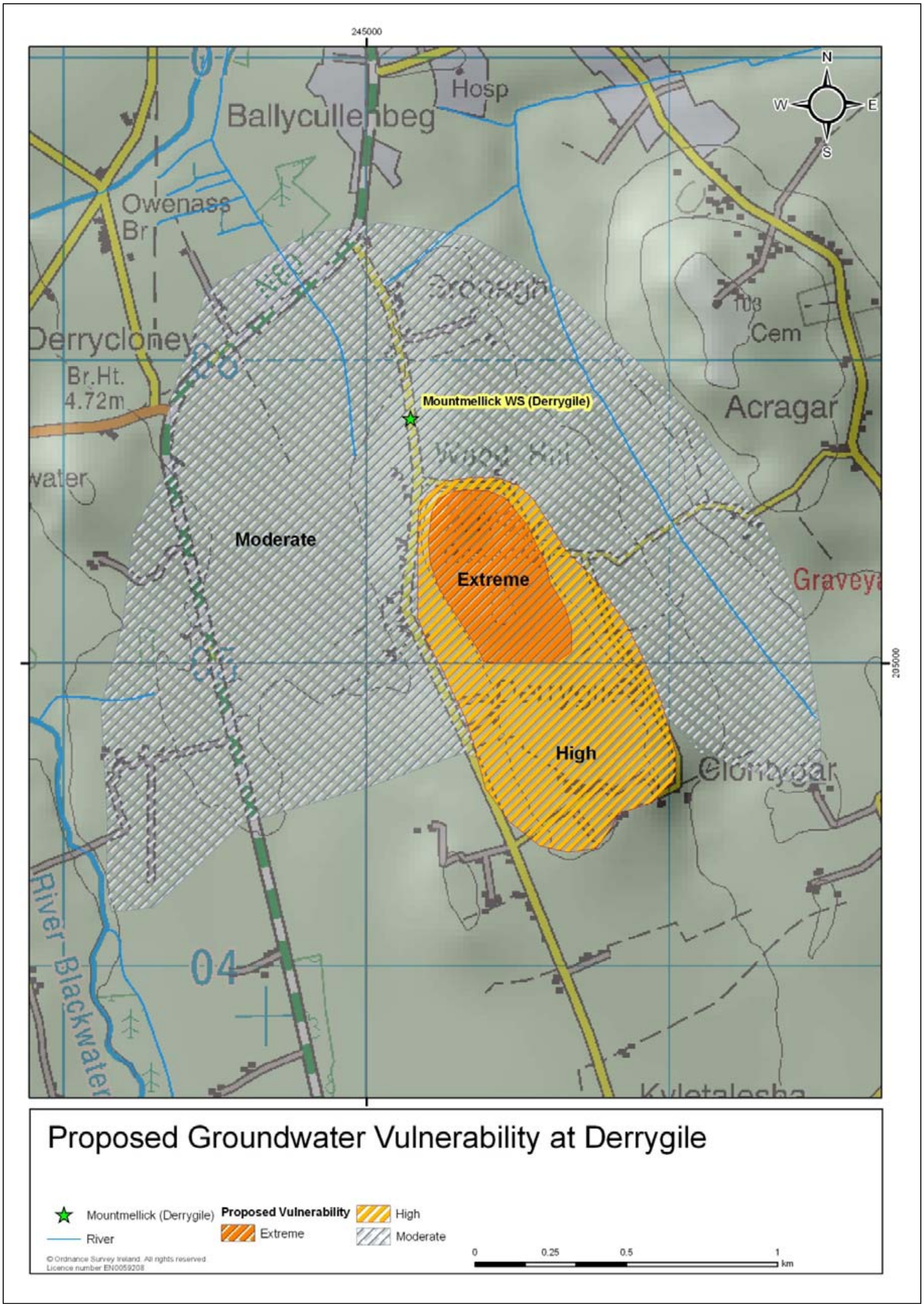

Figure 7 Proposed Groundwater Vulnerability in the vicinity of Derrygile

9 Hydrogeology

This section describes the current understanding of the hydrogeology in the vicinity of the Derrygile borehole. Hydrogeological and hydrochemical information was obtained from the following sources:

- GSI Website and Databases
- County Council Staff
- EPA website and Groundwater Monitoring database
- Local Authority Drinking Water returns
- Test pumping in 1998 for Laois Groundwater Protection Scheme (Deakin and Wright, 2000)
- Hydrogeological mapping and test pumping by TOBIN Consulting Engineers in 2010.

9.1 Groundwater body and status

The source and the surrounding area are located within the 'Poorly Productive' Portlaoise Groundwater body (GSI, 2004), that is classified as being of 'Good Status'. The groundwater body descriptions are available from the GSI website: www.gsi.ie and the 'status' is obtained from the WFD website: www.wfdireland.ie.

9.2 Groundwater levels, flow directions and gradients

The water level in the borehole on 23rd September 2010, after 30 hours of no pumping, is recorded at 0.54 m below the top of the casing (1.7 m below ground level), which is 78.33 m OD. A number of springs, shown on Figure 4, are mapped around the base of Wood Hill, at about 80 m OD. Further there is a dense network of artificial drains across the lowest areas. The water level across Wood Hill is unknown, though it is assumed to be relatively close to ground surface as the available relief is approximately 10–20 m (including the highest points of Wood Hill) and the rock type suggests a relatively high water table.

The regional surface water flows are to the north and north east, and it is assumed that regional groundwater flow directions are similar. There are likely to be localised flow directions driven by topography due to the geology. For instance there are springs, drains and streams around flanks of Wood Hill and the other neighbouring ridge, thus a component of the groundwater flow paths are short and it is assumed that local flow directions mirror the topography. The springs are likely to be focused discharges for shallow groundwater issuing at the break in slope. Groundwater gradients are expected to be less than the local topographic gradient of 0.07. Guesstimating that the groundwater levels toward the top of the hill are approximately 85 to 90 m OD, and assuming the distance to the borehole to be 375 m, then the groundwater gradient is taken to be approximately 0.01. Groundwater level data for a site 3 km south of the borehole in Kyletalesha, in the same rock type indicates gradients of 0.005, though the topography is flatter.

9.3 Hydrochemistry and water quality

The hydrochemical analyses of 32 untreated samples show that the water is very hard, with total hardness values of 322–705 mg l^{-1} (equivalent $CaCO_3$) and electrical conductivity (EC) values of 633–832 µS cm^{-1}, (average 755 µS cm^{-1}) indicating that the groundwater has a calcium bicarbonate hydrochemical signature (EPA data). Alkalinity ranges from 308–410 mg/l $CaCO_3$. The pH ranges 6.9–7.8, with an average of 7.3, which is slightly alkaline. Figure 8 shows the data for the key indicators of contamination and the main points are as follows:

- Nitrate concentrations range from 0.4–88.5 mg/l with a mean of 25 mg/l from 32 samples. The mean is less than the groundwater Threshold Value of 37.5 mg/l (Groundwater regulations S.I. No. 9 of

2010). The standard set out in the Drinking Water Regulations (S.I. No. 278 of 2007) for nitrate is 50 mg/l; this was exceeded once – 18/11/2003. There is no upward trend through the data, shown in Figure 8. The two extreme values in the range appear to be anomalous, as the other nitrate concentrations occur much closer to the mean as can be seen in the graph. Chloride, ammonium, iron, manganese, conductivity and total coliform counts are all elevated on the same date that nitrate is recorded as 0.4 mg/l (25/9/2001) which suggests that a contamination event which caused temporary reducing conditions in the aquifer occurred. Mean Ammonium concentrations are below the threshold value of 0.175 mg/l N at 0.09 mg/l as N. Nitrite was elevated on four occasions, with the highest reported concentration of 4.4 mg/l as NO2. on 24/1/2001.

- Chloride is a constituent of organic wastes, sewage discharge and artificial fertilisers, and concentrations higher than 24 mg/l (Groundwater Threshold Value for Saline Intrusion Test, Groundwater Regulations S.I. No. 9 of 2010) may indicate contamination, with levels higher than 30 mg/l usually indicating significant contamination (Daly, 1996). Chloride concentrations range from 4–30 mg/l with a mean of 20 mg/l.

- The average concentration of Molybdate Reactive Phosphorous (MRP) is 0.02 mg/L P, which is below the Groundwater Threshold Value (Groundwater Regulations S.I. No 9 of 2010) of 0.035 mg/L P.

- The ratio of potassium to sodium (K:Na) is used to help indicate if water has been contaminated, along with other parameters, and may indicate contamination if the ratio is greater than 0.4. From 32 analyses, the ratio exceeded 0.4 on 28/8/2000, in which case the potassium concentration was elevated – 14 mg/l.

- Faecal coliforms counts are consistently zero, although total coliform counts did exceed zero on 10 occasions.

- Iron and manganese concentrations are generally low, but on one occasion on 25/9/2001, Manganese concentrations were recorded at 0.126 mg/l, which is greater than 0.05 mg/l, the standard set in the Drinking Water Regulations (S.I. No. 278 of 2007). Iron concentrations were also greater than the standard set in the Drinking Water Regulations (S.I. No. 278 of 2007) (0.2 mg/l), and were recorded at 0.63 mg/l. On four other occasions iron concentrations have approached or exceeded the standard set in the Drinking Water Regulations (S.I. No. 278 of 2007).

- Sulphate concentrations range 20–61 mg/l with a mean of 35 mg/l. There is a sulphur smell from water at the well head.

In summary, the water quality is generally good though occasionally contaminated, as evidenced by sporadically elevated chloride, nitrite, ammonia, nitrate, iron, manganese, the potassium:sodium ratio and total coliforms.

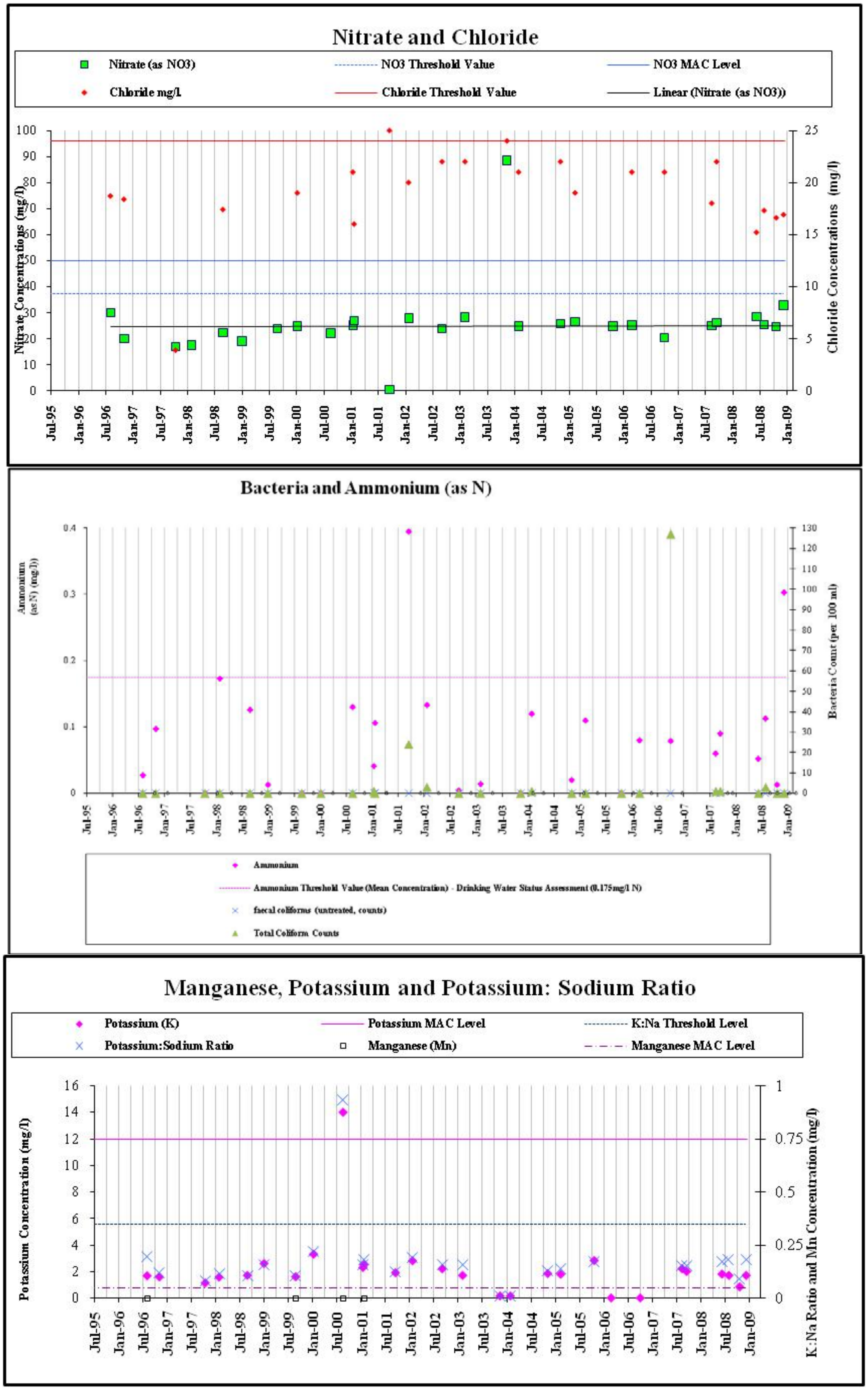

Figure 8 Key Contaminant Indicators at Derrygile Borehole

9.4 Aquifer characteristics

The Derrygile borehole has a yield of 545 m^3/day (Deakin, 2000), which is an 'Excellent' yielding borehole according to the GSI classification. The abstraction rate is currently is 350 m^3/d, and the drawdown is approximately 18 m, giving a specific capacity of approximately 20 m^3/d/m, similar to that reported in the Laois GWPS (Deakin, 2000) of 18.45 m^3/d/m; for a corresponding discharge of 418 m^3/d and a drawdown of 23 m. A fracture zone appears to the main conduit delivering water to the borehole.

Figure 9 below is a plot of specific capacity against pumping rate for the test pumping conducted in 1998 and 2010; it is a measure of 'Productivity', developed by GSI (Wright, 1997). It takes account of drawdown, rather than relying on yield alone. The Derrygile data plots in Class III, which is at the upper range for the Ballysteen Limestones (Dinantian Lower Impure Limestones), classified as a Locally Important Aquifer (LI) which is moderately productive only in Local Zones.

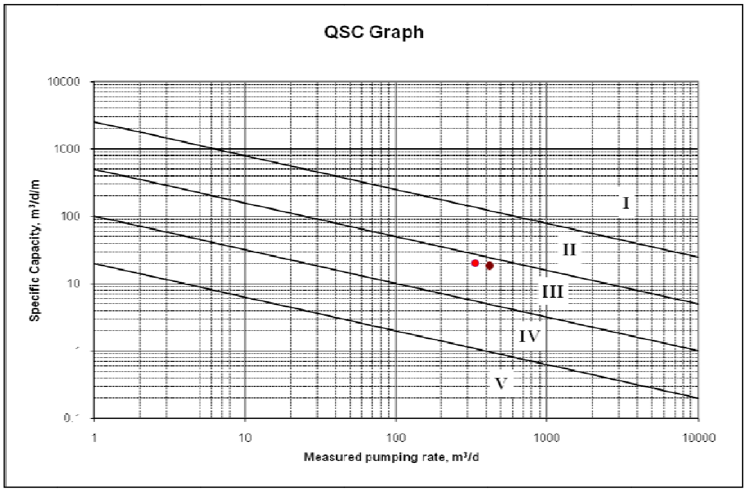

Figure 9 QSC Graph: Derrygile Borehole (Mountmellick WS)

Constant rate tests were carried out in 1998 (GSI) and 2010 (Tobin). The data are attached in Appendix 1 and a plot of drawdown against time for both tests is shown in Figure 10, and plot of drawdown against log time is shown in Figure 10 for the test conducted in 2010 and the recovery data is shown in Figure 11. In addition to the test pumping a data logger was inserted down the borehole to observe the abstraction cycle over a few days. A plot of this is shown in Figure 12.

The pumping data indicate that the drawdown is very rapid in the first 10 – 20 minutes and stabilises quickly. The recovery data also indicate a very rapid recovery to the static water level. The data suggest that a fracture zone is feeding the borehole.

During the 2010 test, it was recorded that after about 2.5 minutes water could be heard entering the borehole, corresponding to a depth of 13.8 m below the top of the casing. This is also the recorded depth to bedrock of the borehole. This indicates that while there was some groundwater present in the weathered zone at the top of bedrock, and/or the overlying subsoils, it was not sufficient to supply the borehole.

A noticeable difference between the two pumping tests is that the slightly higher discharge rate for the GSI test in 1998 (17.45 m^3/hr – 14.55 m^3/hr = a difference of 3 m^3/hr) generates an apparently far greater drawdown response which appears to have reached equilibrium conditions though the water levels fluctuated.

The key aspect of the data is the recharge boundary. The equilibrium conditions suggest a recharge boundary has been reached – this is likely due to the abstraction rate being matched by groundwater from a fracture zone at depth. The pumping rate does not dewater the fracture zone. It is inferred that the fracture zone is about 20 mbtoc.

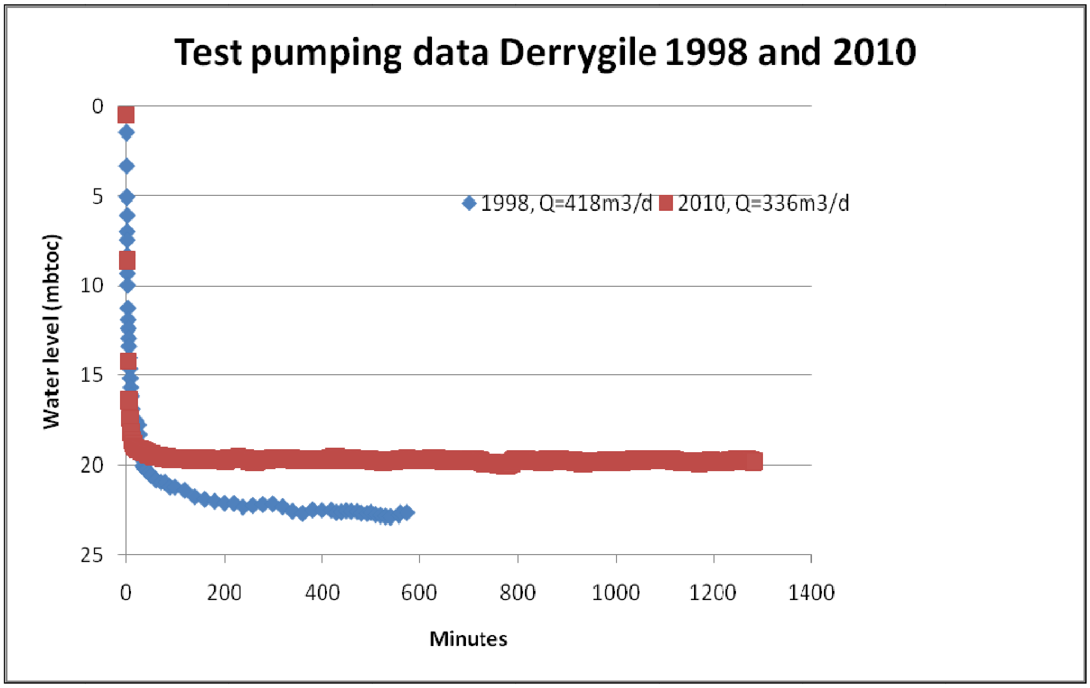

Figure 10 Drawdown response curves for Derrygile

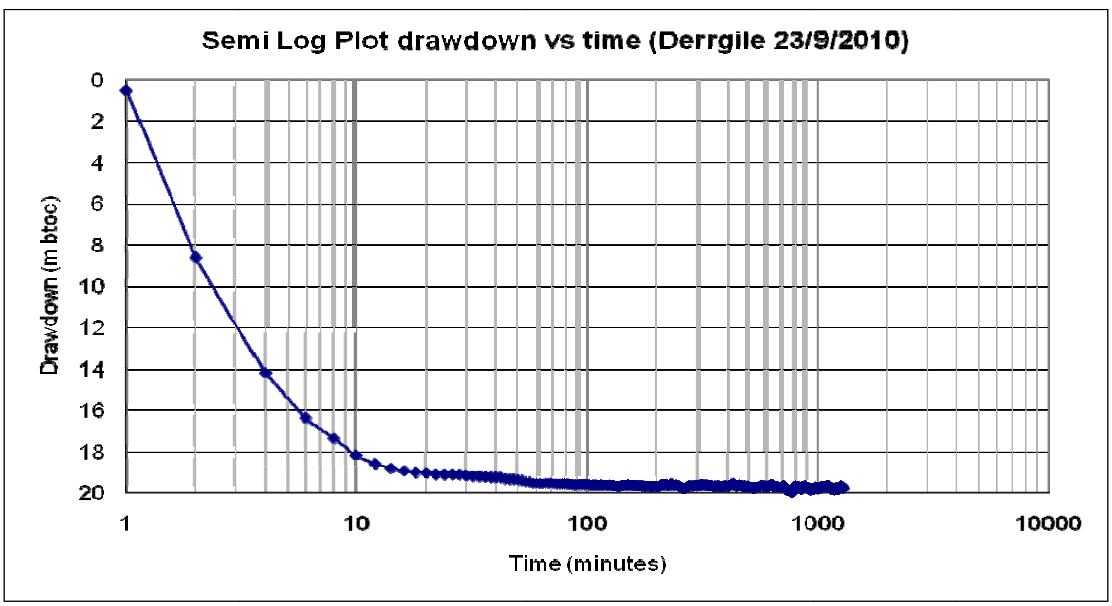

Figure 11 Constant rate test at Derrygile

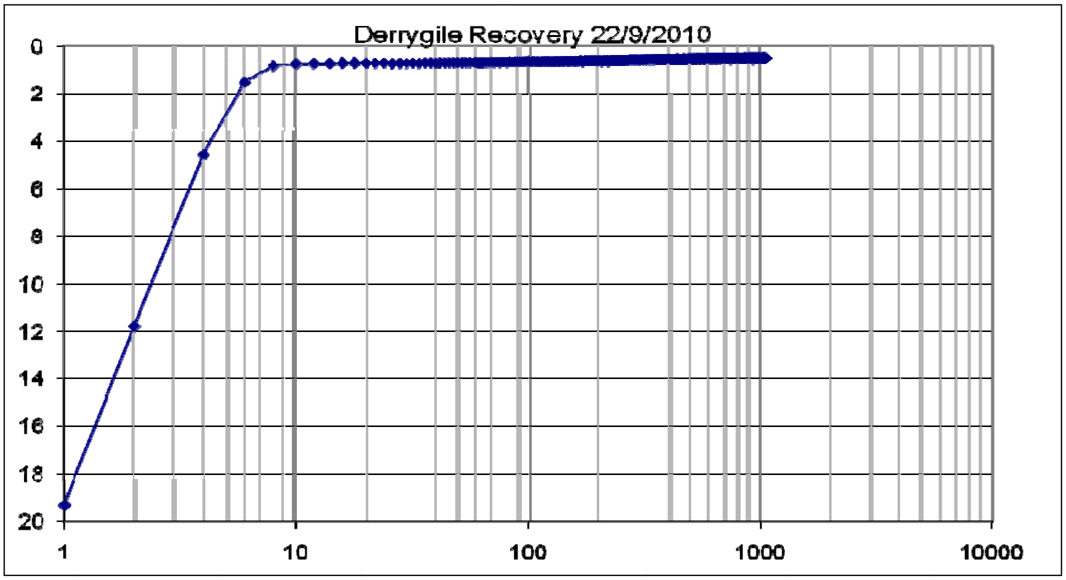

Figure 12 Recovery test at Derrygile

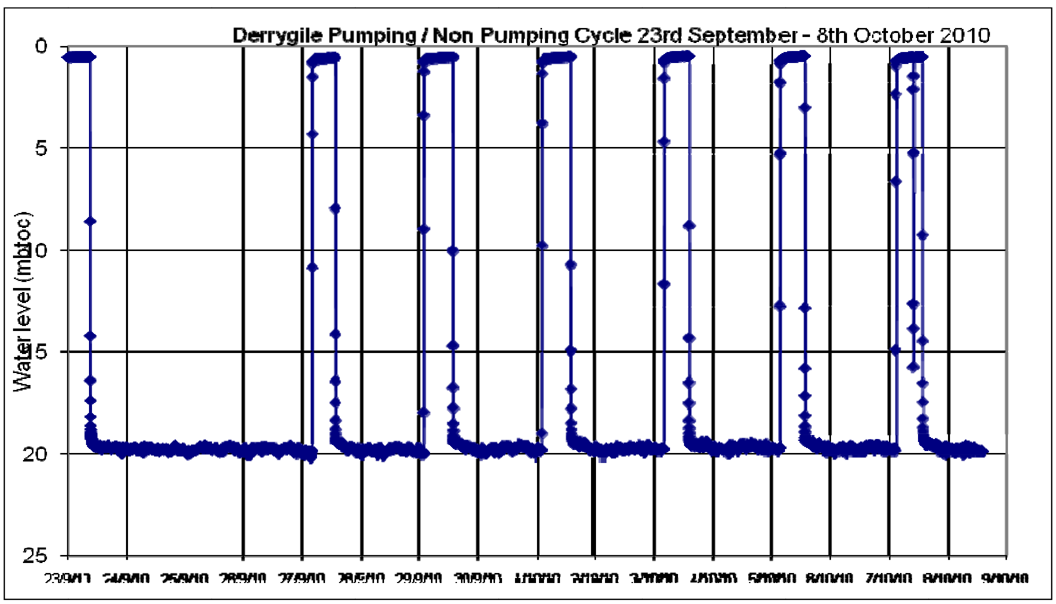

Figure 13 Abstraction cycle at Derrygile

Given the nature of the source: that a fracture zone at depth feeds the borehole it is difficult to assess the aquifer properties of transmissivity and permeability.

The GSI reports the apparent transmissivity as 87–216 m^2/d (discharge data, recovery data respectively). An estimate of the apparent transmissivity using the constant rate test and non-equilibrium methods such as Jacob-Cooper equation is difficult as the water level drops to the level of the fracture zone very quickly and remains there during pumping.

The pumping data indicate that equilibrium conditions are reached rapidly thus it may be more appropriate to estimate the aquifer properties using equilibrium methods of approximation such as Logan (Misstear, 1998). As such, Transmissivity based on the Specific Capacity is approximately 20 – 23 m^2/day.

An assessment of apparent transmissivity using a method outlined by Misstear (2006) (De Lange and Van Tonder, 2000) allows for characterising the properties of the fracture zone feeding the borehole. This method gives a range of 60 to 75 m^2/day for apparent transmissivity, which relates to the fault / fracture zone at depth. For the purposes of the report 75 m^2/day is used.

Based on the estimated bedrock aquifer transmissivity and the aquifer hydraulic gradients, the groundwater flow velocity can be estimated based on the equation:

$$v = \frac{T \cdot i}{b \cdot n_e}$$

where:
- v = average groundwater velocity (m/day);
- T = aquifer transmissivity (m^2/day);
- n_e = effective porosity (dimensionless)
- i = hydraulic gradient; and,
- b = aquifer thickness.

Using the transmissivity values and an assumed aquifer thickness of 32 m (46 borehole depth - 14 m depth to rock) the permeability is estimated to be approximately 2 m/d, which is considered to be representative of the fault and 0.6 m/d is considered to represent the bulk of the bedrock.

As the borehole is fed by a fracture zone the velocity is calculated using the permeability considered to represent the fracture zone. Thus, based on a gradient estimated to be in the order of 0.01 to 0.005 and the porosity assumed to be in the order of 1%, the velocities are in the order of 1 to 2 m/d, which is likely to be more representative of the fault zone feeding the borehole. Given the uncertainty about the orientation and extent and width of the fault zone the velocity used for defining the inner protection area is 2 m/d.

10 Zone of contribution

10.1 Conceptual model

The current understanding of the geological and hydrogeological situation is given as follows. The Zone of Contribution is shown in Figure 14.

A relatively high yielding borehole at Derrygile, positioned toward the base of Wood Hill appears to abstract groundwater from the top of the rock (this can be heard entering the well) and a significant fracture zone at depth - the configuration or extent of which is unknown. The dominant contribution appears to be from the fracture zone, the depth of the which is inferred to be about 20 m below the top of the borehole based on the pumping water level and the pumping tests. A fault trace is mapped in the vicinity of the borehole at Wood Hill; it is likely that this fault is the fracture zone at depth in the borehole. It is considered that the main groundwater flow direction is toward the north.

The mixing of shallow and deep groundwater components, with a greater proportion of deeper groundwater, is indicated in the pumping test data. It is possible that the very occasional contamination events in the borehole are associated with the shallow flow component.

10.2 Boundaries of the ZOC

Given that the borehole is fed dominantly by a deep fracture zone which extends out in an unknown direction the boundaries delineated below represent the shallow, local flow path component.

The **Northwestern Boundary** is based on a combination of hydrogeological mapping and the uniform flow equation (Todd, 1980).

The uniform flow equation (Todd, 1980) is:

$x_L = Q / (2\pi * T * i)$ where

Q is the daily pumping rate (525 m^3/d = 150% current abstraction rate)
T is Transmissivity (taken from aquifer characteristics 75 m^2/d)
i is the background non-pumping gradient (0.005-0.01).

The uniform flow equation suggests the borehole could pump from 110 – 230 m downgradient at the higher abstraction rate. At the current rate, the downgradient distance is approximately 78 – 160 m. The distance used for the report and the outer protection area is the maximum most conservative distance of 230 m.

The delineation of the **Eastern, Western and Southern Boundaries** is very difficult due to the uncertainty regarding the configuration of the fracture zone in the vicinity of the borehole and the groundwater flow direction. This is further complicated by the mapped fault which cross cuts the area – the precise location of the fault is unknown. The most likely contributing area is the elevated ground around Wood Hill. To account for a regional head and deeper groundwater flow, and the occurrence of a fracture zone, the majority of the elevated area above the borehole is assumed to be feeding the fracture zone that delivers water to the borehole. The boundaries are based on hydrogeological mapping, topography, the uniform flow equation, and assumed the groundwater flow regime, and the presence of the mapped fault. The Southern boundary is taken to the fault, with an arbitrary 100 m extension beyond it. The uniform flow equation is used to estimate the downgradient width of the zone of contribution as follows:

The uniform flow equation (Todd, 1980) is:

$y_L = Q / (2 * T * i)$ where

Q is the daily pumping rate (525 m^3/d = 150% current abstraction rate)
T is Transmissivity (taken from aquifer characteristics 75 m^2/d)
i is the background non-pumping gradient (0.005-0.01).

Therefore y_L = 700 m at the higher abstraction rate and steeper gradient.

The western boundary is delineated based on topography, extending to the southern boundary at the mapped fault. It is considered that the dominant groundwater flow direction would be toward the stream occurring in the base of the valley east of Wood Hill. The eastern boundary is based on the uniform flow equation and the assumed regional groundwater direction, considered to be northward.

The overall shape of the ZOC allows for uncertainty in the groundwater flow direction. The zone of contribution provides for the shallow topographical component; the fault which provides the dominant flow to the borehole. The western portion of the ZOC is uncertain, conservative and allows for artificial recharge due to the pumping and the large associated drawdown. The static water level is approximately 78 m OD and the pumping water level is approximately 61 m OD.

10.3 Recharge & Water balance

The term 'recharge' refers to the amount of water replenishing the groundwater flow system. The recharge rate is generally estimated on an annual basis, and is assumed to consist of the rainfall input (*i.e.* annual rainfall) minus water loss prior to entry into the groundwater system (*i.e.* annual evapotranspiration and runoff). The estimation of a realistic recharge rate is critical in source protection delineation, as this dictates the size of the zone of contribution to the source (*i.e*. the outer Source Protection Area).

At Derrygile, the main parameters involved in the estimation of recharge are: annual rainfall; annual evapotranspiration; and a recharge coefficient.

The recharge coefficient is estimated using Guidance Document GW5 (Groundwater Working Group 2005) and due to the aquifer category (Locally Important Aquifer which is moderately productive only in local zones (LI)), a recharge cap of 200 mm is applied to estimate recharge to the aquifer. The area of recharge is assumed to be the area elevated above the borehole up to Wood Hill. The lowest areas are considered to be a discharge zone, with springs discharging at the toe slopes and streams/drains flowing north. The recharge cap is therefore considered to be reasonable in this instance.

These calculations are summarised as follows:

Average annual rainfall (R)		900 mm
Estimated P.E.		450 mm
Estimated A.E. (95% of P.E.)		428 mm
Effective rainfall		472 mm
Recharge	CAP Applied	200 mm

Water balance: The area described above is 0.7 km^2, which is approximately the area required to supply the current sustainable abstraction rate (350 m^3/day). The area is insufficient to match a 150% increase to the abstraction rate (525 m^3/day). The zone of contribution provides for the shallow topographical component; the fault which provides the dominant flow to the borehole.

11 Groundwater source protection zones

The Source Protection Zones are a landuse planning tool which enables an objective, geoscientific assessment of the risk to groundwater to be made. The zones are based on an amalgamation of the source protection areas and the aquifer vulnerability. The source protection areas represent the horizontal groundwater pathway to the source, while the vulnerability reflects the vertical pathway. Two source protection areas have been delineated, the Inner Protection Area and the Outer Protection Area, shown in Figure 15.

The **Outer Protection Area (SO)** encompasses the entire zone of contribution to the source, described in the previous section.

The **Inner Protection Area (SI)** is designed to protect the source from microbial and viral contamination and it is based on the 100-day time of travel to the supply (DELG/EPA/GSI 1999). It is calculated from the velocity of groundwater flow in the bedrock, which was given as 2 m/d in the Aquifer Characteristics. Therefore, the 100-day horizontal time of travel is calculated to extend 200 m around the source.

The groundwater protection zones are shown in Figure 16, and are based on an overlay of the source protection areas on the proposed groundwater vulnerability. Therefore the groundwater protection zones present in the ZOC are SI/M, SO/E, SO/M and SO/H and the percentage breakdown for the categories is given in Table 10.1.

Table 11-1 Source Protection Zones

Source Protection Zone	% of total area ($0.68km^2$)
SI/Moderate	17%
SO/Extreme	21%
SO/High	10%
SO/Moderate	52%

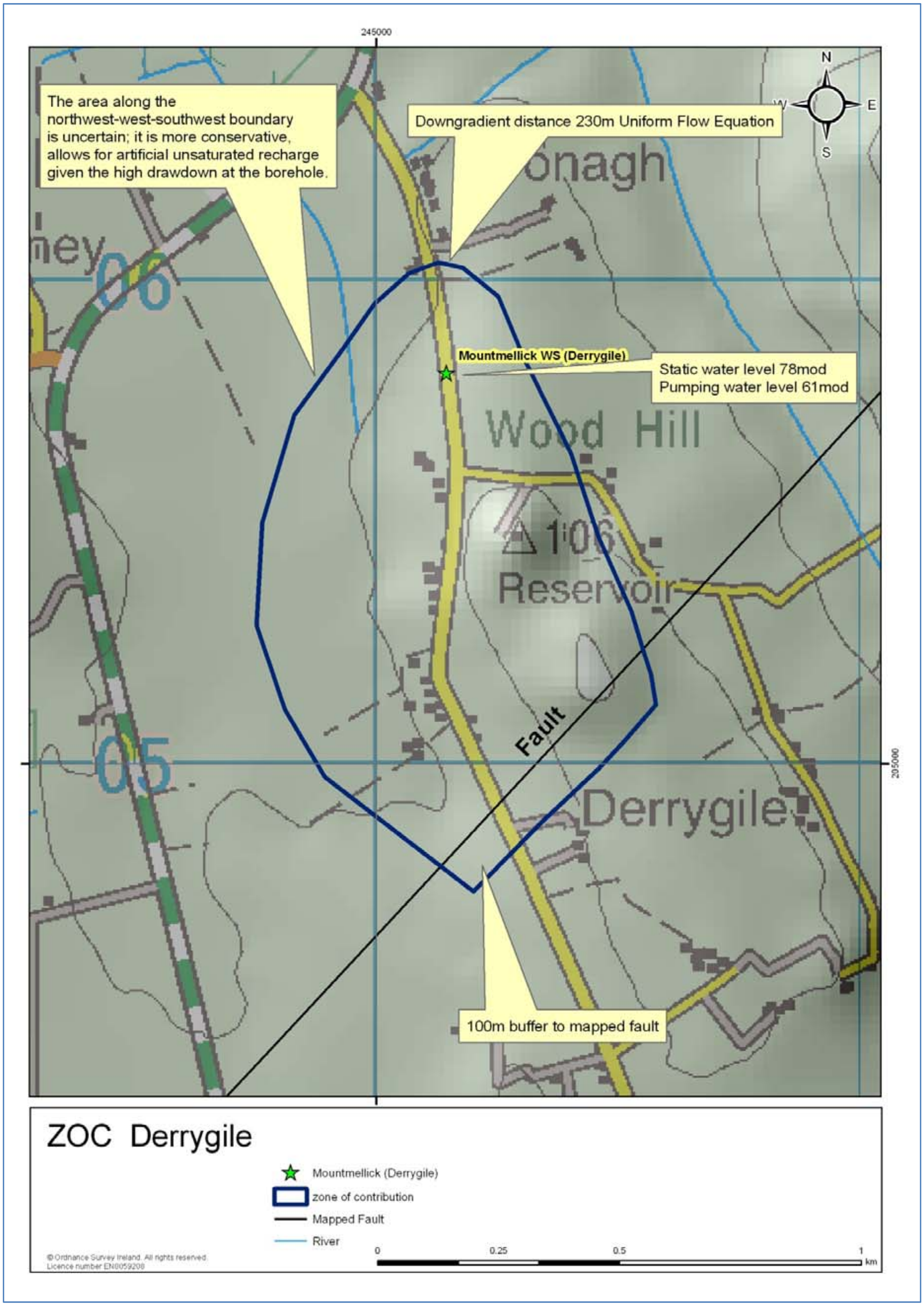

Figure 14 Derrygile Groundwater Zone of Contribution

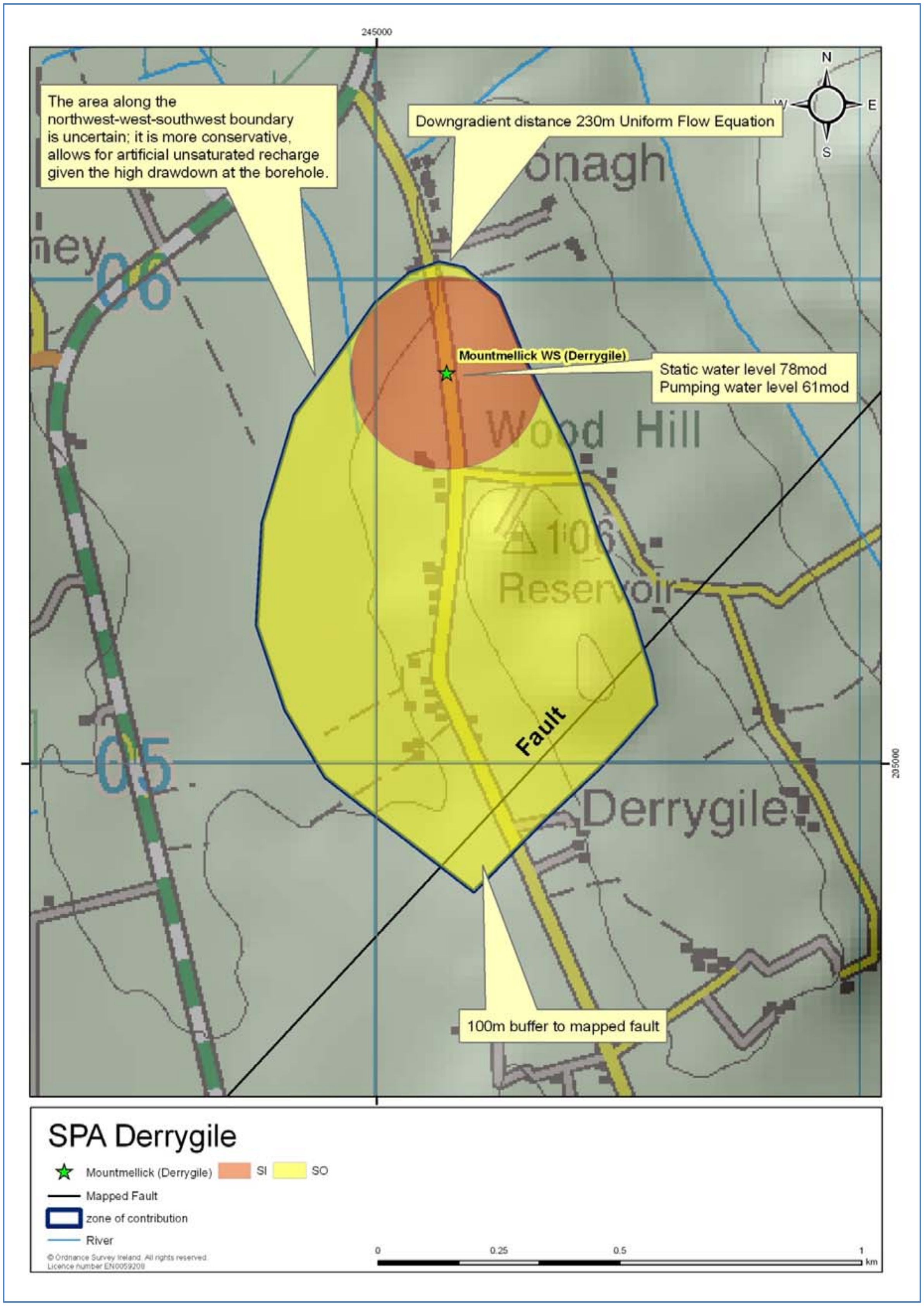

Figure 15 Derrygile Groundwater Source Protection Areas

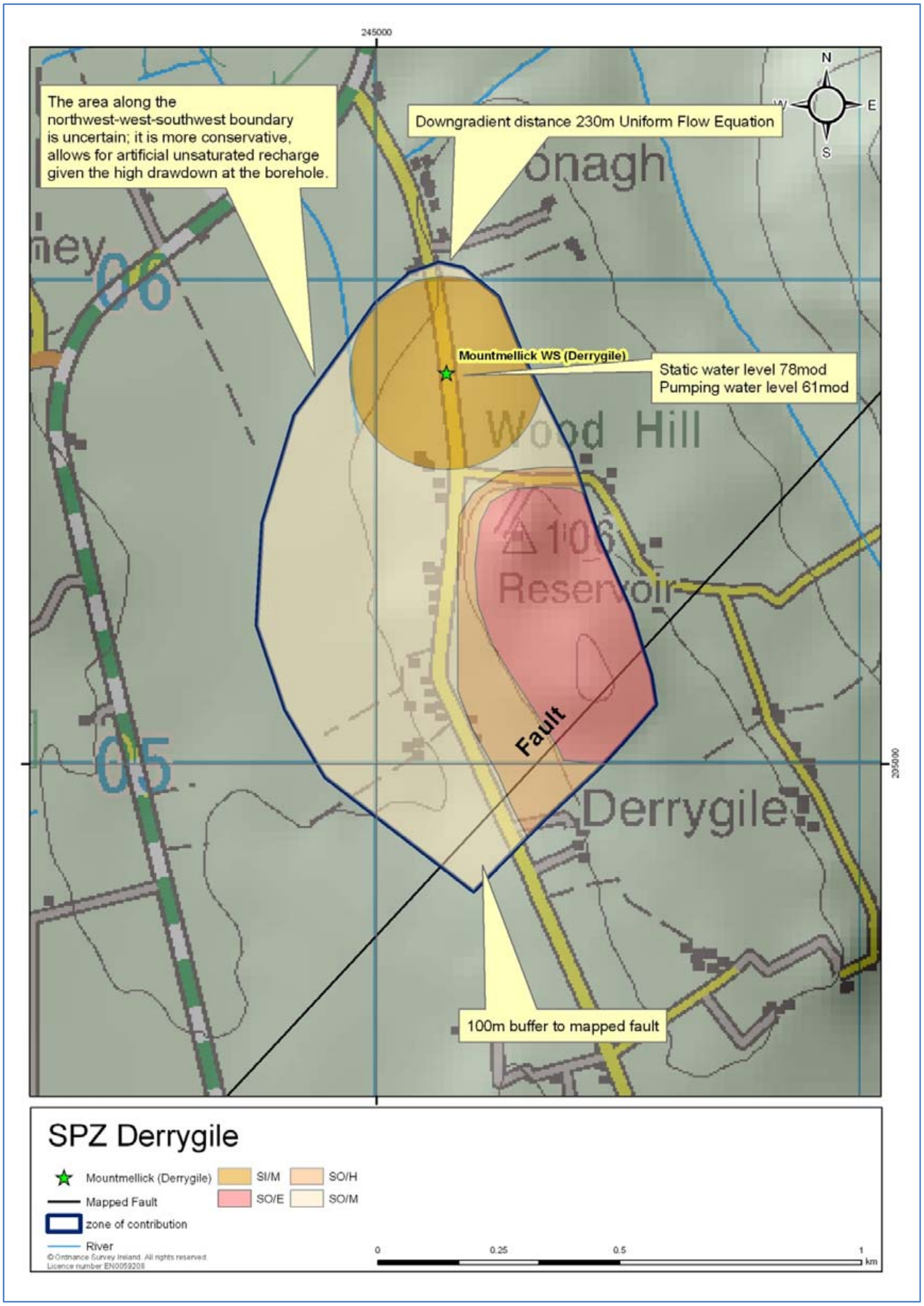

Figure 16 Derrygile Groundwater Source Protection Zones

12 Potential pollution sources

The main potential sources of contamination within the ZOC farms and old burial ground marked on the 6 inch sheets and the roads.

13 Recommendations

The main recommendations are further assessments to improve the zone of contribution, in particular to delimit the extent of the fault zone. These include the following:

- A step test using the current abstraction rate, the rate used in 1998 and a further higher rate to test the recharge boundary. A longer term pump test using a rate established from the step test (likely to be similar to the rate used in 1998 or perhaps up to 450 m3/day).
- A chemical assessment of the springs around Wood Hill and a comparative assessment with the groundwater from early pumping and late pumping.
- Geophysics could help in delimiting the extent of the fault zone.

14 References

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APPENDIX Test pumping data

Test data 1998

SITE Derryguile **DATE** 17/08/1998

Groundwater Section			Project Title	Laois GWPS
Geological Survey of Ireland	PUMPING TEST	PUMPING WELL	Page No.	1

Borehole Name	Derryguile	Well Depth	45.7	Datum Point	Top of Casing
Borehole No.		Well Diameter		Height of Datum	
Well Owner	County Council	Pump Depth		Ground Elevation	
Location		Aquifer	ABL	Datum Elevation	
Grid ref.				Weather	Brright, some drizzle on and off
6" Sheet No.	8			Observer	C. Cronin, R. Buckley

Date	Time	Elapsed Time	Water level below datum	Drawdown	Discharge		Discharge	Remarks
		Mins	(m)	(m)	Meter	Spot	(m3/d)	
17/08/1998		0.183333333	1.49	1.49				
		0.483333333	3.34	3.34				
		0.85	5.08	5.08				No control over Q i; average Q = 17.45m3/hr.
		1.833333333	6.08	6.08				
		1.35	6.99	6.99				Momentary blips where Q drops to 16.8 m3/hr
		1.483333333	7.47	7.47				
		1.766666667	8.34	8.34				every 20 mins (see chart sheet at back of Derryg
		2.15	9.305	9.305				
		2.45	9.97	9.97				
		3	11.265	11.265				
		3.61	11.915	11.915				
		4	12.4	12.4				
		4.66	12.915	12.915				
		5	13.36	13.36				
		6	14.017	14.017				
		7	14.63	14.63				
		8	15.175	15.175				
		9	15.69	15.69				
		10	16.125	16.125				
		12	16.845	16.845				
		14	17.33	17.33				
		19.43	17.535	17.535				
		24.38	17.755	17.755				
		26	18.292	18.292				
		32	19.64	19.64				
		34	20	20				
		36	20.1	20.1				
		38	20.2	20.2				
		40	20.242	20.242				T = 10.7 oC. K = 659, 738 uS/cm
		46	20.4	20.4				
		50	20.55	20.55				
		60	20.8	20.8				
		71	20.93	20.93				
		80	20.94	20.94				
		90	21.2	21.2				
		100	21.21	21.21				
		120	21.39	21.39				T = 11.0oC, K = 655, 728 uS/cm
		140	21.76	21.76				
		160	21.9	21.9		17.6 m3/hr	422.4	
		180	22.01	22.01				
		200	22.12	22.12				
		220	22.13	22.13				
		240	22.34	22.34				
		260	22.25	22.25				
		280	22.19	22.19		17.5	420	T = 11.0oC, K = 661, 738 uS/cm
		300	22.16	22.16				
		320	22.32	22.32				
		340	22.58	22.58				
		360	22.7	22.7				T = 10.9oC, K = 659, 736uS/cm
		380	22.5	22.5				
		400	22.52	22.52				
		420	22.515	22.515				T = 11.0oC, K = 658, 734uS/cm
		430	22.64	22.64				
		440	22.61	22.61		17.45 m3/h	418.8	
		450	22.55	22.55				
		460	22.58	22.58				
		472	22.59	22.59				
		480	22.68	22.68				T = 10.9oC, K = 660, 738 uS/cm
		492	22.7	22.7				
		500	22.64	22.64				
		510	22.76	22.76				
		520	22.8	22.8				
		530	22.85	22.85				
		540	22.875	22.875				T = 10.8, K = 660, 737 uS/cm
		557	22.785	22.785				
		561	22.65	22.65				
		575	22.65	22.65				

Summary Test Data 2010

	drawdow	102	19.614	208	19.645	314	19.626
min	n	104	19.633	210	19.612	316	19.626
1	0.502	106	19.633	212	19.642	318	19.624
2	8.578	108	19.632	214	19.612	320	19.636
4	14.21	110	19.634	216	19.603	322	19.636
6	16.4	112	19.644	218	19.602	324	19.638
8	17.39	114	19.612	220	19.6	326	19.636
10	18.17	116	19.636	222	19.612	328	19.636
12	18.618	118	19.644	224	19.672	330	19.658
14	18.828	120	19.636	226	19.644	332	19.648
16	18.96	122	19.636	228	19.63	334	19.656
18	19.04	124	19.635	230	19.578	336	19.658
20	19.058	126	19.656	232	19.598	338	19.644
22	19.118	128	19.656	234	19.628	340	19.674
24	19.128	130	19.666	236	19.628	342	19.662
26	19.128	132	19.683	238	19.65	344	19.684
28	19.128	134	19.693	240	19.638	346	19.674
30	19.188	136	19.703	242	19.628	348	19.681
32	19.208	138	19.706	244	19.638	350	19.726
34	19.22	140	19.656	246	19.648	352	19.696
36	19.248	142	19.666	248	19.668	354	19.682
38	19.268	144	19.634	250	19.698	356	19.694
40	19.288	146	19.644	252	19.718	358	19.694
42	19.29	148	19.622	254	19.75	360	19.681
44	19.35	150	19.613	256	19.76	362	19.711
46	19.372	152	19.642	258	19.758	364	19.684
48	19.358	154	19.644	260	19.8	366	19.672
50	19.4	156	19.632	262	19.818	368	19.666
52	19.41	158	19.654	264	19.818	370	19.694
54	19.46	160	19.674	266	19.82	372	19.696
56	19.47	162	19.654	268	19.78	374	19.721
58	19.508	164	19.654	270	19.74	376	19.731
60	19.53	166	19.672	272	19.728	378	19.721
62	19.53	168	19.672	274	19.686	380	19.711
64	19.53	170	19.662	276	19.686	382	19.691
66	19.51	172	19.694	278	19.668	384	19.722
68	19.532	174	19.674	280	19.69	386	19.692
70	19.522	176	19.684	282	19.68	388	19.691
72	19.542	178	19.704	284	19.678	390	19.691
74	19.558	180	19.685	286	19.688	392	19.694
76	19.558	182	19.694	288	19.688	394	19.674
78	19.568	184	19.686	290	19.67	396	19.674
80	19.568	186	19.696	292	19.68	398	19.684
82	19.57	188	19.736	294	19.678	400	19.694
84	19.59	190	19.704	296	19.668	402	19.694
86	19.602	192	19.695	298	19.672	404	19.711
88	19.612	194	19.694	300	19.648	406	19.694
90	19.634	196	19.694	302	19.668	408	19.694
92	19.602	198	19.694	304	19.668	410	19.681
94	19.602	200	19.726	306	19.67	412	19.686
96	19.602	202	19.746	308	19.66	414	19.656
98	19.603	204	19.706	310	19.628	416	19.656
100	19.602	206	19.656	312	19.628	418	19.606

420	19.604	528	19.78	636	19.657	744	19.873
422	19.592	530	19.786	638	19.659	746	19.871
424	19.584	532	19.778	640	19.667	748	19.901
426	19.554	534	19.748	642	19.697	750	19.893
428	19.574	536	19.748	644	19.726	752	19.923
430	19.584	538	19.748	646	19.729	754	19.913
432	19.604	540	19.752	648	19.749	756	19.923
434	19.634	542	19.758	650	19.73	758	19.931
436	19.656	544	19.76	652	19.741	760	19.943
438	19.661	546	19.76	654	19.741	762	19.931
440	19.68	548	19.75	656	19.737	764	19.923
442	19.691	550	19.75	658	19.729	766	19.961
444	19.684	552	19.74	660	19.729	768	19.983
446	19.694	554	19.728	662	19.711	770	19.985
448	19.661	556	19.732	664	19.711	772	19.995
450	19.644	558	19.7	666	19.701	774	20.015
452	19.644	560	19.683	668	19.741	776	20.025
454	19.644	562	19.682	670	19.739	778	19.985
456	19.634	564	19.68	672	19.748	780	19.963
458	19.666	566	19.673	674	19.769	782	19.945
460	19.654	568	19.674	676	19.753	784	19.935
462	19.646	570	19.664	678	19.753	786	19.898
464	19.656	572	19.674	680	19.741	788	19.873
466	19.674	574	19.654	682	19.751	790	19.806
468	19.696	576	19.665	684	19.751	792	19.744
470	19.698	578	19.684	686	19.761	794	19.694
472	19.716	580	19.686	688	19.753	796	19.685
474	19.738	582	19.704	690	19.751	798	19.698
476	19.728	584	19.724	692	19.751	800	19.675
478	19.718	586	19.684	694	19.763	802	19.687
480	19.676	588	19.694	696	19.775	804	19.697
482	19.686	590	19.686	698	19.735	806	19.71
484	19.682	592	19.686	700	19.715	808	19.72
486	19.716	594	19.709	702	19.715	810	19.722
488	19.728	596	19.729	704	19.705	812	19.721
490	19.716	598	19.726	706	19.703	814	19.722
492	19.716	600	19.706	708	19.675	816	19.732
494	19.698	602	19.689	710	19.675	818	19.714
496	19.698	604	19.696	712	19.665	820	19.722
498	19.698	606	19.709	714	19.693	822	19.722
500	19.728	608	19.706	716	19.737	824	19.732
502	19.738	610	19.709	718	19.745	826	19.761
504	19.758	612	19.696	720	19.765	828	19.774
506	19.778	614	19.686	722	19.767	830	19.752
508	19.758	616	19.656	724	19.795	832	19.774
510	19.752	618	19.669	726	19.817	834	19.754
512	19.75	620	19.666	728	19.859	836	19.764
514	19.75	622	19.616	730	19.859	838	19.764
516	19.74	624	19.619	732	19.897	840	19.762
518	19.75	626	19.619	734	19.899	842	19.784
520	19.778	628	19.619	736	19.889	844	19.794
522	19.782	630	19.611	738	19.917	846	19.806
524	19.81	632	19.609	740	19.899	848	19.824
526	19.78	634	19.638	742	19.889	850	19.864

852	19.836	960	19.835	1068	19.737	1176	19.868
854	19.816	962	19.823	1070	19.725	1178	19.858
856	19.786	964	19.826	1072	19.739	1180	19.838
858	19.736	966	19.845	1074	19.727	1182	19.846
860	19.718	968	19.825	1076	19.707	1184	19.808
862	19.718	970	19.835	1078	19.705	1186	19.818
864	19.718	972	19.815	1080	19.707	1188	19.798
866	19.74	974	19.806	1082	19.703	1190	19.788
868	19.77	976	19.797	1084	19.687	1192	19.768
870	19.78	978	19.749	1086	19.685	1194	19.768
872	19.729	980	19.729	1088	19.677	1196	19.798
874	19.689	982	19.735	1090	19.675	1198	19.81
876	19.683	984	19.745	1092	19.697	1200	19.81
878	19.679	986	19.747	1094	19.685	1202	19.828
880	19.678	988	19.745	1096	19.677	1204	19.838
882	19.69	990	19.785	1098	19.678	1206	19.828
884	19.68	992	19.789	1100	19.687	1208	19.818
886	19.678	994	19.807	1102	19.667	1210	19.848
888	19.71	996	19.815	1104	19.677	1212	19.858
890	19.722	998	19.816	1106	19.679	1214	19.86
892	19.732	1000	19.817	1108	19.669	1216	19.842
894	19.729	1002	19.819	1110	19.68	1218	19.852
896	19.739	1004	19.817	1112	19.681	1220	19.862
898	19.763	1006	19.805	1114	19.699	1222	19.828
900	19.782	1008	19.826	1116	19.729	1224	19.842
902	19.77	1010	19.807	1118	19.749	1226	19.83
904	19.78	1012	19.809	1120	19.761	1228	19.804
906	19.788	1014	19.789	1122	19.781	1230	19.79
908	19.798	1016	19.777	1124	19.79	1232	19.782
910	19.798	1018	19.767	1126	19.791	1234	19.792
912	19.788	1020	19.747	1128	19.794	1236	19.772
914	19.78	1022	19.77	1130	19.806	1238	19.772
916	19.8	1024	19.74	1132	19.801	1240	19.782
918	19.84	1026	19.749	1134	19.823	1242	19.764
920	19.84	1028	19.751	1136	19.834	1244	19.732
922	19.84	1030	19.771	1138	19.834	1246	19.766
924	19.818	1032	19.781	1140	19.821	1248	19.702
926	19.843	1034	19.739	1142	19.801	1250	19.714
928	19.86	1036	19.701	1144	19.811	1252	19.704
930	19.86	1038	19.721	1146	19.784	1254	19.714
932	19.884	1040	19.691	1148	19.791	1256	19.692
934	19.884	1042	19.693	1150	19.814	1258	19.684
936	19.844	1044	19.691	1152	19.824	1260	19.706
938	19.82	1046	19.723	1154	19.824	1262	19.696
940	19.813	1048	19.705	1156	19.814	1264	19.696
942	19.815	1050	19.723	1158	19.804	1266	19.696
944	19.82	1052	19.725	1160	19.835	1268	19.718
946	19.843	1054	19.755	1162	19.834	1270	19.748
948	19.8	1056	19.737	1164	19.866	1272	19.73
950	19.813	1058	19.725	1166	19.856	1274	19.728
952	19.823	1060	19.723	1168	19.856	1276	19.76
954	19.814	1062	19.745	1170	19.886		
956	19.833	1064	19.745	1172	19.866		
958	19.824	1066	19.745	1174	19.858		