Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Ballyroan Public Water Supply
Ballyroan Springs

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Prepared by:
Coran Kelly TOBIN

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

And with assistance from:
Laois County Council

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).

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FIGURES

1 INTRODUCTION

Groundwater Source Protection Zones are delineated for the Ballyroan Public Water Supply (Ballyroan Springs) 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 source springs.
- 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 the caretaker), site walk-overs, flow measurements and field mapping (including a well survey, mapping of drainage indicators and logging of bedrock outcrops and subsoil exposures) of the study area were conducted during July and August 2010. Any available additional data were acquired and interpreted together with field data from this study using hydrogeological techniques.

3 LOCATION, SITE DESCRIPTION AND WELL HEAD PROTECTION

Ballyroan Spring is located in County Laois, 3.7 km northeast of Abbeyleix and 2 km south of Ballyroan, in the townland of Tullore as shown in Figure 1. The source is approximately 400 m north of a narrow road running east from the stretch of the R425 between Ballyroan and Abbeyleix. The location of the access gate is shown in Figure 2 along with the three other adjacent outflows, one of which was previously, but is no longer, used for the supply.

The spring is covered and contained within a large concrete chamber, which has two manhole covers: 1) into the main spring chamber; 2) into an accompanying v-notch weir, which measures the overflow from the main spring only, though currently there is no overflow. The water from the chamber flows *via* gravity to Ballyroan, through an intake pipe set into the chamber – see Photograph 1. The water is treated in Ballyroan village and distributed through the network. Photographs 1, 2, 3 and 4 show the intake, v-notch weir, concrete chamber, and access points. The concrete chamber is fenced and gated at the edge of the chamber itself and there is no compound surrounding the source. The spring cannot meet the current demand, hence the scheme is augmented from a borehole at Meelick, part of the Portlaoise Water Supply, which provides approximately 400–450 m^3/d *via* a booster pump adjacent to the Meelick Borehole in Portlaoise. The Meelick source is detailed in a separate report (Kelly *et al* 2010).

4 SUMMARY OF SPRING DETAILS

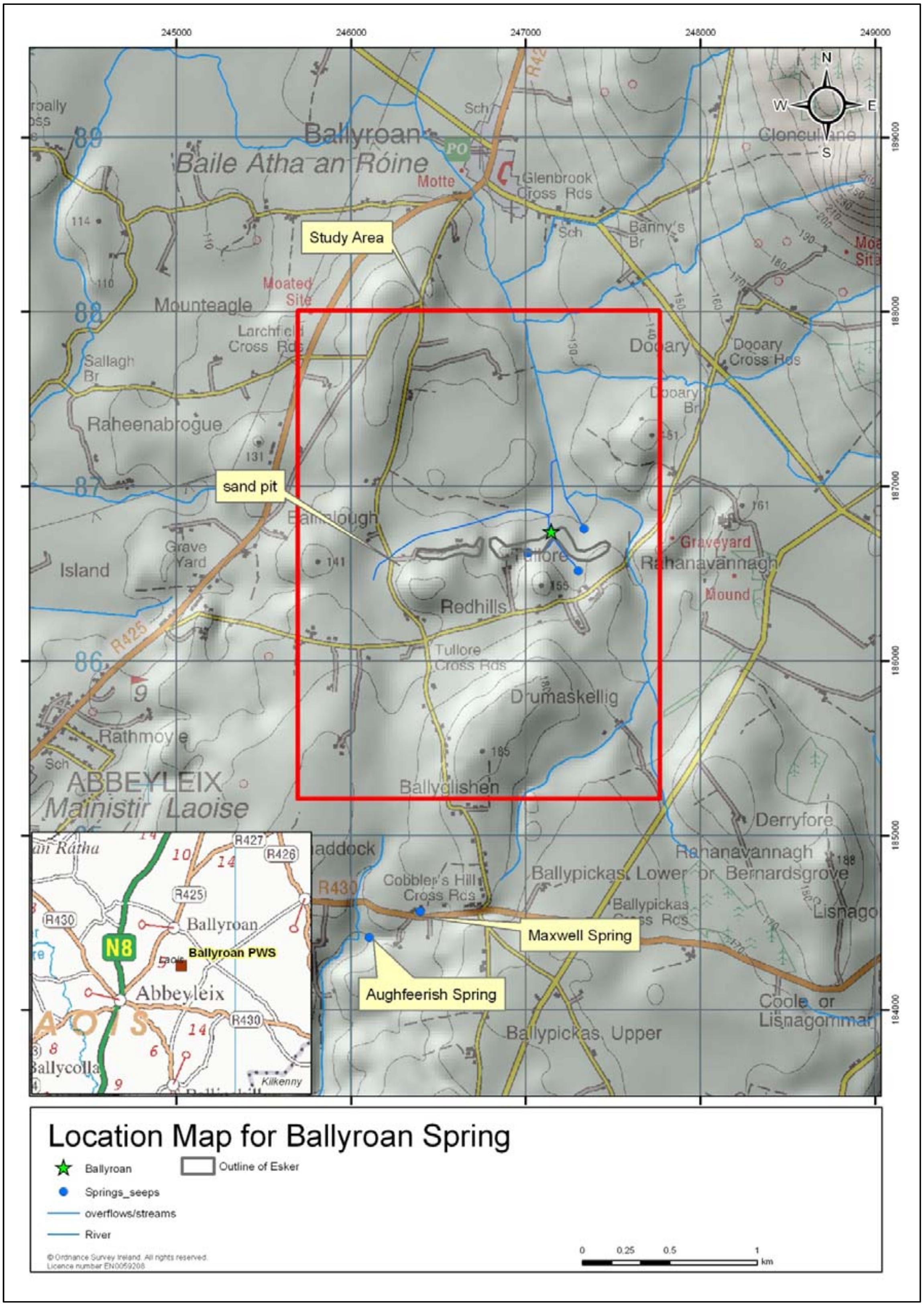
The average abstraction from the spring is 600 m^3/day, based on Laois County Council data.

Table 4-1 Summary of Spring Details – Ballyroan Spring Source

	Ballyroan Springs
EU Reporting Code	IE_SE_G_107_11_003
Source Name	Ballyroan
Grid reference	E247145 N186742
Townland	Tullore
Source type	Spring
Owner	Laois County Council
Elevation (Ground Level)	~131 m OD
Depth to rock	Unknown
Average abstraction rate (Co Co records)	600 m^3/day
Total Discharge	600 m^3/day




Photographs 1-4 of Site Compound (Intake pipe, v-notch weir, concrete cover, access points)


Location Map for Ballyroan Spring
Ballyroan
Outline of Esker
Springs_seeps
overflows/streams
River
Study Area
sand pit
Maxwell Spring
Aughfeerish Spring
Ballyroan PWS
Ballyroan
Baile Átha an Róine
Mounteagle
Raheenabrogue
Island
Redhills
Tullore Cross Rds
Drumaskellig
Ballyglishen
ABBEYLEIX
Mainistir Laoise
Dooary
Rahanavannagh
Derryfore
Ballypickas Lower or Bernardsgrove
Ballypickas Upper
Cobbler's Hill Cross Rds
Coole or Lisnagommar
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Licence number EN0059208
0 0.25 0.5 1 km

Figure 1 Location, topography and hydrology around Ballyroan spring

Figure 2 Aerial View of immediate area around Ballyroan Spring, indicating access gate and adjacent outflows

5 TOPOGRAPHY, SURFACE HYDROLOGY AND LANDUSE

The regional topography shown in Figure 1 is dominated by a low ridge between Abbeyleix and Ballyroan, west of the source, and a hill at Drumaskellig, south of the source which rises to 185 m OD.

At a local scale the topography is hummocky, which can be picked out on Figure 1 as the small hills just south and southwest of the source at Tullore and Redhills. At field scale there are rapid localized changes of slope due to the presence of a west-east aligned esker adjacent to the spring, which at site scale can obscure the more prevalent northerly decline. The outline of the esker is shown in Figure 1.

Whilst the topography is variable, the general gradient falls northwards across the study area, as evidenced by the course of the Ballyroan stream. The slope south of the small third class road running east-west 400 m south of the source is about 0.1, and north of the road down to the spring the topographic gradient is shallower – approximately 0.03, which is more representative of the regional slope.

The Ballyroan stream is the main water course in the area and it originates on the southern side of Drumaskellig, flows north to Ballyroan, swings west and then south back toward Abbeyleix, ultimately to the River Nore. In general the land is free draining and the natural drainage density is very low, particularly south of the source toward Drumaskellig and Ballyglishen. The drainage density is high on the lowest areas north of the source.

There is a cluster of springs at Ballyroan shown in Figure 1 and 2, which are located at the foot of Drumaskellig's northerly slope and they outflow to the Ballyroan stream. These springs include the source spring, an adjacent spring which used to be used as the source, and two smaller springs upgradient of the source spring. The outflow of these two springs flows passes the source spring, combining with the overflow, when it occurs, from the source spring and onto Ballyroan Stream. The v-notch weir is in the main spring chamber, thereby only measuring the overflow from the main spring – which does not occur currently as all the outflow is used. The outflow from the 'old' spring flows directly to the Ballyroan Stream. Also shown in Figure 1 are two notable spring sources which provide water to the northerly component of Abbeyleix PWS and the Ballypickas Group Water Scheme (Aughfeerish and Maxwell spring sources).

Landuse in the study area is mainly agricultural, split between tillage and pasture (Figure 2). Cattle graze the fields adjacent to the spring. A small closed sand pit is located north of Tullore Cross roads, west of the source, marked on Figure 1. There are a number of houses and farms along the road immediately south of the springs.

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: taken to be 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.

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 10 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 Ballyroan source. 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, 2003) and accompanying memoir (Gately et al, 2003),
- the GSI Well, Borehole and Karst Databases,
- EPA Soils and Subsoils Maps (Teagasc, 2006a and 2006b), and
- bedrock outcrops and subsoil exposures encountered and mapped during site visits.

7.1 Bedrock geology

The bedrock across the area is dominated by Namurian Shales as shown in Figure 3. In the vicinity of Ballinlough, *i.e.,* along the ridge between Abbeyleix and Ballyroan, there is a geological boundary mapped marking a change to the underlying Pure Bedded Limestones, which occupy the area west of the ridge.

7.2 Soils and subsoils

Figure 4 and Figure 5 are based on the soils and subsoils maps available from the EPA (Teagasc, 2006a and b). The soils of the area are shown in Figure 4. Shallow well drained soils of basic reaction dominate the hummocky areas south and west of the springs, and also occur on the crest of Drumaskellig, whilst deeper, well drained soils of basic reaction occupy the ridge between Abbeyleix and Ballyroan. The exception to this is an area in Ballinlough, as well as on the backslopes of Drumaskellig, where the soils are shallow dry soils. The shallow well drained soils tend to correspond to gravel subsoils, but in the area on Drumaskellig, they overlie rock close to the surface. Poorly drained soils dominate the lowest areas north and northwest of the springs. Alluvium is mapped along the Ballyroan Stream.

The subsoils around the springs are dominated by sands and gravels which generally occupy the lower portions of the landscape, with the exception of a gravel extension across the ridge at Ballinlough. Southwest of Drumaskellig, the gravels extend along a narrow trough to Ballyglishen. Bedrock outcrop or subcrop is present on Drumaskellig. A small west–east oriented esker is present just south of the spring. Figure 5 shows the mapped subsoils.

Regionally, the sand and gravel deposits are associated with the River Nore and are glaciofluvial in origin; they were deposited by the large quantities of meltwater associated with ice-retreat at the end of the last Ice Age. This glacial history therefore suggests a dominance of coarse sands and gravels.

7.3 Depth to bedrock

Depth to bedrock data are sparse for the area. Drumaskellig has bedrock outcrop / subcrop present on the summit and is therefore rock–cored, and the faces in the sand pit to the west of the springs indicates that the gravels in the vicinity of Redhills and Tullore are greater than 15 m thick. There are also other gravel pits east of Ballyroan Stream. It is assumed that the ridge between Abbeyleix and Ballyroan is rock cored as there is rock close to the surface mapped along the ridge at the northern limit of the study area, as shown in Figure 5. The possible exception to this trend is the presence of the gravels across the ridge at Ballinlough.

8 GROUNDWATER VULNERABILITY

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater ‘target’. 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 is shown in Figure 6. For the purposes of vulnerability mapping in the immediate vicinity of the springs, the “**water table**” is the target, as this lies above the top of the bedrock in the gravels. This map incorporates a proposed area in the immediate vicinity of the springs where the water table is within 3 m of ground level and therefore the vulnerability is Extreme. The extent of this zone is not known for certain, though is considered to approximate the extent of the cutover peat adjacent to the esker. It is expected that the water table does not mimic the local scale topographic changes in the gravels.

Further south towards Drumaskellig, then the “**top of the rock**” is the target. Around the source, sands and gravels, interpreted to be “**high**” permeability, dominate up to the lower flanks of Drumaskellig ridge. Around the upper slopes, limestone till is mapped, which is interpreted to be ‘**moderate’** permeability in the County Laois Groundwater Protection Scheme (Deakin, *et al*, 2000).

Depth to bedrock varies from being greater than 10 m around the springs to zero where the bedrock outcrops on Drumaskellig. At subsoil thicknesses of less than 3 m, as indicated by the outcrop, subcrop and Groundwater Protection Scheme data, bulk subsoil permeability becomes less relevant in mapping vulnerability across wide areas (as opposed to at specific sites). This is because infiltration is more likely to occur through ‘bypass flow’ mechanisms such as cracks in the subsoil. Therefore across the uppermost slopes of Drumaskellig, where bedrock is mapped to be within 3 m of the ground surface, the vulnerability is classed as ‘Extreme’ and where bedrock is at or within a metre of the surface, the vulnerability is denoted as ‘X’, which is a subset of ‘Extreme Vulnerability’. Much of the area is classed as ‘High’ vulnerability corresponding to the ‘high’ permeability sands and gravels. The areas of ‘Moderate’ vulnerability are the areas of ‘moderately’ permeable till, greater than 10 m thick.

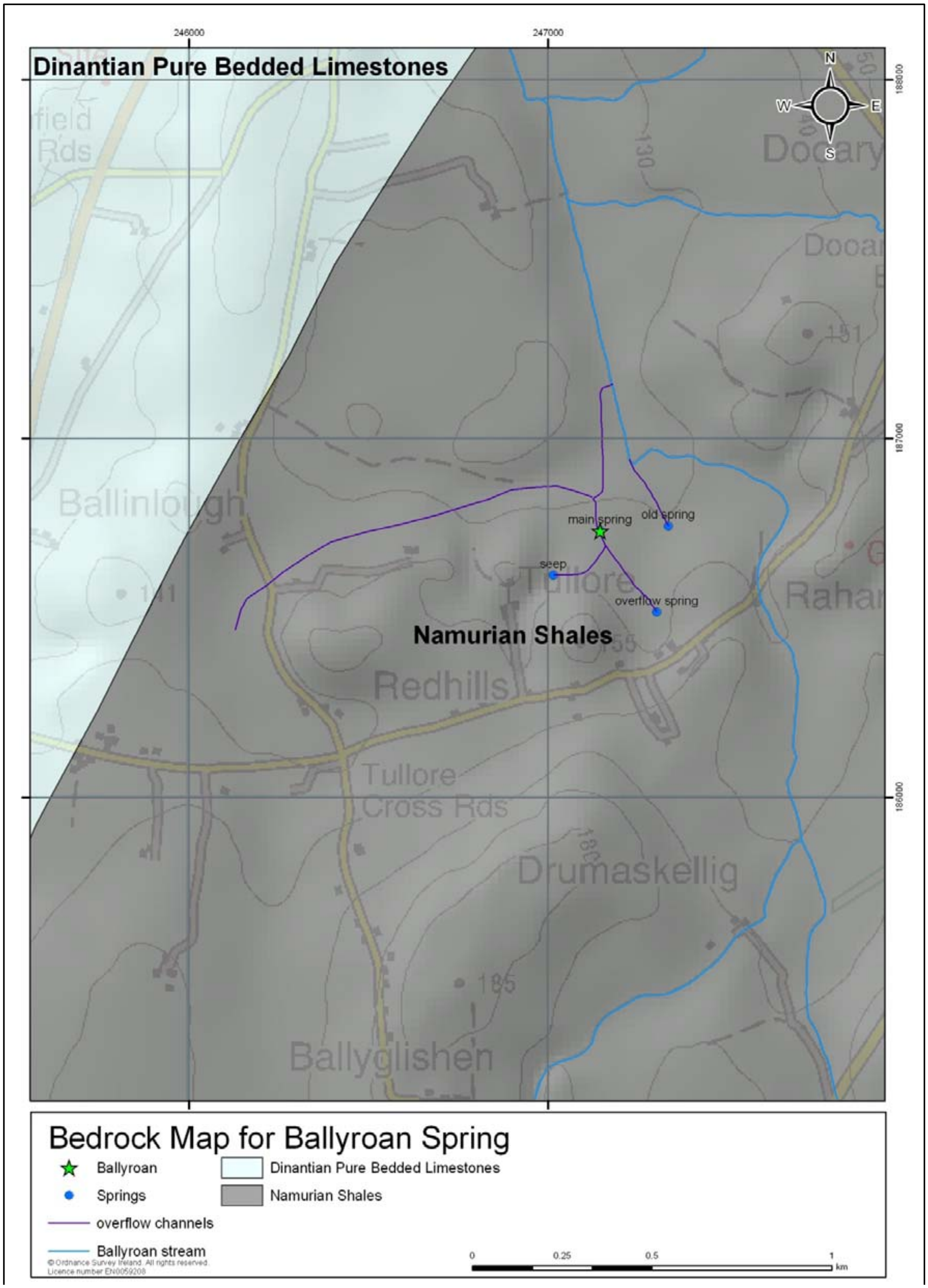


Figure 3 Geology in the vicinity of Ballyroan Spring (no faults or folds mapped in study area)

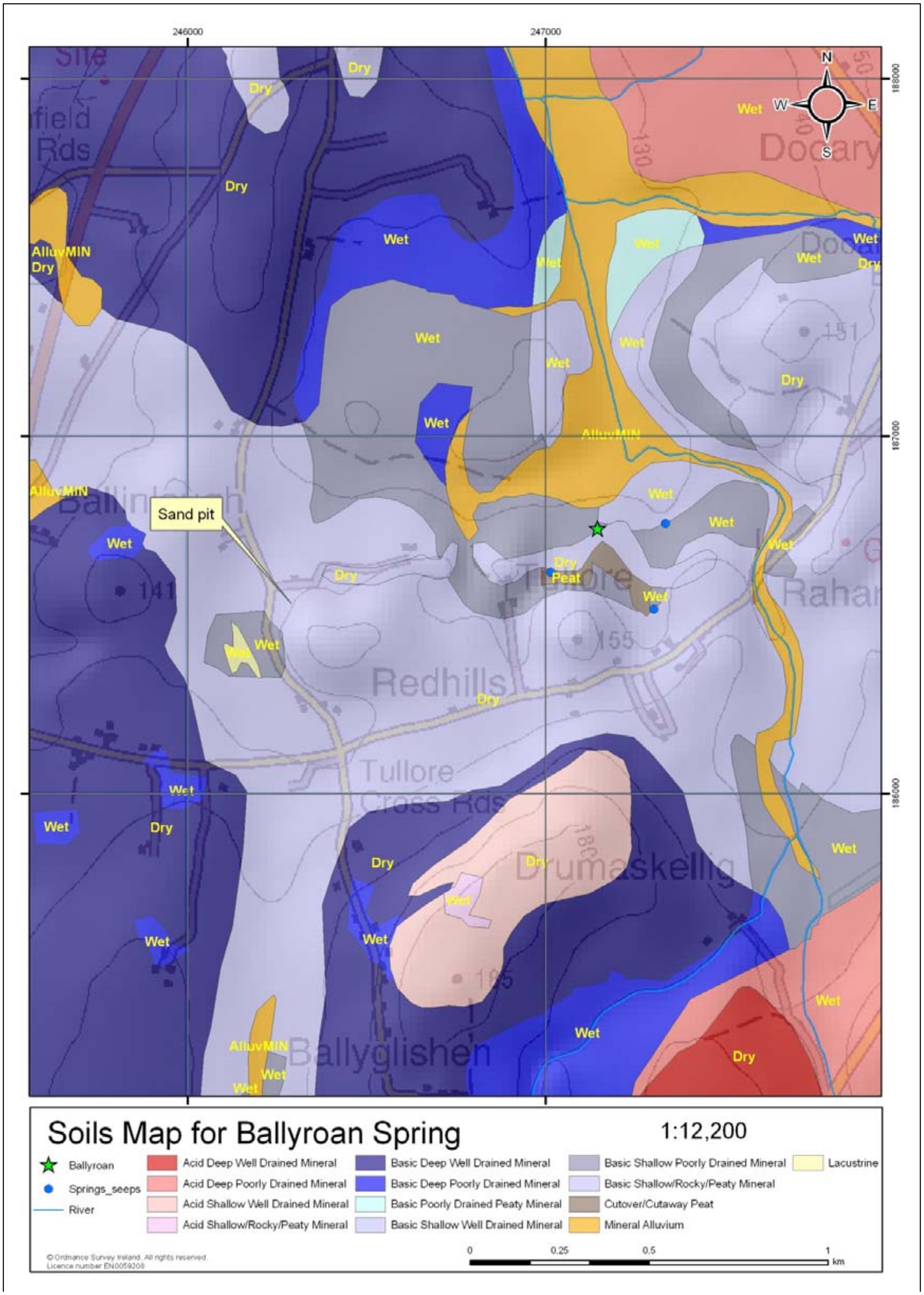


Figure 4 Soils in the vicinity of Ballyroan Spring

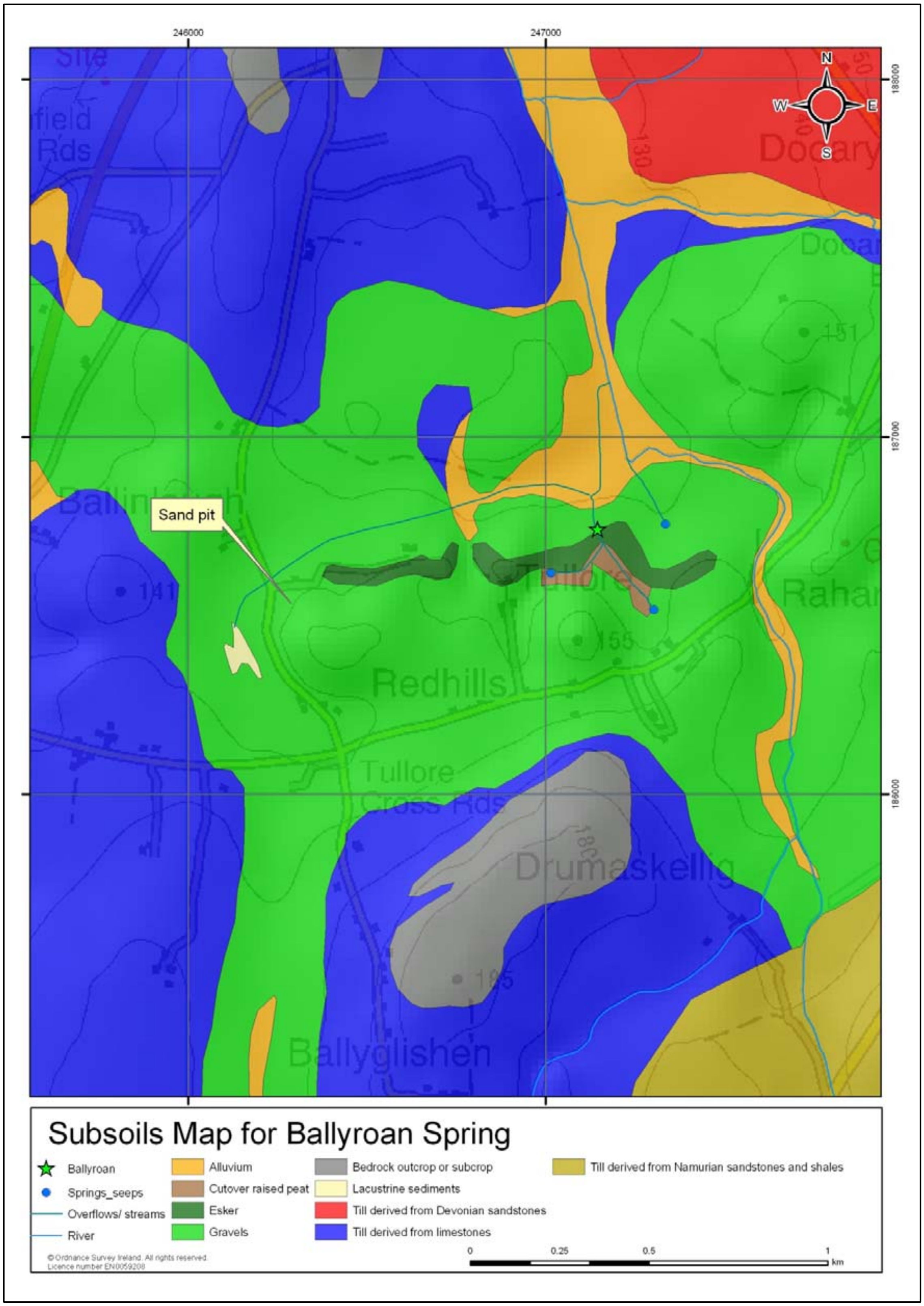


Figure 5 Subsoils in the vicinity of Ballyroan Spring

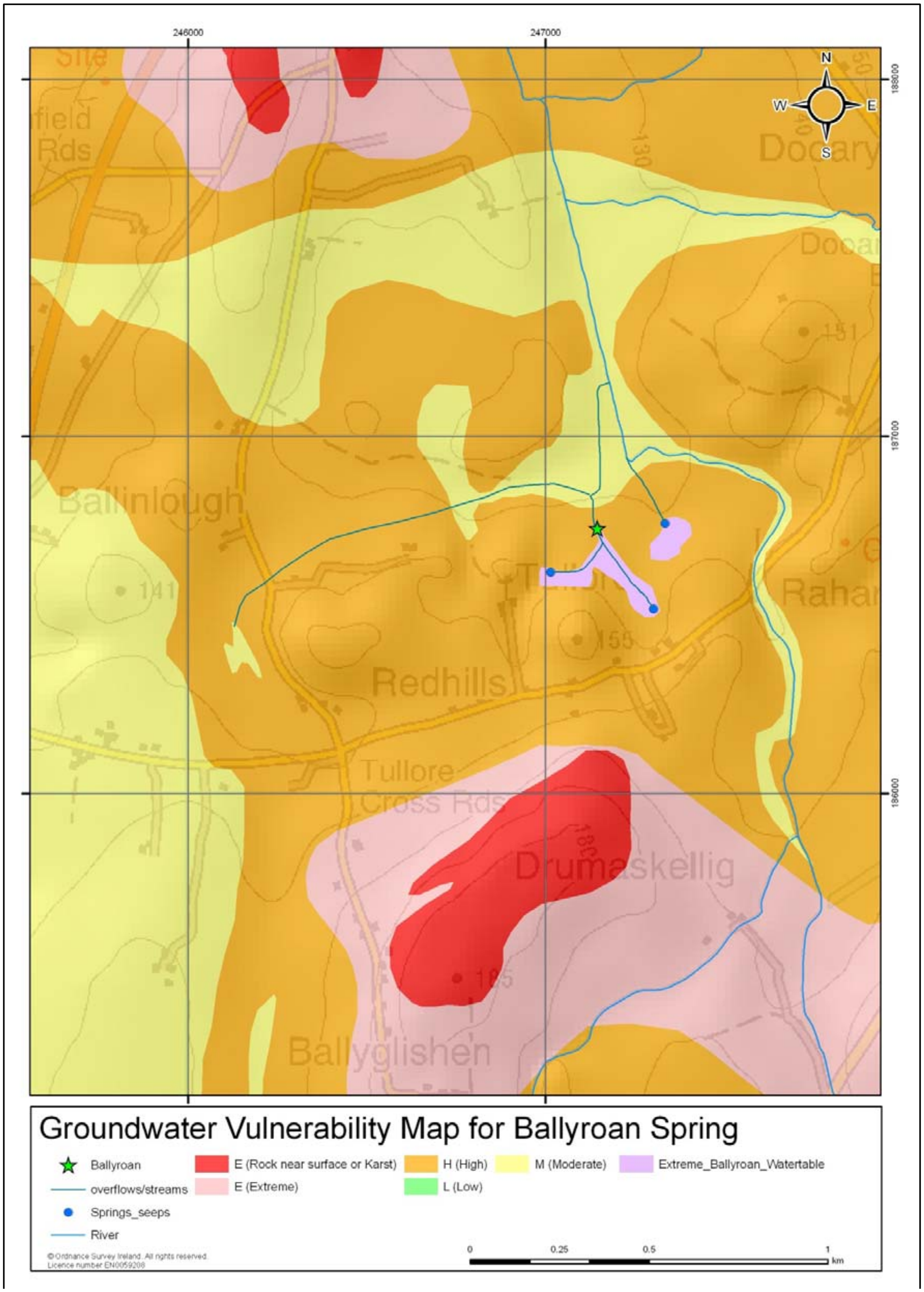


Figure 6 Groundwater Vulnerability in the vicinity of Ballyroan Spring

9 HYDROGEOLOGY

This section describes the current understanding of the hydrogeology in the vicinity of the source. 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
- County Laois Groundwater Protection Scheme (Deakin *et al,* 2000) Geological Survey of Ireland
- An Assessment Of The Quality Of Public And Group Scheme Groundwater Supplies In County Laois. (Fitzsimons, V. and G.R., Wright, 2000) Geological Survey of Ireland
- Hydrogeological mapping by TOBIN Consulting Engineers and Robert Meehan July 2010
- Groundwater Resources of the Nore River Basin (Daly, EP., 1994) Geological Survey of Ireland.

9.1 Groundwater body and status

The source and the surrounding area are located within the Freshford groundwater body (GWB) (GSI, 2005), that is classified as “at 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 Spring discharge

The location of all the main springs in the area are shown on Figures 1 to 6. Figure 1 also shows Aughfeerish and Maxwell Springs, located on the southern side of Drumaskellig.

The springs at Ballyroan comprise the main spring, the old spring and two upgradient outflows. The main spring and old spring are much larger than the two small outflows. Figure 2 indicates the spring currently used for abstraction, the spring previously used for abstraction and two much smaller outflows. Based on field measurements during a dry period, the total outflow from the Ballyroan springs (including abstraction) is in the order of 16 l/s. Further field measurements would improve the reliability of the total discharge estimate.

The main spring has a V-notch built into the chamber. Historically, when abstraction was much less, there was overflow that the caretaker measured. Presently however, the entire flow from the spring is used to contribute to the Portlaoise supply.

The main spring is the largest outflow, approximately 7 l/s, accounting for approximately 45% of the total flow. The most southerly spring marked is a single outflow which flows along a deepened drain where it meets a significantly smaller outflow from the most westerly mapped spring/seep. The southern discharge is larger and visibly gains along the drain also evidenced by field measurements, given in Appendix 1. The outflow from these 2 springs passes the main spring, continuing to gain as it does so, i.e., the outflow does not appear to lose in magnitude, despite uncertainty in measuring the discharge across the gravels in the immediate vicinity of the main spring. The discharge from these 2 springs combined is in the order of 4–5 l/s as they flows passed the main spring, approximately 30% of total outflow.

The ‘old’ spring discharges in the order of 4 l/s based on 2 field estimates, representing about 25% of the total flow.

9.3 Groundwater levels, flow directions and gradients

Apart from the springs, hydrogeological data are sparse. The springs represent the water table intersecting the groundwater surface.

Flow directions comprise a component of flow that is N–S from Drumaskellig hill and a component of flow that sweeps around the base of this hill from Ballymaddock. It is assumed groundwater is flowing towards Ballyroan Stream discharging at the break in slope before flowing onto the stream.

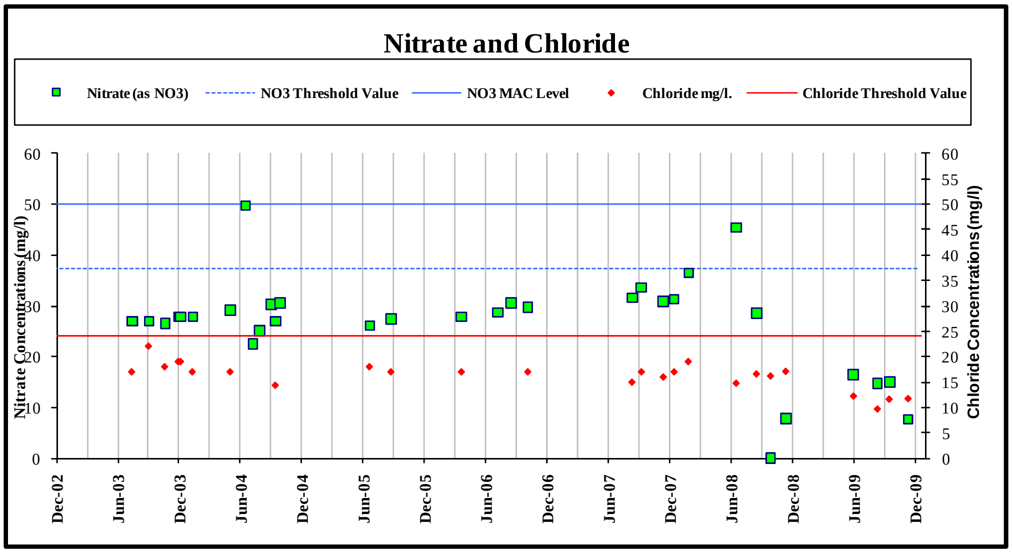
The road to the south of the springs paralleling the 150 m OD contour marks a regional change in slope. South of the road up to the top of Drumaskellig hill, the topographic gradient is about 0.1, and north of the road down to the springs the gradient is shallower – approximately 0.03, which is more representative of the regional slope. The gradient of the water table in the gravels is considered to be less than 0.03, in the order of 0.008.

9.4 Hydrochemistry and water quality

The hydrochemical analyses of 13 EPA untreated samples from 2007–2009 and Local Authority drinking water returns from 2003–2006, show that the water is moderately hard to very hard, with total hardness values of 213–421 mg/l (equivalent $CaCO_3$) and electrical conductivity (EC) values of 464–722 μS/cm, (average 643 μS/cm) indicating that the groundwater has a calcium bicarbonate hydrochemical signature (EPA data). Alkalinity ranges from 230–410 mg/l $CaCO_3$. The pH ranges 6.9-8.3, with an average of 7.4, which is alkaline. Figure 7 shows the data for the key indicators of contamination and the main points are as follows:

- Nitrate concentrations range from 7.7–49.7 mg/l with a mean of 27.4 mg/l. The mean is less than the groundwater Threshold Value (Groundwater regulations S.I. No. 9 of 2010) value of 37.5 mg/l and less than the standard (50 mg/l) set out in the Drinking Water Regulations (S.I. No. 278 of 2007). It is possible that recent wet summers have influenced the data. Since late 2008 there has been a significant reduction in nitrate concentrations which has affected the average and the overall trend. The average prior to September 2008 is 30 mg/l and the trend in the data was upward.
- Ammonia and manganese concentrations are low.
- 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 9.8 to 22 mg/l with a mean of 16 mg/l. The most recent data from 2009 indicate that the average concentration has decreased recently, prior to September 2008 the average concentration was 17 mg/l.
- The mean concentration of Molybdate Reactive Phosphorous (MRP) is 0.01 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. The ratio exceeded 0.4 on 10/5/2004.
- Faecal coliform counts exceeded the Drinking Water Standard of zero (Drinking Water regulations S.I. No. 278 of 2007) on 12/8/2004, with a count of 6/100ml. Counts above 10/100 ml indicate gross contamination. Total coliform counts were exceeded on 9 occasions from 13 untreated water samples from 2007–2009.

In summary, the water quality is currently generally good though occasionally contaminated, as evidenced by elevated nitrate, potassium:sodium ratio, total coliforms and one recorded exceedance of faecal coliforms. Fitzsimons (2000) highlighted nitrate as a particular issue at Ballyroan.



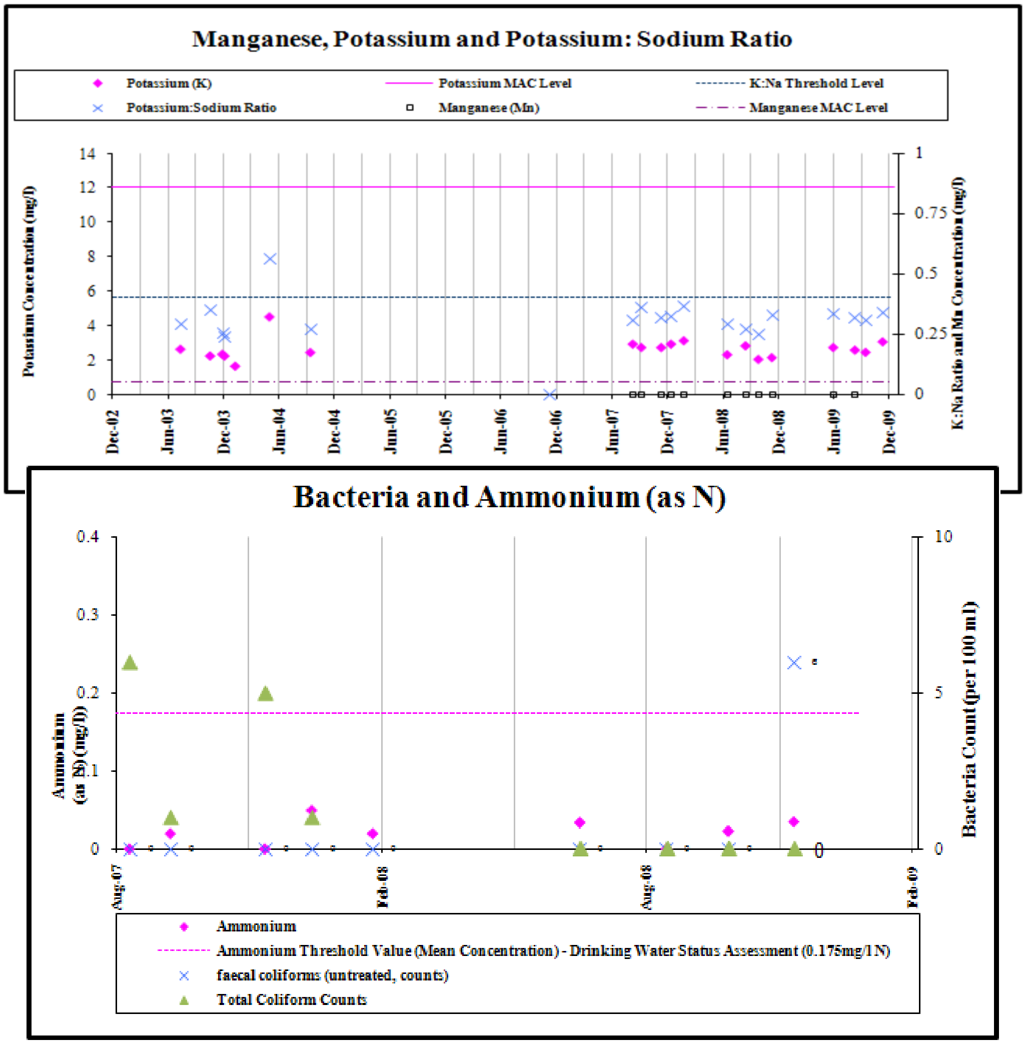


Figure 7 Key indicators of contamination at Ballyroan Spring

9.5 Aquifer characteristics

Ballyroan springs discharge from a sand and gravel deposit at a break in slope, where groundwater is focussed at a central location, probably due to a funnelling effect of the topography driving the groundwater. The sand/gravel in the area is classed as a Regionally Important Sand and Gravel aquifer (Rg).

Permeability values are unknown at Ballyroan but across the Freshford Sand and Gravel Groundwater Body (GSI, 2005) permeability values are expected to be high because of the coarse nature of the deposits.

Permeability is assumed to be 50 m/d (based on work by E.P. Daly for estimates for the gravel deposits in Laois and Kilkenny within the River Nore Catchment; Daly, 1994, Buckley *et al*, 2002), and porosity assumed to be in the order of 10%.

Velocity = K (permeability) x i (gradient) / n (porosity)
= 50 * 0.008 / 0.1
= 4 m/d.

The discharge at the springs is greater than 5 l/s, which is a ‘large’ spring according to the GSI Spring classification scheme. In the vicinity of the springs groundwater velocities are likely to be high and the sand and gravel aquifer is unconfined.

10 ZONE OF CONTRIBUTION

10.1 Conceptual model

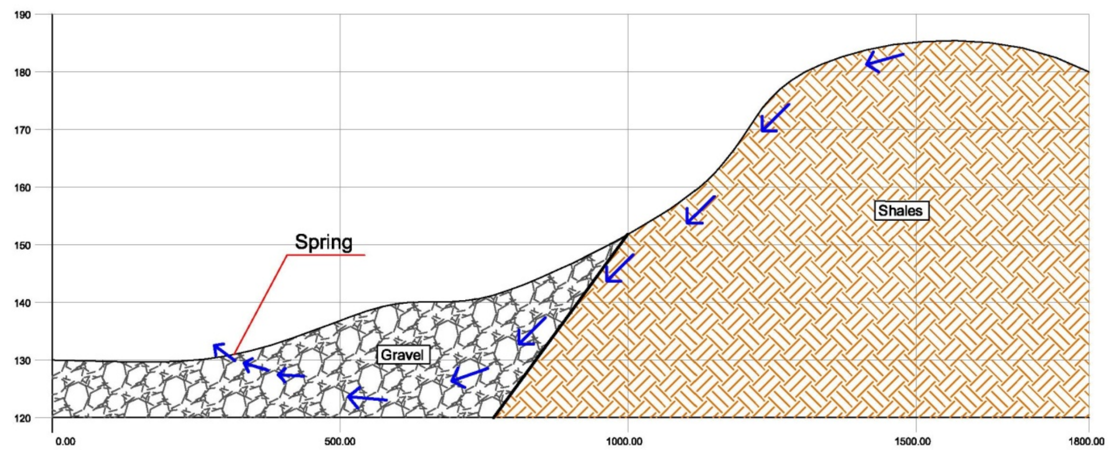
Ballyroan spring is one of a cluster of four springs discharging from a sand and gravel deposit at a break in slope, where groundwater is focused at a central location, due to a funneling effect of the topography driving the groundwater. The sand/gravel in the area is classed as a Regionally Important Sand and Gravel aquifer (Rg).

The outflow from Ballyroan Spring and an adjacent spring make up 75% of the total flow, whilst the two smaller outflows present upgradient of the main spring are significantly smaller and are considered to be overflows of the main springs. The combined outflow of the springs joins Ballyroan Stream, which flows north to Ballyroan.

The groundwater is considered to flow through the sand and gravel focusing mainly at the Ballyroan Spring. Groundwater in the bedrock is assumed to ‘recharge’ into the gravels issuing at the springs. Recharge over the rock cored hill to the south ‘recharges’ into the sand and gravel which also receives direct recharge, *i.e.,* recharge to the sand and gravel is both direct and indirect.

A cross section is shown in Figure 8.

LOCATION MAP SHOWING LOCATION OF LONGITUDINAL SECTION
Scale 1:50,000



LONGITUDINAL SECTION SHOWING GEOLOGY
Scale H: 1:10,000 V: 1:1,000

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL DRAWINGS TO BE CHECKED BY THE CONTRACTOR ON SITE
3. ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
4. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.
B	16.05.11	SECTION AMENDED	MN	CK
A	06.12.10	DRAFT ISSUE FOR REVIEW	MN	JD

Client: EPA / GSI

Project: ABBEYLEIX

Title: CONCEPTUAL LONGITUDINAL SECTION N - S

Scale @ A3: As Shown

Prepared by: M. Nolan | Checked: J. Dillon | Date: December 2010

Project Director: D. Grehan

TOBIN
Patrick J. Tobin & Co. Ltd.
Consulting, Civil and Structural Engineers,
Block 10-3, Blanchardstown Corporate Park,
Dublin 15, Ireland.
tel: +353-(0)1-8030406
fax:+353-(0)1-8030409
e-mail: info@tobin.ie
www.tobin.ie

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Figure 8 Cross section through Drumaskellig to Ballyroan Spring

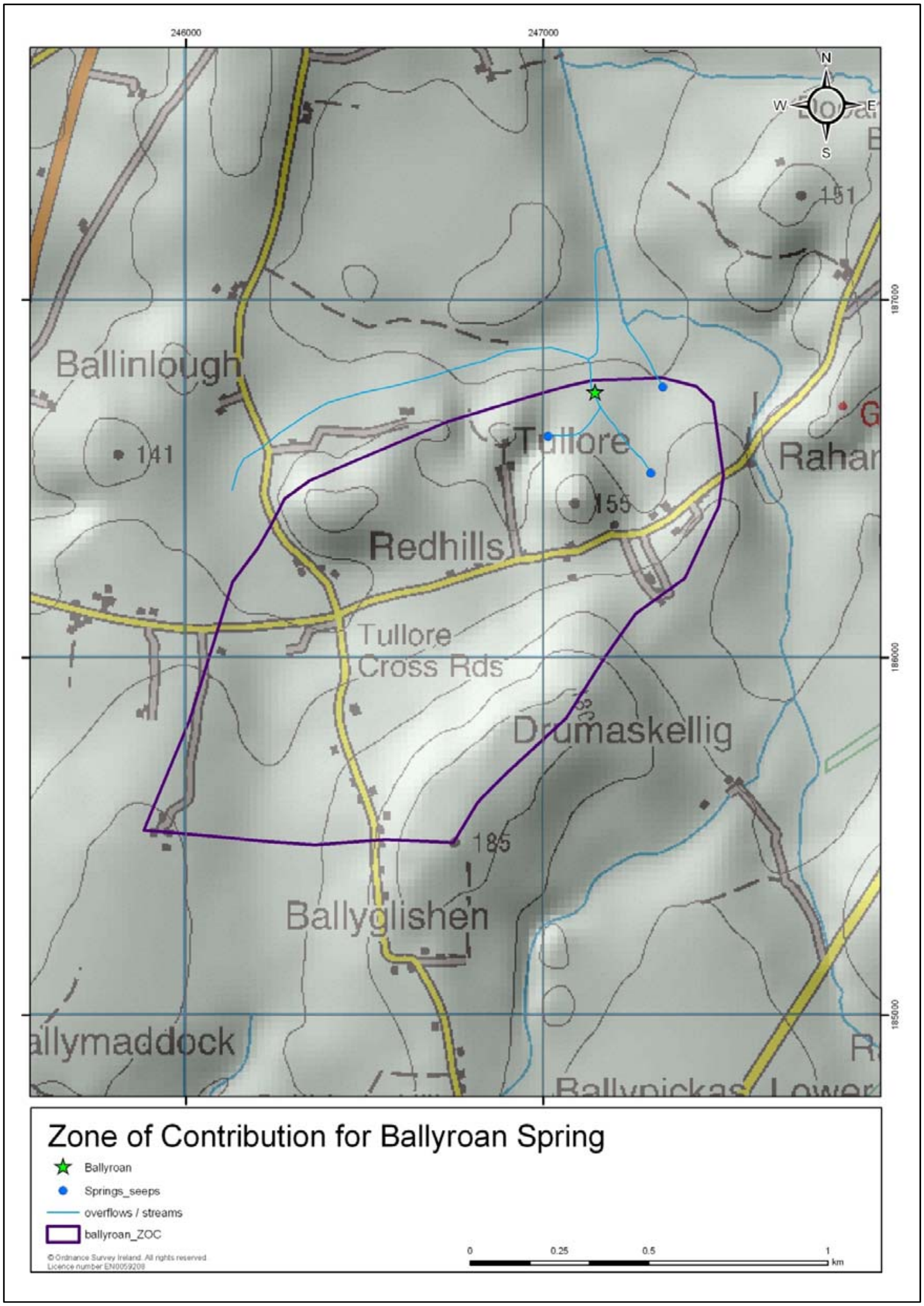

Figure 9 Zone of Contribution for Ballyroan Spring

10.2 Boundaries of the ZOC

The boundaries of the area contributing to the source are shown in Figure 9 and considered to be as follows.

The **northern** boundary is defined by a 30 m buffer applied to the location of the 2 larger outflows. It is assumed that groundwater cannot flow to the springs from the northern downgradient side of the springs.

The **southern** and **southwestern** and **western** boundaries are constrained by the rock cored hill of Drumaskellig, the north-south ridge between Abbeyleix and Ballyroan both assumed to be surface water and groundwater divides, the occurrence of Aughfeerish and Maxwell springs south of Drumaskellig, and the absence of springs, seeps or major outflows from the area between Tullore cross roads and Ballyglishen. It is assumed that groundwater in this area is funnelled toward Ballyroan Springs. There is considerable uncertainty about the location of the boundary joining Drumaskellig and the north-south ridge. The area of particular uncertainty is depicted in Figure 9.

The **northwestern** boundary is based on the assumption that groundwater from the southwestern part of the zone of contribution is discharging at Ballyroan. The local topographic highs in the hummocky terrain of the gravel deposit at Redhills and Tullore do not define a groundwater divide. The boundary is based on extending the southwestern boundary toward Ballyroan Springs and there is considerable uncertainty about the location of this boundary as the groundwater flow directions are not known. It is conservatively delineated allowing for this uncertainty.

The **eastern** boundary is constrained by Drumaskellig and is based on the assumption that the northeastern limit of the ridge is rock cored, and that it separates groundwater flowing to the river or to the springs.

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 Ballyroan, 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, which is given in Appendix 2.

The recharge over the extreme and high vulnerability areas comprising gravels and moderately permeable till and rock close to or at surface is mainly diffuse, and is in the order of 85%.

The recharge 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 potential recharge	472 mm
Recharge coefficient	85%
Recharge	400 mm

Water Balance: The area described above, and shown in Figure 12, is 1.3 km^2, which is two times greater than required for the actual abstraction rate at the public supply. However, the area described above is for the total spring discharge (as the ZOCs for the individual springs cannot be separated) which is in the order of 15–16 l/s (1300–1400 m^3/day). The area described is also larger than the area required to provide the total outflow by approximately 11%. This greater area allows for uncertainty in flow directions, and variations in spring flows, and includes the most likely hydrogeological area that feeds the springs. In order to take a more conservative approach and to allow for uncertainties, a ZOC based on 50% increased yield is typically adopted. In this particular case the total mean flow is used, which at 1400 m^3/day is much greater than 50% of the abstraction rate.

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 10.

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). This is based on the velocity estimate of 4 m/d given in the Aquifer Characteristics. Therefore the 100 day Time of Travel is estimated to be 400 m.

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

The Source Protection Zones are shown in Figure 11 and are listed in Table 11-1.

Table 11-1 Source Protection Zones

Source Protection Zone		% of total area (1.35km^2)
SI/E	Inner Source Protection area / <3 m to water table	2% (0.03 km^2)
SI/H	Inner Source Protection area / High vulnerability	16% (0.21 km^2)
SO/X	Outer Source Protection area / ≤1 m subsoil	12% (0.16 km^2)
SO/E	Outer Source Protection area / <3 m subsoil	13% (0.17 km^2)
SO/H	Outer Source Protection area / High vulnerability	49% (0.65 km^2)
SO/M	Outer Source Protection area / Moderate vulnerability	6% (0.08 km^2)

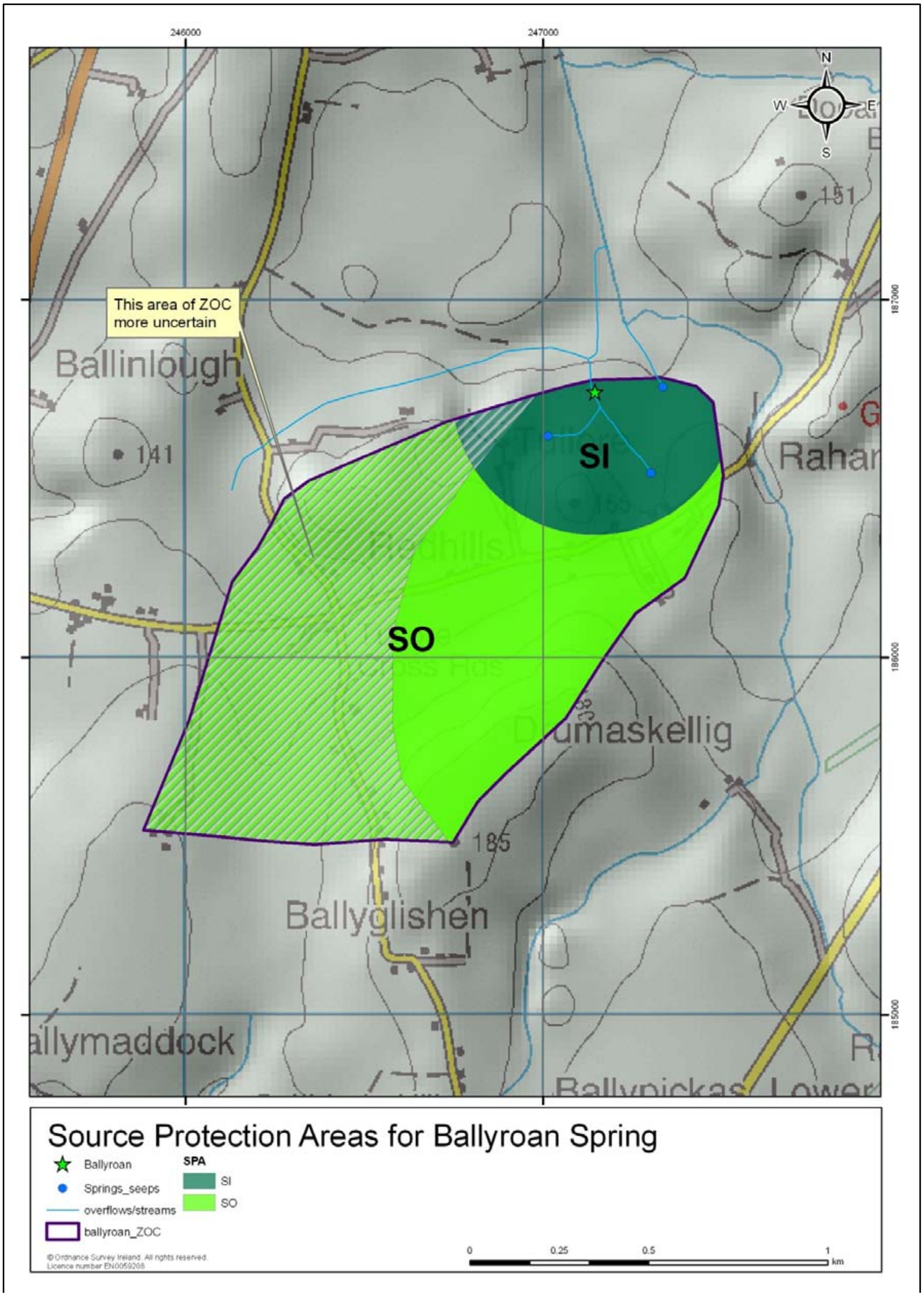

Figure 10 Source Protection Areas for Ballyroan Spring

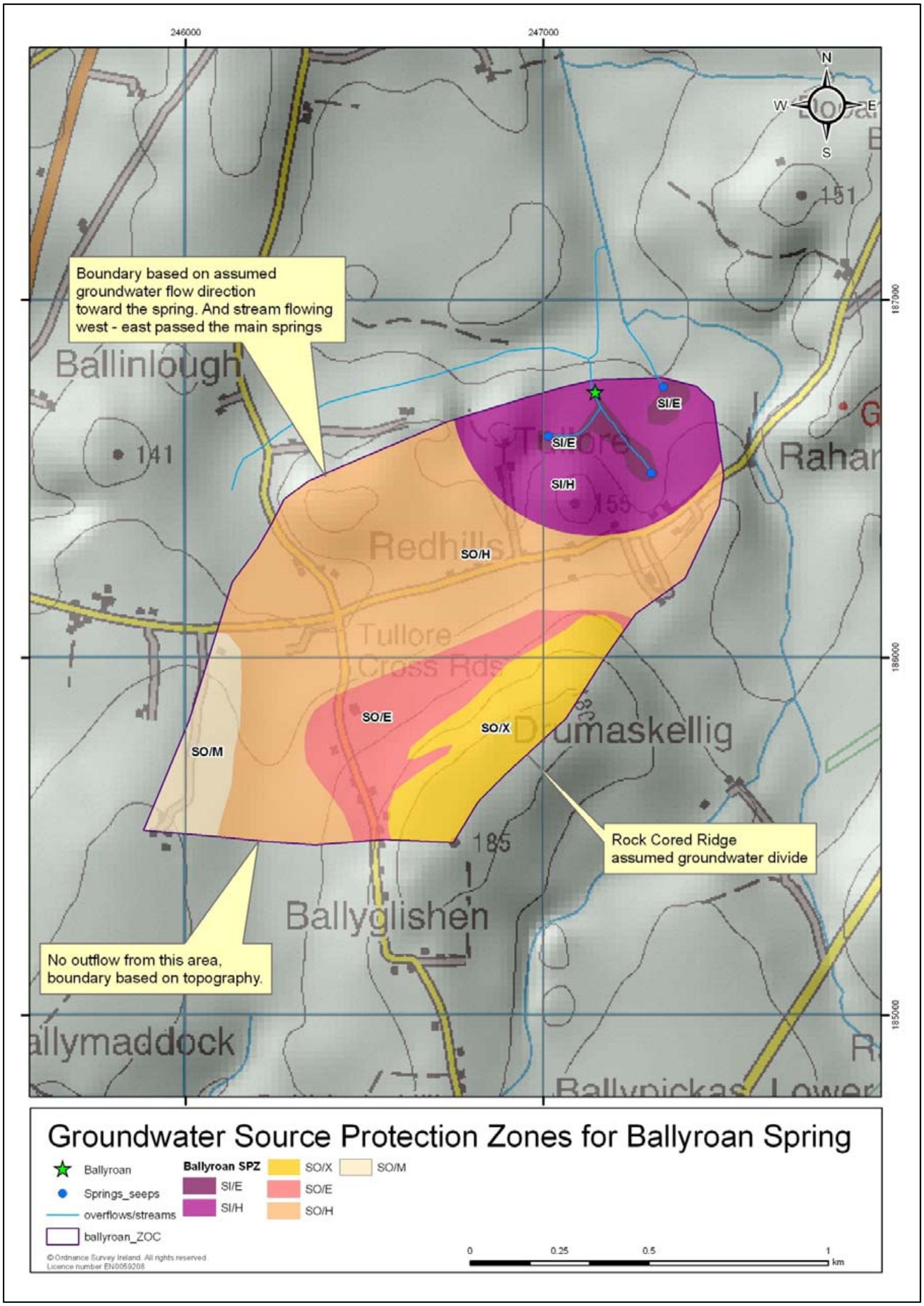

Figure 11 Groundwater Source Protection Zones for Ballyroan Spring

12 POTENTIAL POLLUTION SOURCES

The spring is contained within a covered concrete chamber. There is a slope down to the spring. On the downgradient side the ground declines to the north more steeply, therefore there is little chance for any contamination getting to the spring from the downgradient side. The chamber, despite being covered, is not fenced (????) and is directly bounded by fields, and therefore cattle, for instance, can stand right next to the chamber. The risk of contamination immediately up-gradient of the chamber is moderately high. The water table at the spring is at ground surface thus the vulnerability is ***'Extreme***' and velocity at the spring is '***high***'. Regular Total coliforms are in evidence in the untreated water.

The inner protection area encompasses a 400 m buffer around the spring, all of which is either '**extremely'** or '**highly**' vulnerable to contamination. Rainfall landing on the fields within 400 m upgradient of the source can get to the springs relatively quickly. Land use in this area is mainly set to grazing cattle.

Across the rest of the outer protection area (SO), the groundwater vulnerability is '***Extreme'*** (both '**E'** and '**X'**) or '**High'**. There are a number of houses and farms and farm yards on the flanks of Drumaskellig directly upgradient of the springs which pose a risk to the source. Finally, there are a number of roads present in the ZOC. The main potential contaminants from this source are surface water runoff contaminated with hydrocarbons and metals. However, the low traffic density locally indicates that the risk of such contamination is low.

13 CONCLUSIONS

The Ballyroan Water Supply Scheme comprises a spring, though the scheme is currently being augmented by Portlaoise WS (Meelick Borehole). The source spring is one of a cluster of four springs discharging from a sand and gravel deposit classified as a Regionally Important Sand and Gravel Aquifer (Rg). The total outflow is in the order of 16 l/s (1300 m^3/d) and the source spring represents just under half of the total outflow.

The groundwater vulnerability with the Inner Source Protection Area is '***Extreme'*** or '***High***'. Nitrate concentrations have been historically high and the recent apparent decrease appears to be influenced by recent wet summers. Over the majority of the remainder of the area, the vulnerability is predominantly ***High***. The uppermost slopes and crest of Drumaskellig are mapped as '***Extreme'*** (both '**E'** and '**X'**) thus represent a high level of risk to the source.

The ZOC encompasses an area of 1.3 km^2. The Source Protection Zones are based on the current understanding of the groundwater conditions and the available data. Additional data obtained in the future may require amendments to the protection zone boundaries.

14 RECOMMENDATIONS

Further investigations might usefully include:

- Drilling of monitoring wells to assist in defining the water table.
- Further flow monitoring.
- Preparation of landspreading exclusion zones.
- Liaising with landowners about the inner protection area and implementing the Good Agricultural Practices.

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APPENDIX 1 FLOW DATA

		Ballyroan spring streams						
South eastern arm; just downfrom field-bridge & before confluence with Sth Western arm								
						Easting	Northing	
		Section 1				**247169**	**286688**	
		Width	Depth	Cross Sec area				
		0.4	0.05	0.02				
3 Minute Average Velocity Reading				0.08	m/s			
		Discharge		0.0016	m3/s			
				1.6	litres/s			
		Section 2						
		Width	Depth	Cross Sec area				
		0.3	0.04	0.012				
3 Minute Average Velocity Reading				0.18	m/s			
		Discharge		0.00216	m3/s			
				2.16	litres/s			
		Section 3						
		Width	Depth	Cross Sec area				
		0.4	0.03	0.012				
3 Minute Average Velocity Reading				0.21	m/s			
		Discharge		0.00252	m3/s			
				2.52	litres/s			
South western arm; tried a few locations along the stream line								
Dpeth of water << 2cm; Vane wouldn't turn								
After confluence of SW and SW arms, just 'upstream' / alongside of source sump						Easting	Northing	
at the water feeding area for cattle between the two fields						**247147**	**286729**	
According to the GPS, elevation 134m to 12.7m accuracy								
		Section 1						
		Width	Depth	Cross Sec area				
		0.3	0.05	0.015				
3 Minute Average Velocity Reading				0.34	m/s			
		Discharge		0.0051	m3/s			
				5.1	litres/s			
		Section 2						
		Width	Depth	Cross Sec area				
		0.3	0.07	0.021				
3 Minute Average Velocity Reading				0.18	m/s			
		Discharge		0.00378	m3/s			
				3.78	litres/s			
	Note; just taken for refernece							

APPENDIX 2 RECHARGE COEFFICIENT TABLE

Table 1: Recharge coefficients for different hydrogeological settings.

'ulnerability category		Hydrogeological setting	Recharge coefficient (rc)		
			Min (%)	Inner Range	Max (%)*
Extreme	1.i	Areas where rock is at ground surface	60	80-90	100
	1.ii	Sand/gravel overlain by 'well drained' soil	60	80-90	100
		Sand/gravel overlain by 'poorly drained' (gley) soil			
	1.iii	Till overlain by 'well drained' soil	45	50-70	80
	1.iv	Till overlain by 'poorly drained' (gley) soil	15	25-40	50
	1.v	Sand/ gravel aquifer where the water table is = 3 m below surface	70	80-90	100
	1.vi	Peat	15	25-40	50
High	2.i	Sand/gravel aquifer, overlain by 'well drained' soil	60	80-90	100
	2.ii	High permeability subsoil (sand/gravel) overlain by 'well drained' soil	60	80-90	100
	2.iii	High permeability subsoil (sand/gravel) overlain by 'poorly drained' soil			
	2.iv	Moderate permeability subsoil overlain by 'well drained' soil	35	50-70	80
	2.v	Moderate permeability subsoil overlain by 'poorly drained' (gley) soil	15	25-40	50
	2.vi	Low permeability subsoil	10	23-30	40
	2.vii	Peat	0	5-15	20
Moderate	3.i	Moderate permeability subsoil and overlain by 'well drained'soil	25	30-40	60
	3.ii	Moderate permeability subsoil and overlain by 'poorly drained' (gley) soil	10	20-40	50
	3.iii	Low permeability subsoil	5	10-20	30
	3. iv	Basin peat	0	3-5	10
Low	4.i	Low permeability subsoil	2	5-15	20
	4.ii	Basin peat	0	3-5	10
High to Low	5.i	High Permeability Subsoils (Sand & Gravels)	60	85	100
	5.ii	Moderate Permeability Subsoil overlain by well drained soils	25	50	80
	5.iii	Moderate Permeability Subsoils overlain by poorly drained soils	10	30	50
	5.iv	Low Permeability Subsoil	2	20	40
	5.v	Peat	0	5	20

Acknowledgement: many of the recharge coefficients in this table are based largely on a paper submitted by Fitzsimons and Misstear.

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