Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Glenbeha Water Supply Scheme

Glenbeha Springs PWS

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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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1 Introduction

Groundwater Source Protection Zones (SPZ) are delineated for the Glenbeha Springs PWS (IE_SE_G_086_22_003) 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 SPZ Delineation.

Glenbeha Springs PWS is the main groundwater source for the town of Roscrea. The PWS comprises two enclosed springs. When spring flow levels decrease at Glenbeha, water abstraction is augmented by surface water abstraction from the Little Brosna River, 5 km to the north of Glenbeha Springs PWS.

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the Glenbeha area, where the springs are located.
- To delineate source protection zones for the Glenbeha Springs.
- To assist the EPA and North Tipperary County Council in protecting the water supply from contamination.

The protection zones are intended to provide a guide in the planning and regulation of development and human activities to ensure groundwater quality is protected. More details on protection zones are presented in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

2 Methodology

The methodology consisted of data collection, desk studies, site visits and field mapping. Analysis of the information collected during the studies was used to delineate the SPZ.

The initial site visit and interview with the caretaker took place on 28/08/2010. Site walk-overs, groundwater monitoring and field mapping of the study area (including measuring the electrical conductivity and temperature of streams in the area) were conducted on 28/08/2010 and 02/09/2010.

A large quantity of information was gathered for the Glenbeha Springs Assessment (Hyder Consulting, 2007) as part of the monitoring work on the M7 Castletown to Nenagh Scheme. This information was gathered to assess the potential impact on the source as a result of a 10 m deep motorway cutting approximately 450 m to the south and southwest of Glenbeha Springs PWS. Additional rainfall and abstraction data were made available from North Tipperary County Council. Site investigation and monitoring at Glenbeha springs by Hyder Consulting included geophysics surveys, borehole drilling, groundwater level monitoring, rainfall monitoring and surface water runoff monitoring.

The maps produced are based largely on the readily available information in the area, specific field work for this source protection mapping project, as well as 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. More details on protection zones are presented in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

3 Location, site description and well head protection

Glenbeha springs are located 3 km to the southwest of Roscrea town centre in the townland of Ballycrine, as shown in Figures1 and 2. The source corresponds to the location of a spring 'St Patrick Well' marked on the OSI 6" maps. According to the caretaker, the springs were developed in the 1950s with upgrade works completed in 2002. A house and septic tank located upgradient of the springs was removed as part of the upgrade works. Additional works included culverting of groundwater/surface water from Spring 3, along with enclosing the springs and the purchase of lands surrounding Spring 1 and Spring 2.

The source comprises two enclosed springs (Springs 1 and Spring 2) on either side of a laneway. A third spring (Spring 3) is not used at present as it is not covered and is susceptible to potential contamination. Two weirs are installed to monitor the surface water discharge and the discharge from Spring 3. Spring 3 currently discharges to the surrounding surface drainage network and is culverted from the intake point, through Weir 1 and discharged via Weir 2. The arrangement is illustrated below in Figure 1.

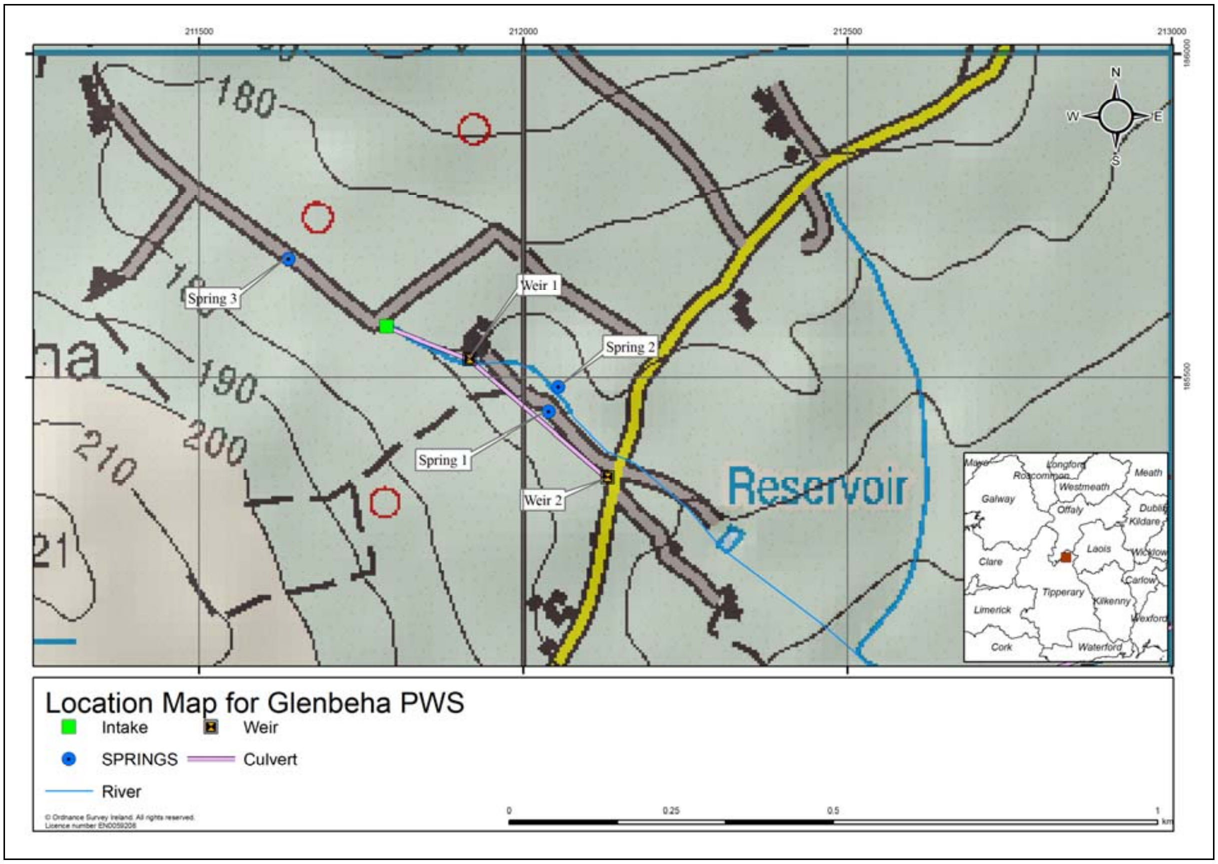

Figure 1 Spring layout at Glenbeha PWS

North Tipperary County Council acquired approximately 25 hectares around the source to enable better source protection and improve the raw water quality in the early 2000s. The council currently own land surrounding Spring 1 and Spring 2, as well as the intake culvert for Spring 3. As part of the source protection at the springs, no grazing or landspreading occurs within the council owned lands. The site is fenced off and is secured with a padlocked gate.

The Glenbeha Water Supply Scheme abstracts on average 1,400 m^3/day of groundwater from Springs 1 and 2 but is highly variable as a result of the flashy nature of the springs. A submersible pump delivers the groundwater to the pump house where the untreated water is chlorinated and stored in a reservoir.

Photograph 1 Cover of Glenbeha Spring 1

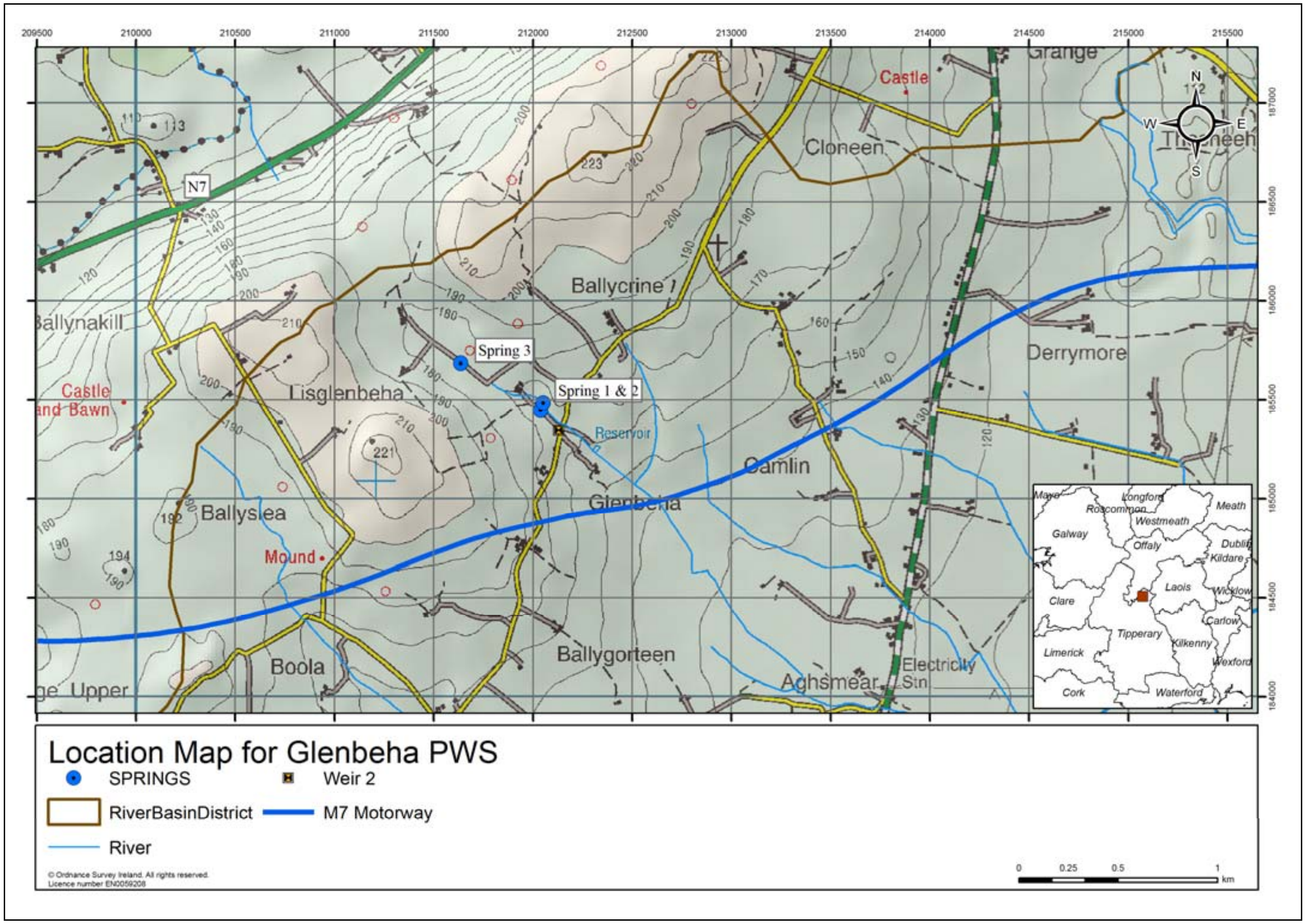

Figure 2 Location Map at Glenbeha Springs PWS

4 Summary of spring details

The groundwater abstraction varies thought the year based on data obtained from North Tipperary County Council. The maximum quantity of water possible is abstracted from the sump areas in Spring 1 and Spring 2, with the average abstraction being 1,400 m^3/day based on 2007 – 2010 data from North Tipperary County Council. The abstraction increases up to 6,600 m^3/day during wet periods and drops to less than 100 m^3/day during prolonged dry periods.

All groundwater entering Springs 1 and 2 is abstracted during low flow periods. Some groundwater is diverted to Weir 2 during winter high flow periods when groundwater supply exceeds the treatment capacity at the adjacent water works. The yield of spring 3 has not been measured but is know to dry up in the dry summer period and at time of low rainfall. The overflow at Weir 2 is 600 m^3/day on average, but can increase to 10,000 m^3/day during wet periods. It is estimated that at least 50% of the water collected at Weir 1 is groundwater from Spring 3.

The water levels at the springs were dipped to establish the depth of the watertable and were recorded to between 0.8 and 1.0 m below the top of the spring housing. Levels are known to drop by approximately 0.5 m during dry summers. **Error! Reference source not found.** provides a summary of the details as currently known.

Table 4.1 Summary of Source Details

	Glenbeha springs
EU Reporting Code	IE_SE_G_086_22_003
Grid reference	E212040 N185450
Townland	Ballycrine
Source type	Spring
Owner	North Tipperary Co. Co.
Elevation (Ground Level)	161.5 m OD
Depth of housing within both Spring 1 and Spring 2 sumps	1.5 m
Depth to rock	0.7 m
Static water level	0.8 to 1 m bgl
Consumption (Co. Co. records)	Daily average 1,400 m^3/d (spring 1& 2) Varies between 100 m^3/d to 6,600m^3/d
Overflow and Spring 3 (as measured at Weir 2)	0 – 10,000 m^3/day 600 m^3/d (average)
Depth of Sump (Spring 1 & Spring 2)	1.5 m

5 Topography, surface hydrology and landuse

The source springs are located at approximately 161 m OD (Springs 1 and 2) and 171 m OD (Spring 3). The Glenbeha Springs PWS are elevated springs situated on the southern edge of a northeast-southwest orientated ridge. The elevated ridge and springs are located between the N7 road and the M7 motorway.

Typical topographic gradients in the study area range from between 1:20 on elevated areas and 1:100 on lower lying areas. Moderate gradients of 1:100 are located in the area around the springs. The density of drainage ditches are generally low in the till areas. The source is located within the upper River Nore watershed, close to the River Nore (HA17)/River Shannon (HA25) catchment divide. Few surface water features are evident in the elevated areas around the source. The stream indicated on the OSI maps is culverted from the intake to Weir 2 (See Figure 1). The River Nore is located over 2.5 km southeast of Glenbeha Springs PWS which flows in a north easterly direction.

The area around Glenbeha Springs PWS has a low population density, being rural. Land use in the area is primarily agricultural, with lands set to pasture. A number of farmyards are located both upgradient and downgradient in the surrounding area. The nearest farmyard is located 300 m to the southwest of the source. Grazing and manure spreading is prohibited in county council lands around Glenbeha Springs PWS. No major industry was identified in the environs of Glenbeha Springs PWS.

6 Hydrometerology

Establishing groundwater source protection zones requires an understanding of general hydrometeorological patterns across the area of interest. This information was obtained from Met Eireann.

Annual rainfall: 1232 mm. The closest long term meteorological station to the Glenbeha Springs is at Roscrea. Met Eireann Rainfall data (Met Eireann, 1996) for the Roscrea rainfall gauging station indicate that average rainfall at Roscrea is 882 mm/year. However the Glenbeha spring and study area is 140 m above Roscrea and as a result is likely to encounter higher average rainfall events. According to Met Eireann, annual precipitation levels can increase by 250 mm per 100 m elevation. The height difference between the rainfall gauging station and the existing Roscrea rain gauge is approximately 140 m. Therefore, the annual precipitation due to the elevation of the Glenbeha Springs PWS is adjusted by 350 mm to 1232 mm.

Additional rainfall data are available from the rain gauge at Glenbeha Reservoir. The Rain gauge was installed at Glenbeha Reservoir to provide site specific information for the M7 monitoring programme. The average rainfall was 1570 mm at Glenbeha during the 2009 monitoring period, considerably above the 1232 mm/year. However, rainfall averages for 2009 were approximately 20% higher than the 30-year annual averages which suggests that the long term estimate of 1232 mm is probably reasonable.

Annual evapotranspiration losses: 427 mm. Potential evapotranspiration (P.E.) is estimated to be 450 mm/yr (based on data from Collins and Cummins, 1996). Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits.

Annual Effective Rainfall: 805 mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this, or 805 mm/year.

7 Geology

7.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the site. It provides a framework for the assessment of groundwater flow and delineation of the source protection zones.

The desk study data used comprised the following:

- Hyder Consulting (2007) Glenbeha Springs Assessment;
- Geology of Tipperary. Bedrock Geology 1 : 100,000 Map series, Sheet 18, Geological Survey of Ireland (J.B. Archer, *et al*, 1996); and
- Forest Inventory and planning system – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map, Teagasc (Teagasc, 2004a).

7.2 Bedrock geology

This section briefly describes the relevant characteristics of the geological materials that underlie the Glenbeha Spring. The geological information is based the bedrock geological map of Tipperary Sheet 18, 1:100,000 Series (Archer *et al,* 1996) and the Glenbeha Springs Assessment report (Hyder Consulting, 2007). The bedrock map (Figure 3) indicates that the elevated area is a Devonian inlier underlain principally by the Cadamstown Formation. The Cadamstown Formation is also referred to as Devonian Old Red Sandstones, for the purposes of the generalised rock unit map prepared for the WFD in characterising and describing the groundwater bodies by the GSI.

Boreholes completed as part of the Glenbeha Springs Assessment report (Hyder Consulting, 2007) indicated that the sandstones underlying the area surrounding the springs are comprised of moderately strong to strong, thinly laminated to thinly bedded, light grey sandstones. Borehole locations are shown in Figure 4. The strata generally show a repeated fining upwards sequence with course grained, light grey sandstone fining upwards to become red siltstone.

The sandstones are typically slightly to moderately weathered with close to medium spaced discontinuities. Discontinuities within the sandstone are typically found along bedding planes with some fractures at approximately 30 degrees to horizontal. Approximately 3–10 m of fissured/fractured, weathered sandstones directly underlies Glenbeha Springs 1 and 2 based on borehole information and geophysics.

The Devonian Old Red Sandstones are situated on the northeastern limb of the Slieve Phelim-Devil's Bit-Silvermines Inlier, bounded by Dinantian (early) Sandstones, Shales and Limestones to the north, east and south. Dinantian lower impure limestone form the lowland areas surrounding the Devonian Inlier. The elevated area is located on an anticline known as the Devil's Bit Anticline. The presence of faulting/fracturing of the thick bedded competent sandstones within the Old Red Sandstones is significant as it is generally associated with high permeability values. The bedrock exposures (S1 and S2) comprised of thickly bedded sandstones, generally dipping less than 15^0 from the Devils Bit Anticline.

Along the Glenbeha Springs col, the Glenbeha fault runs in a northwest/southeastly direction through the Glenbeha springs.

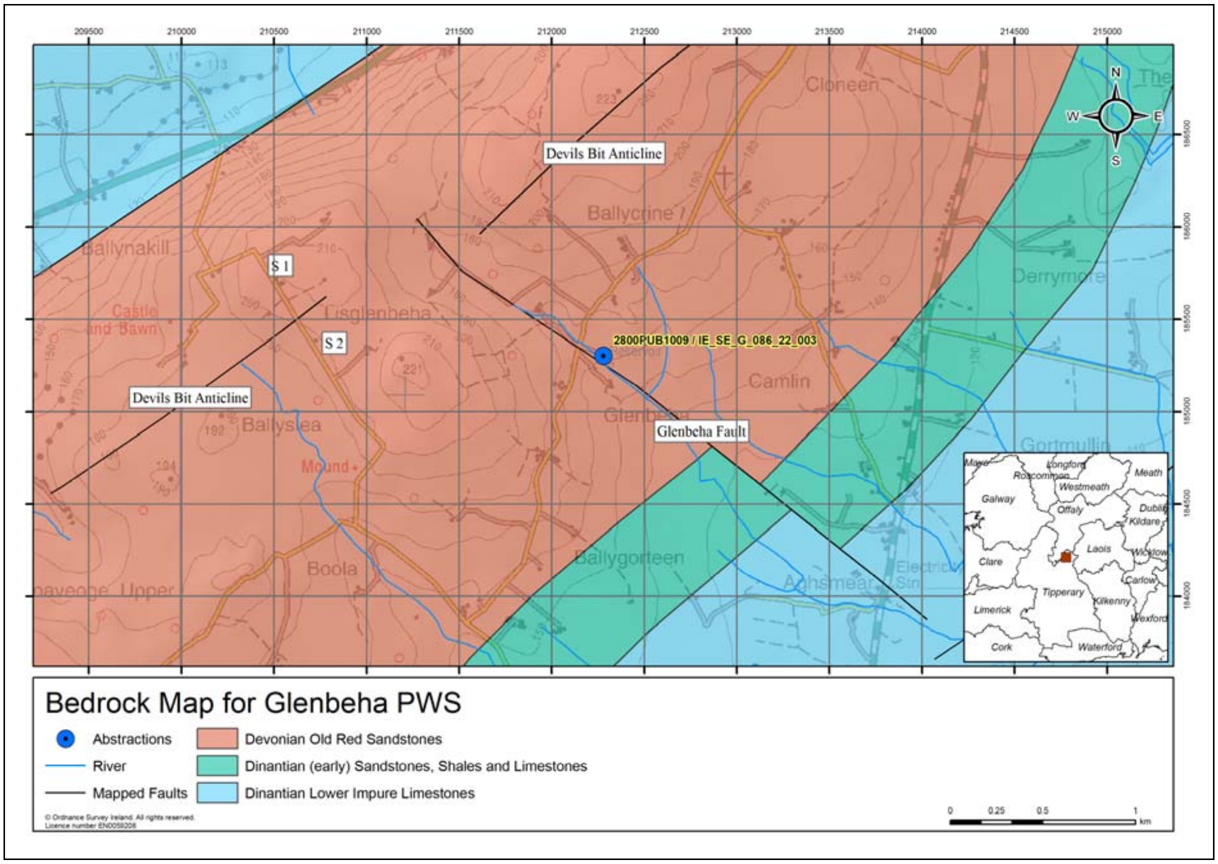

Figure 3 Bedrock geology map of the area around Glenbeha Springs PWS

7.3 Subsoils geology

According to GSI and EPA web mapping, the study area is dominated by till derived from Devonian sandstone and shales (TDSs) and bedrock outcrop (Rck). In the vicinity of the Glenbeha Springs 1 and 2, and surrounding Spring 3, small areas of alluvial deposits are mapped which coincide with the springs.

The soils on the till areas are dominated by dry soil types: typically well drained shallow mineral soils (AminSW) and well drained deep soils (AminDW) (EPA website and An Foras Talúntais, 1980).

The subsoils are depicted in Figure 4. The glacial till deposits are thin or absent on the elevated areas. The subsoil descriptions described for the boreholes drilled as part of the Hyder Consulting report are consistent with the description of till derived from Devonian sandstone and shales.

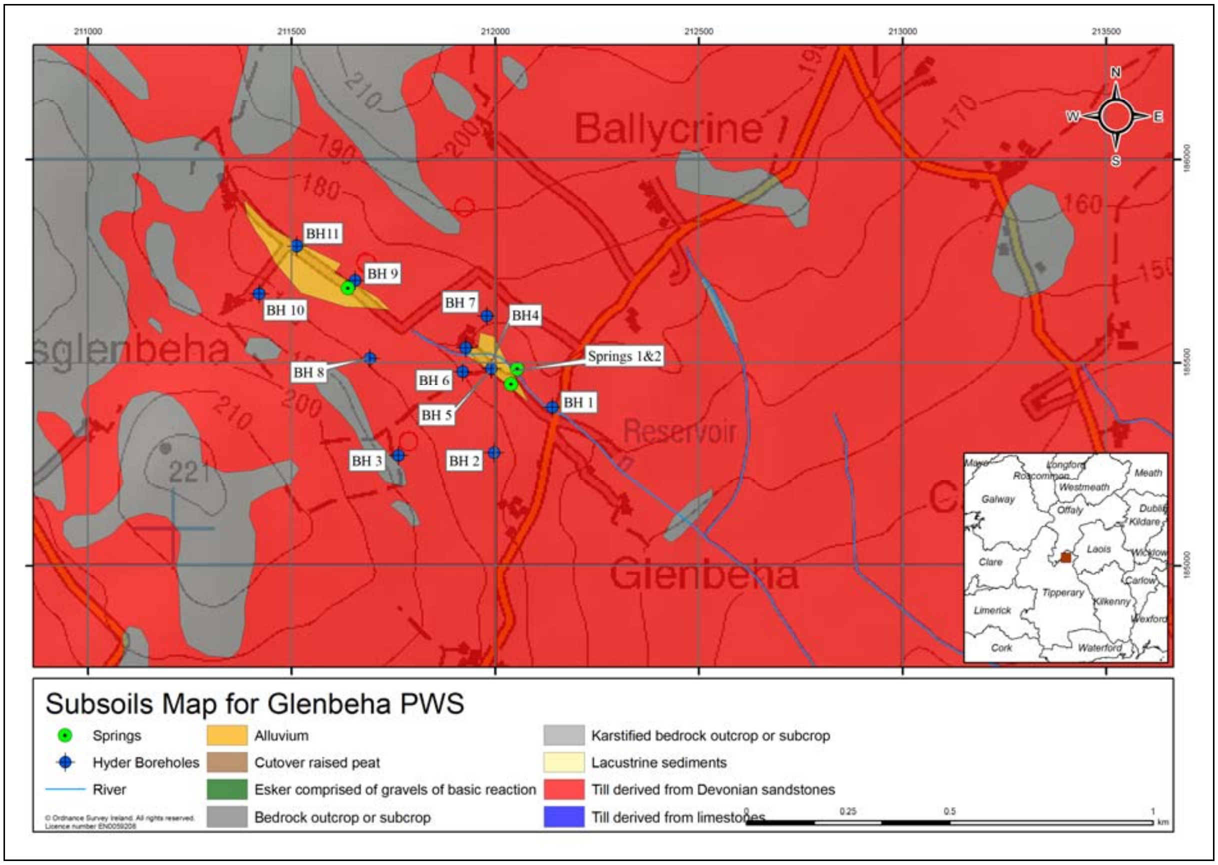

Figure 4 Subsoil map of the area around Glenbeha Springs PWS

7.4 Depth to bedrock

Depth to bedrock varies greatly throughout the study area. Boreholes completed as part of the Glenbeha Springs Assessment report (Hyder Consulting, 2007) provided additional information on the depth to bedrock surrounding Glenbeha Springs PWS. The hydrogeological mapping indicates that the depth of subsoil is generally less than 1 m on the bedrock crags on the ridge and generally less than 3 m surrounding the Glenbeha Springs PWS. A summary is included in table 6.1 below and borehole locations are shown on Figure 4.

Table 6.1 Summary of depth to bedrock at Glenbeha

Borehole I.D.	Depth to bedrock (m bgl)	Borehole I.D.	Depth to bedrock (m bgl)
Glenbeha Spring 1	1.0	BH7	3.5
BH1	1.9	BH8	1.5
BH2	6.0	BH9	2.7
BH3	3.0	BH10	7.5
BH4	1.8	BH11	4.9
BH5	2.4	BH12	2.1
BH6	0.5		

8 Groundwater vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. This means that in this area the 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).

Based on the absence of permanent surface water features and secondary indicators of low subsoil permeability, it is considered that the till in the area is free draining and that the subsoils are dominated by '*Moderately Permeable*' subsoil, in keeping with the regional maps.

The interim Groundwater Vulnerability map (2002) for the Glenbeha PWS area is dominated by 'extreme' with some areas of 'high to low' vulnerability. A revised vulnerability map for North Tipperary produced by GSI/TOBIN will be available in 2011. However based on the Hyder borehole data, a revised provisional vulnerability map is shown on Figure 5.

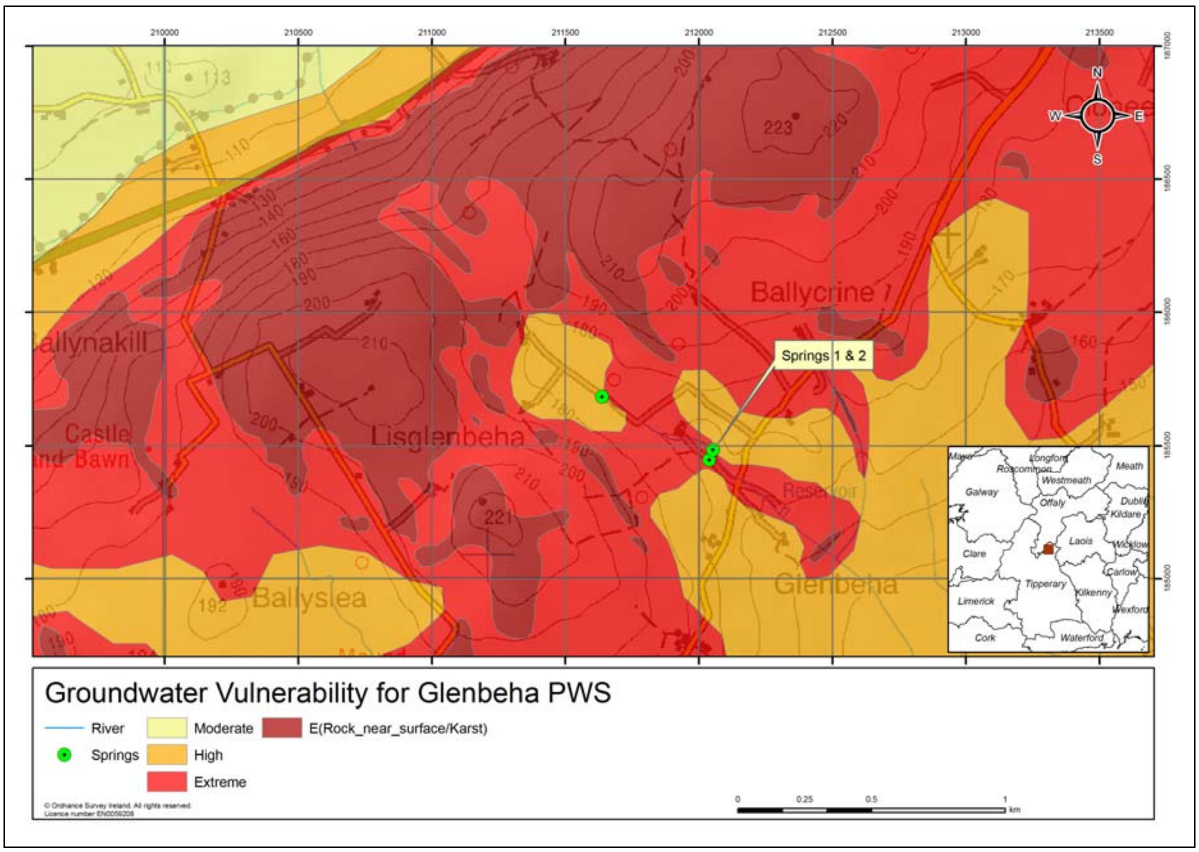

Figure 5 Groundwater Vulnerability in the area around Glenbeha Springs PWS

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:

- Hyder Consulting 2007- Glenbeha Springs Assessment
- GSI Website and Well Database
- North Tipperary County Council Staff
- EPA website and Groundwater Monitoring database
- Local Authority Drinking Water returns
- Hydrogeological mapping carried out by TOBIN Consulting Engineers and Robert Meehan in August 2010.

9.1 Groundwater body and status

The upland area around Glenbeha Springs PWS is within the Knock Groundwater body (IE_SH_G_135), close to the boundary between it and the Shinrone Groundwater Body. Both groundwater bodies are of Good Status www.wfdireland.ie/maps.html. The groundwater body descriptions are available from the GSI website: www.gsi.ie and the 'status' is obtained from the EPA website: www.epa.ie.

9.2 Groundwater levels, flow directions and gradients

Groundwater in the area surrounding the Glenbeha Springs PWS upwells at a number of locations along the minor valley. Groundwater discharges at the three springs, with Spring 3 discharging to the local drainage network within the surrounding alluvial area.

Groundwater levels in Spring 1 and Spring 2 are controlled by the groundwater abstraction. Based on the Glenbeha Springs Assessment (Hyder Consulting, 2007) the groundwater levels with the springs vary by approximately 1 m annually. No pumping test data of the spring source is available. Groundwater levels in the monitoring boreholes typically varied by 1 m to 3 m during the investigation period between 2006 and 2007. BH 3 and BH8 show higher variation in groundwater levels of between 5 and 7 m, possibly because of their smaller catchment area to the southwest. The groundwater elevation in Springs 1 and 2 is approximately 161 mOD. The groundwater elevation in Spring 3 is approximately 171 mOD, with groundwater only issuing at Spring 3 when groundwater levels exceed 171.1 m OD in BH9, which is located adjacent to Spring 3.

Groundwater levels in the surrounding area were established by Hyder Consulting. Flow directions are broadly focused toward the spring discharge area, mirroring topography. Groundwater gradients range from 0.01 to 0.03, depending upon the topography. Groundwater contours are illustrated on Figure 8.

9.3 Spring discharge

The Glenbeha Water Supply Scheme abstracts on average 1,400 m^3/day of groundwater from Springs 1 and 2. All groundwater entering Springs 1 and 2 is extracted during low flow periods, although some discharged groundwater is diverted to Weir 2 *via* a culvert during winter high flow periods when groundwater supply exceeds the treatment capacity. The overflow at Weir 2 is less than 600 m^3/day on average but can increase to 10,000 m^3/day during wet periods.

Hydrogeological field mapping carried out in July 2010 and August 2010 included obtaining field measurements of electrical conductivity and temperature of surface water features which provides information on potential groundwater discharges to the springs and streams. **Error! Reference source not found.** provides the field results of 26th August 2010.

Based on the measurements, the springs have high conductivity values indicating that they are groundwater fed. The slightly lower conductivity value at Spring 3 may suggest a shallower groundwater with more rapid travel times or a surface water influence. The area surrounding Spring 3 appears more conducive to surface water runoff.

Table 9.1 Field measurements of electrical conductivity and temperature at Glenbeha

SW stream ID	Conductivity (µS/cm @ 25°C)	pH	Dissolved Oxygen (%)	Temperature (°C)	Notes
Weir 2	674	7.2	36	11.2	Flow approximately 2 l/s
Spring 1	743	7.1	47	10.9	
Spring 2	754	7.3	75	11.0	
Spring 3	650	7.2	72	10.8	Flow approximately 2 l/s

Note – Measurements undertaken on the 26/08/2010

Springs 1, 2 and 3 react quickly to extended rainfall events, discharging rapidly and virtually dry up during dry periods. This can clearly be seen in the data provided below in Figure 6. It can be seen that a faster response to rainfall events occurred in November 2007 than in June 2007. A soil moisture deficit of 44 mm was recorded on the 10th June 2007 at the nearest Synoptic Station (Birr) and reduced to 3 mm by the 31st June 2007 (Met Eireann, 2007a). A soil moisture deficit of 3 mm was recorded on the 10th November 2007 and at field capacity by the 31st November 2007 (Met Eireann, 2007b). Following a dry period of approximately 30 days the groundwater abstraction from Spring 1 and Spring 2 is typically reduced to 100 m^3/day. Based on the flow data and the rapid response to rainfall events, groundwater time of travel to the springs is fast and typically less than 30 days.

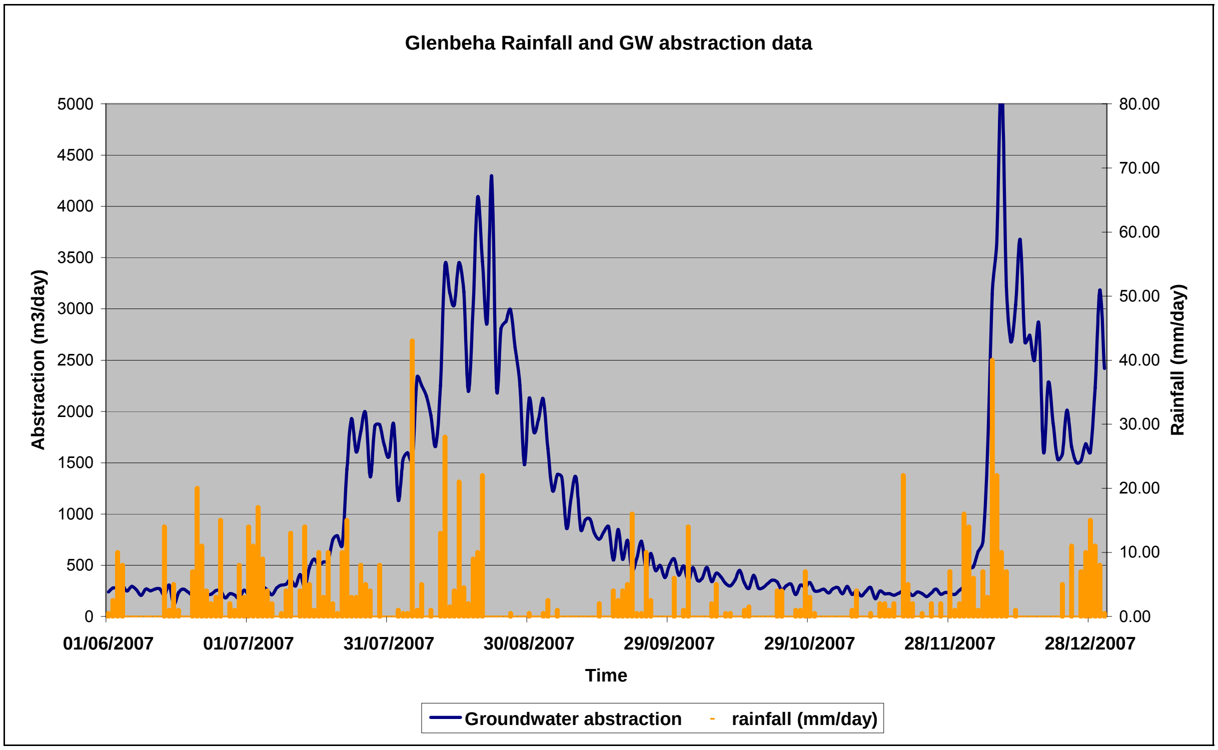

Figure 6 Groundwater abstraction (Springs 1 and 2) and rainfall data (Glenbeha Reservoir) at Glenbeha Springs PWS

9.4 Hydrochemistry and water quality

Twenty seven samples were available from the historical records gathered in the EPA Groundwater Monitoring Network for Glenbeha Springs. The water quality is hard to very hard, (251 to 484 mg/l $CaCO_3$). Alkalinity ranges from 215 to 441 mg/l as $CaCO_3$. The pH ranges between 7.2 and 7.8, which is slightly alkaline. While the springs are located in sandstone bedrock, the Cadamstown Formation is slightly alkaline. The electrical conductivity ranges from 360 to 768 µS/cm @ 25°C. The large variation in electrical conductivity is due to the flashy nature of the springs. The hydrochemical signature is calcium bicarbonate and compares favourably with the signature and data given in the Knock Groundwater body description.

The concentration of nitrate ranges from 3.0 to 53.2 mg/l, with a mean of 16.8 mg/l (as NO_3) which is below the Threshold Value of 37.5 mg/l (Groundwater regulations, S.I. No. 9 of 2010). There is one reported exceedance (53.2 mg/l as NO_3 in 1995) of the EU Drinking Water Directive maximum admissible concentration of 50 mg/l. This exceedance occurred prior to the 2002 upgrade works and coincided with a spike in chloride levels (50 mg/l) and faecal contamination (1000 cfu/100ml) of the springs, which suggest an isolated contamination incident. The decreasing nitrate levels at Glenbeha since 2002 is probably directly due to improved source protection around the springs and low agriculture pressures.

Chloride concentrations range from 6.7 to 50 mg/l, with a mean of 19.1 mg/l which is considered to be above the mean natural background level of 18 mg/l (Baker *et al*, 2007). Again, the majority of the exceedances occurred prior to the upgrade works, and the trend with chloride has also been consistently downwards since. Occasional spikes in chloride concentrations may potentially be as a result of contamination from organic sources.

Faecal coliforms are present in 50% of water samples, with gross contamination on five occasions (greater than 10 faecal coliforms per 100 ml). Potential sources include agriculture and septic tank systems; it is more likely to be the former as there are few septic tanks in the area around the springs, and where septic tanks do occur the protection for groundwater is relatively good. Although the concentrations are highly variable, the highest concentrations generally occurred prior to the 2002 upgrade works.

The concentrations of sulphate, potassium, sodium, magnesium and calcium are within normal ranges. The potassium: sodium (K:Na) ratio is elevated with an average ratio of 0.47. The K:Na ratio increased following the upgrade works possibly reflecting a reduction in surface water contribution to Spring 1 and Spring 2. The high K:Na ratio may indicate inorganic farmyard fertilizer contamination or may reflect the natural groundwater chemistry of the Devonian Sandstone Inlier. The concentration of molybdate reactive phosphate (MRP) is low, with a mean of 0.034 mg/l (as P).

Given the low nitrate concentrations, low molybdate reactive phosphate concentrations, low ammonical nitrogen concentrations and good spring protection, it is unlikely that farmyard organic waste is the source of high K:Na ratios. In addition, no discernable decrease was observed during the landspreading closed season.

An elevated concentration of iron (365 µg/l) was recorded on one occasion in May 1993, exceeding the drinking water standards. A peak in iron concentrations was noted to correspond with high chloride concentrations in 1996 and is potentially as a result of contamination from organic sources.

The average barium concentration (442 ug/l) is slightly elevated but is below the TGV 's. Elevated concentrations of barium have also been encountered in groundwater from analogous sources in Devonian Sandstone aquifers. The concentrations of all other trace metals and of all organic compounds and herbicides are low and/or are below the detection limit of the laboratory. Turbidity values are generally low in spite of flashy nature of the spring.

In summary, bacteriological exceedances, occasionally elevated chloride and occasional high iron suggest sporadic contamination from an organic waste source. Given the land use in the area, the most likely source is farmyard wastes and the previous unfettered access to the springs (pre 2002). Water quality has increased substantially since the 2002 upgrade works.

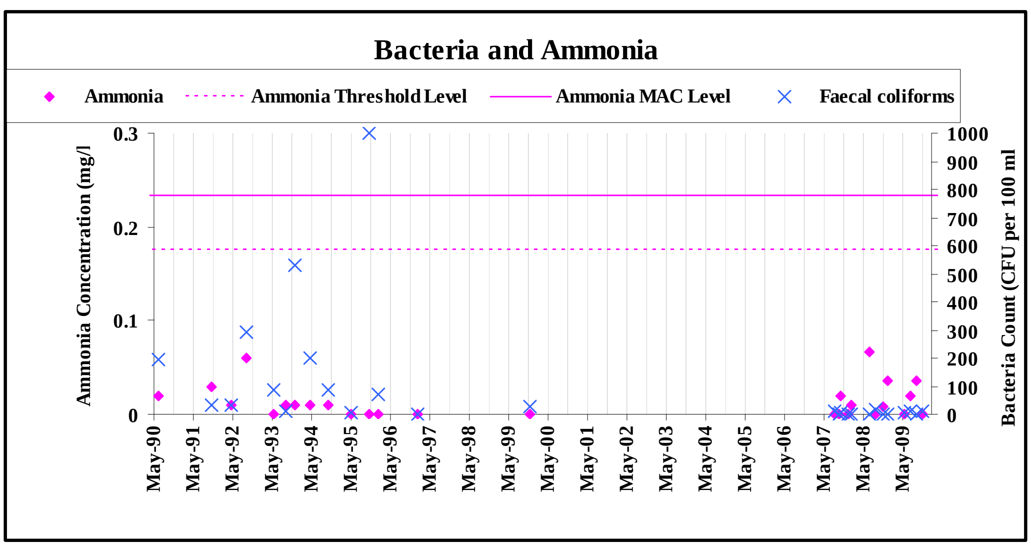

Figure 7 Ammonium and Faecal Coliform data for Glenbeha PWS

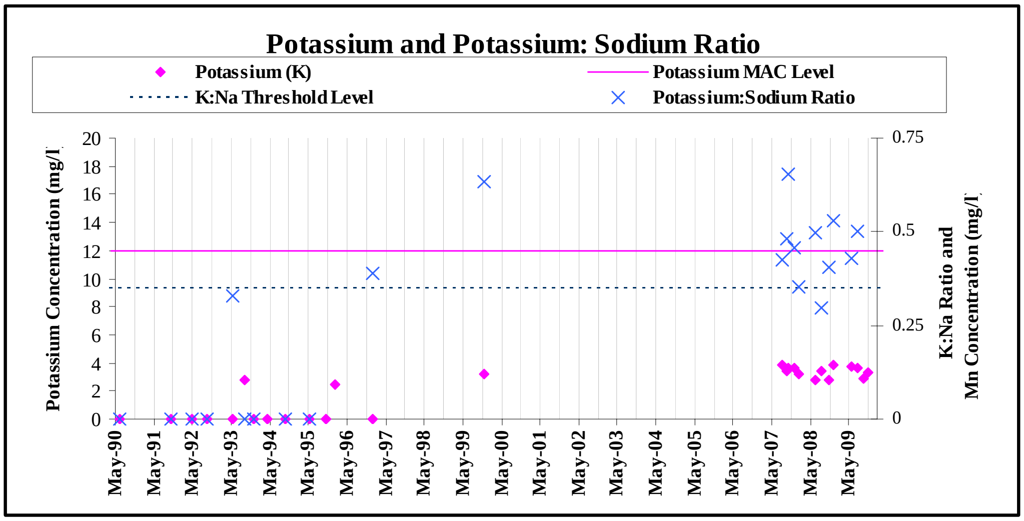

Figure 8 Potassium and K:Na ratios for Glenbeha PWS

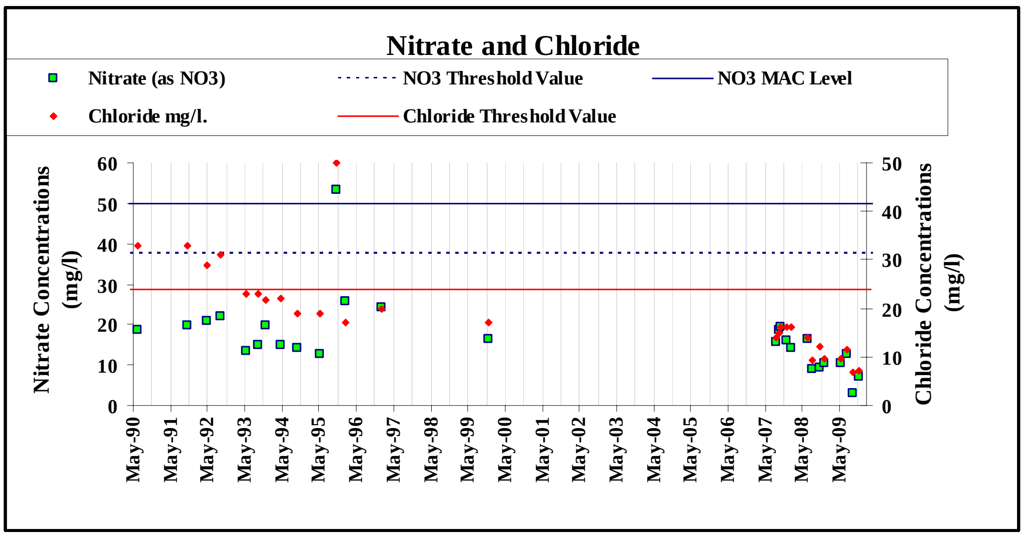

Figure 9 Nitrate and Chloride concentrations for Glenbeha PWS

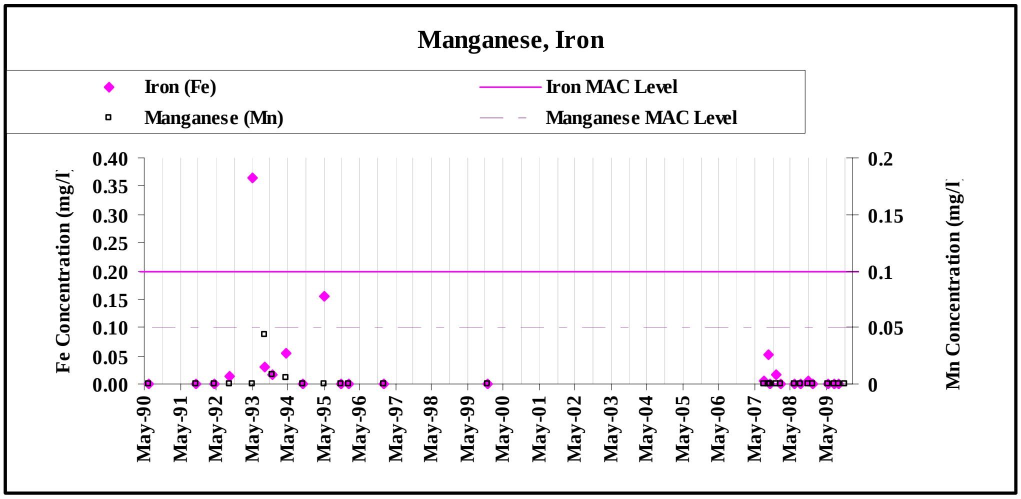

Figure 10 Iron and Manganese Concentrations of Glenbeha PWS

9.5 Aquifer characteristics

The groundwater source is located in the Knock Groundwater Body. The GSI bedrock aquifer map of the area indicates that the Old Red Sandstones are classified as a *Locally Important Aquifer which is moderately productive only in local zones (Ll)*.

Flow in the aquifer is assumed to follow topography and occur through the more permeable, interconnected fault/fracture zones and within the weathered sandstone bedrock. Groundwater velocities through faults/fractures may be high and aquifer storage is frequently low. Spring sources often at a break in slope and also may indicate zones of high transmissivity, permeability and velocities immediately surrounding the spring. There are no specific transmissivity data for the springs at Glenbeha: however, the discharge/abstraction is high with an average of 1,400 m^3/day.

Faults, and additional fracturing associated with these faults, are likely to increase the permeability of the aquifer. The faults and fractures are likely to have resulted in a higher transmissivity zone running NW-SE.

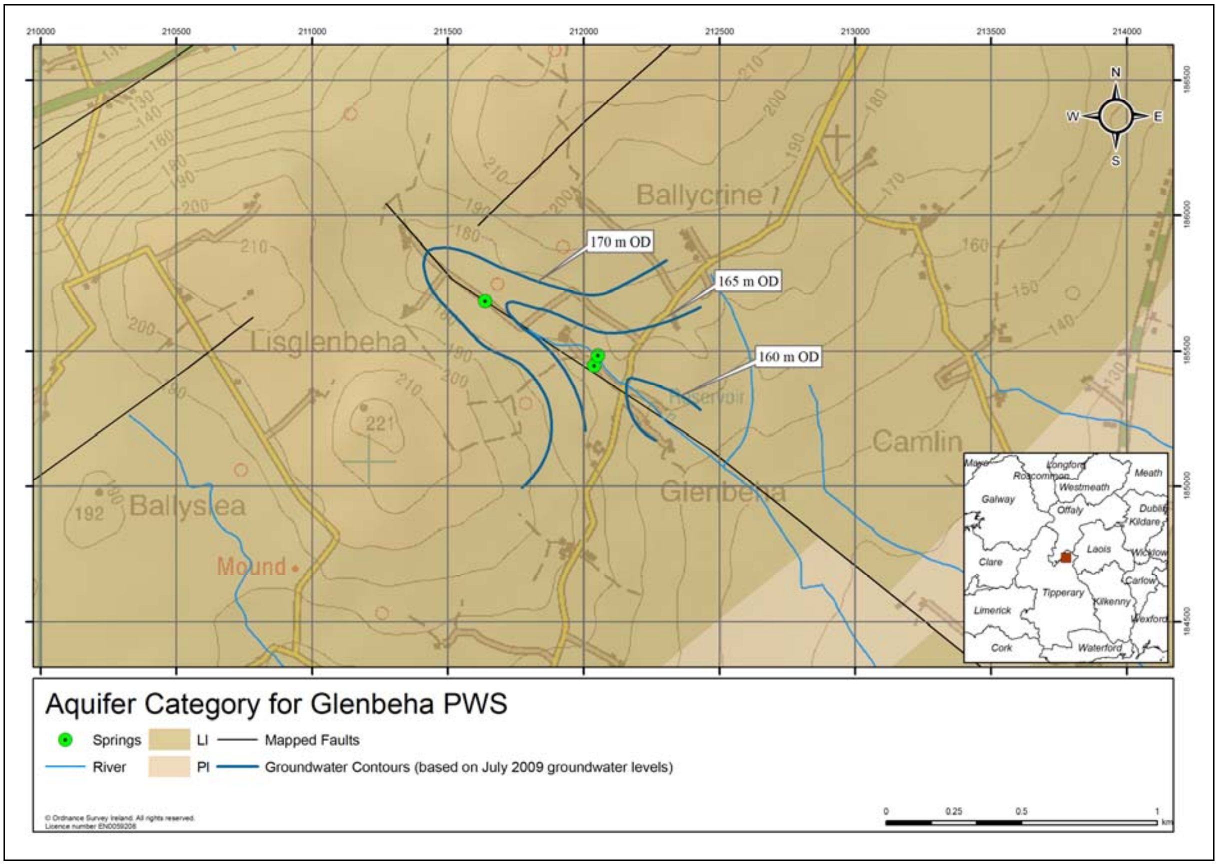

Figure 11 Aquifer map in the vicinity of Glenbeha Springs PWS

10 Zone of contribution

The Zone of Contribution (ZOC) is the complete hydrologic catchment area to the source, or the area required to support an abstraction from long-term recharge. The size and shape of the ZOC is controlled primarily by (a) the total discharge, (b) the groundwater flow direction and gradient, (c) the subsoil and rock permeability and (d) the recharge in the area. This section describes the conceptual model of how groundwater flows to the source, including uncertainties and limitations in the boundaries, and the recharge and water balance calculations which support the hydrogeological mapping techniques used to delineate the ZOC.

10.1 Conceptual model

Groundwater flow to the springs is from the surrounding up-gradient area and is confined by topography in the valley. The spring flow is flashy in character and reacts relatively quickly to rainfall events and seasonal variations. Groundwater flows and abstraction from Springs 1 ands 2 varies between 100 m^3/day to 6,000 m^3/day indicating storage in the aquifer is low. Groundwater flow within the catchment is structurally controlled with enhanced flow and transmissivity along the fissures and faults. The faulting of the sandstones is a particularly important factor for flow through the sandstone units. The less permeable units, such as the siltstones, may inhibit vertical groundwater flow.

The aquifer is unconfined, and has high to extreme vulnerability over all of the area. The springs are recharged locally, through the moderately permeable, often thin subsoils. This is reflected in the water quality results which show the occasional presence of faecal bacteria in the untreated water.

The natural hydraulic gradients in the aquifer are likely to be moderate, approximately 0.01 to 0.03. High groundwater velocities are expected through a network of faults, fractures and fissures.

The conceptual model of flow to the springs is illustrated in Figure 12. Limitations to the model mainly lie with a lack of information on detailed aquifer properties, such as transmissivity and porosity.

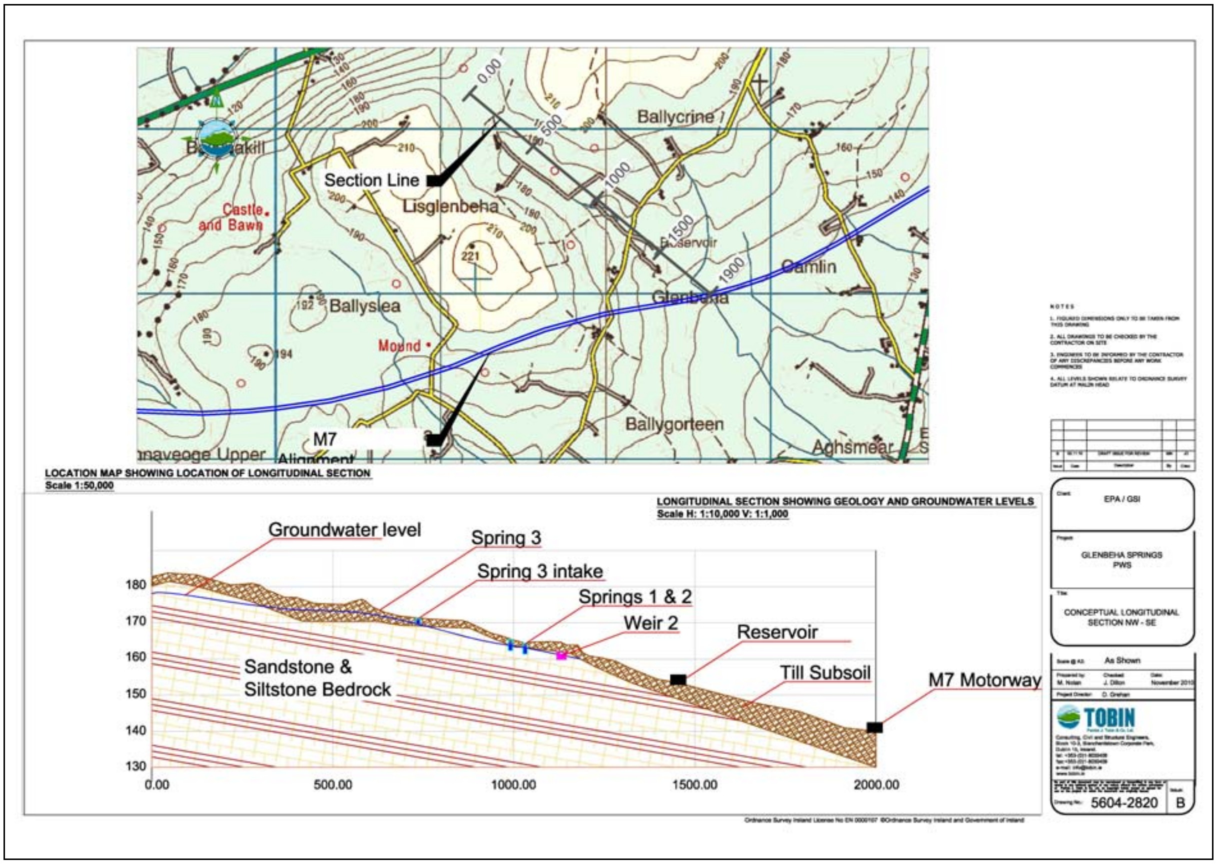

Figure 12 Cross section through Glenbeha Springs PWS

10.2 Boundaries of the ZOC

The boundaries of the area contributing to the source are considered to be as follows (Figure 13):

The Southern boundary is based on the assumption that groundwater cannot flow to the source from the downgradient side as the source is a spring. An arbitrary 30 m distance from the spring is applied for the downgradient boundary, which allows for some drawdown in the spring sump.

The Northern boundary: The northern boundary is based on the topographic divide. It is assumed that groundwater at an elevation higher than the springs, from the hills surrounding them, flows toward the springs.

The Western boundary is based on the interpreted groundwater catchment divide along the topographical high in Lisglenbeha townland. The groundwater divide is assumed to mirror the surface topography divide and is similar to the boundary delineated by Hyder Consulting. Extensive groundwater monitoring for the M7 motorway confirmed a groundwater divide along the western boundary. Monitoring included the use of data loggers and manual dips for over 2 years.

The **Eastern boundary**: is based on a topographical divide and a water balancing exercise. The eastern boundary is based on the topographic divide. It is assumed that groundwater at an elevation higher than the springs, from the hills surrounding them, flows toward the springs.

10.3 Recharge and 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 assumed to consist of input (*i.e*. annual rainfall) less 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 it will dictate the size of the zone of contribution to the source (*i.e*. the outer Source Protection Area).

At Glenbeha, the main parameters involved in the estimation of recharge are: annual rainfall; annual evapotranspiration; and a recharge coefficient. The recharge is estimated as follows.

Runoff losses are assumed to be 15% of potential recharge (effective rainfall). This value is based on an assumption of *c*. 15% runoff for 100% of the area (high and extreme vulnerability - moderate permeability subsoils and soils, few drains or surface streams and moderate to steep slopes, Guidance Document GW5, Groundwater Working Group 2005).

The above calculations are backed up by detailed records of rainfall from the Glenbeha rainfall gauge, abstraction data from North Tipperary Co. Co. and surface water runoff (Weir 2) in the Glenbeha Springs PWS catchment which have been recorded over the last 2.5 years. Based on spring flow data, 70% of the potential recharge flows to spring 1 and spring 2. The average runoff from the catchment at Weir 2 (30%) is a combination of surface water runoff and groundwater discharge at spring 3. It is conservatively assumed that 50% of the water flow at Weir 1 is groundwater fed. Due to the site specific discharge data outlined above, no recharge cap is applied.

The bulk ***recharge coefficient*** for the area is therefore estimated to be 85%.

These calculations are summarised as follows:

Average annual rainfall (R)	1232 mm
Estimated P.E.	450 mm
Estimated A.E. (95% of P.E.)	428 mm
Effective rainfall	805 mm
Potential recharge	805 mm
Bulk recharge coefficient	85%
Recharge	**684 mm**

The water balance calculation states that the recharge over the area contributing to the source should equal the discharge at the source. At a recharge of 684 mm/yr, an average yield of 1,700 m^3/day for springs 1, 2 and 3 would require a recharge area of 0.92 km^2. The area delineated using the topography correlated well with the area from the recharge equation. An area was delineated based on topography (to account for groundwater discharge at Spring 1, 2 & 3) and is shown in Figure 13. Given the Glenbeha Springs PWS current abstractions virtually all water from Springs 1 and Spring 2, there is no potential to increase the abstraction.

11 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. At this source only an Inner Source Protection Area has been delineated.

11.1 Inner protection area

The Inner Source Protection Area (SI) is designed to protect the source from microbial and viral contamination and it is the area defined by the horizontal 100 day time of travel from any point below the watertable to the source (DoELG, EPA, GSI, 1999). The 100-day horizontal time of travel to the source is calculated from the velocity of groundwater flow in the bedrock. The velocities are normally based on the results of the hydraulic test programme, however, in this instance, rainfall data, groundwater abstraction data and surface water discharge data were used to assess the time of travel to the springs.

Based on the abstraction data, recharge response is typically less than 30 days at the springs. Additionally once major rainfall events stop the hydrograph begins to recede within 1 to 2 days. On this basis, the entire ZOC is designated as the Inner Protection area of the spring. Groundwater flow data from the Glenbeha springs PWS; suggest that water can reach the source from all areas within the ZOC within the 100-day time of travel. On this basis, all of the ZOC is designated as part of the inner protection area to the source, denoted as SI, and the Outer Protection Area does not apply.

Groundwater protection zones are shown in Figure 14 and are based on an overlay of the groundwater vulnerability on the source protection areas. Therefore the groundwater protection zones are SI/X, SI/E and SI/H. The majority of the area is designated SI/E.

Table 11.1 Source Protection Zones

Source Protection Zone	% of total area
SI/X – <1 m subsoil	31.8%
SI/Extreme	51.2%
SI/High	17%
Source Protection Zone	% of total area (0.986 km^2)

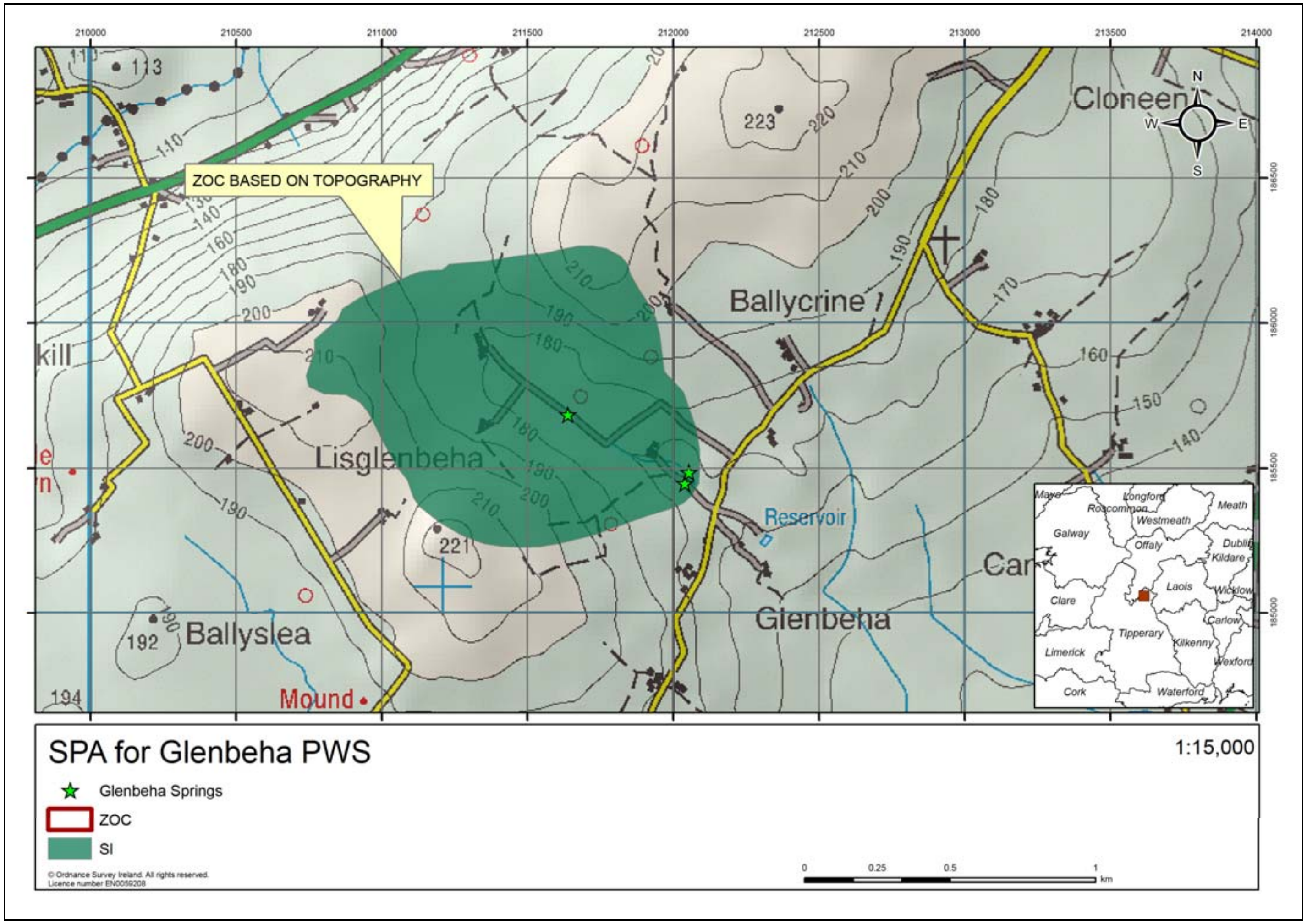

Figure 13 Source Protection Areas for Glenbeha Springs PWS

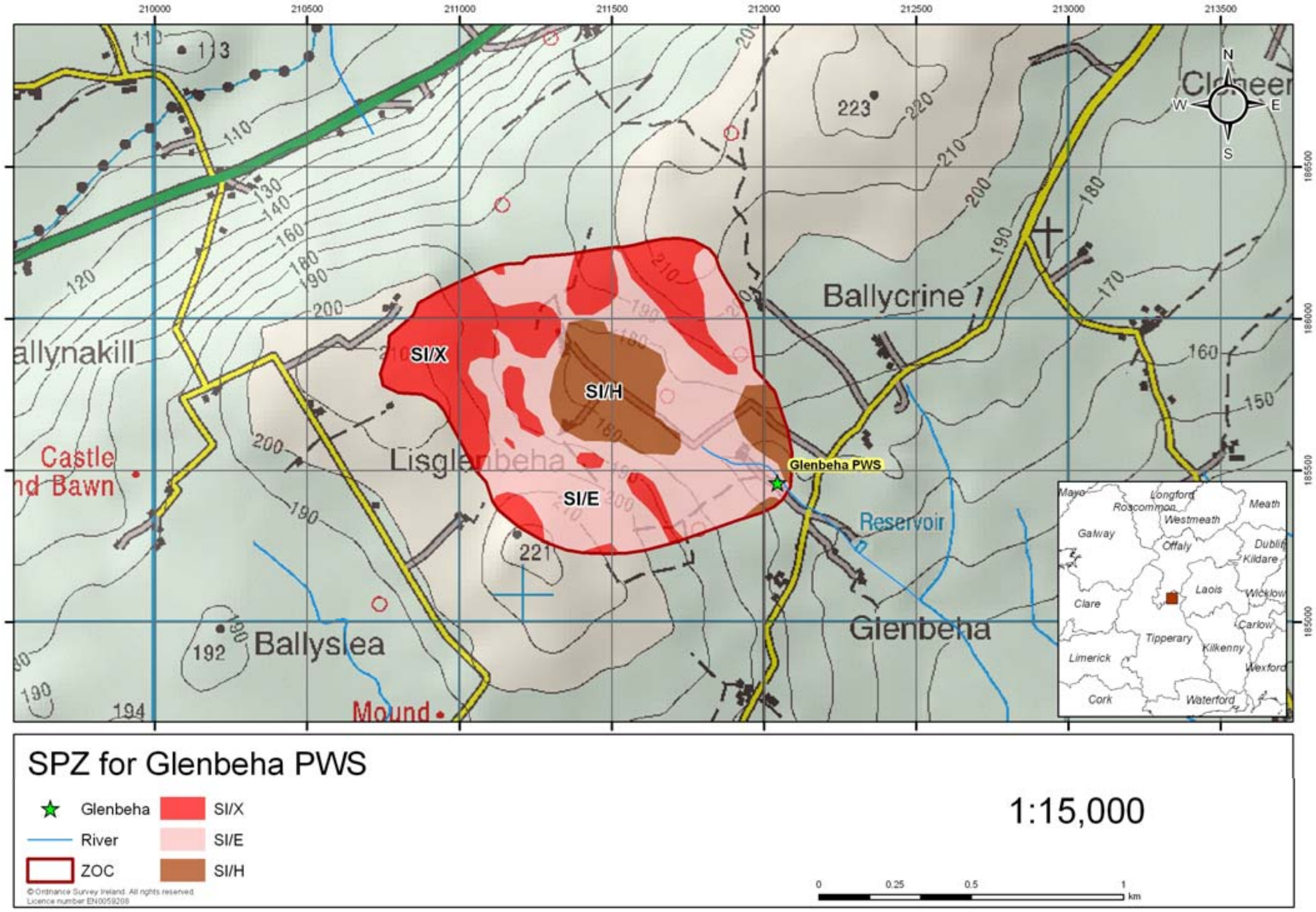

Figure 14 Source Protection Zones around Glenbeha Springs PWS

12 Potential pollution sources

Spring 1 and Spring 2 are capped and housing is secured though vermin could probably get in at the back where there is a small gap. A cordon around the source is in place by North Tipperary County Council in order to ensure that potentially polluting materials are not stored or deposited in the immediate vicinity of the source. No Landspreading or fertilizers are applied within the council lands.

The inner protection area encompasses the entire catchment, all of which is 'extremely' or '**highly**' vulnerable to contamination. Land use in this area is mainly set to grazing cattle. The majority of land within the ZOC is agricultural land, primarily grassland and there are a number of farming operations present. The main potential contaminants from these sources are ammonia, nitrates, phosphates, chloride, potassium, BOD, COD, TOC, pesticides, faecal bacteria, viruses and cryptosporidium.

A very limited number of private residences (2 houses) are located within the ZOC. Private residences within the ZOC are serviced by septic tank systems or mechanical aeration systems discharging to soakholes or percolation areas. The main potential contaminants from this source are ammonia, nitrates, phosphates, chloride, potassium, BOD, COD, TOC, faecal bacteria, viruses and cryptosporidium. As well as this, there are some private home heating fuel tanks located within the catchment area. The main potential contaminants from this source are hydrocarbons. There is currently no evidence of any contamination from hydrocarbons at the source.

Finally, there is only a small length of road present in the ZOC and the traffic density is low and the risk of contamination is low from this source.

13 Conclusions

The untreated groundwater at the spring source at Glenbeha is currently impacted by microbial contamination. Available data suggests that contamination of the source is occurring probably from agriculture and organic waste sources; such as farmyards. However the levels of contamination have been greatly reduced since completing the upgrade works in 2002.

Due to the rapid groundwater velocities, it is considered that groundwater in any part of the ZOC could potentially reach the spring within 100 days. Therefore the entire ZOC has been classified as the Inner Protection Area.

The SPZ delineated is based on the current understanding of groundwater conditions and bedrock geology; and on the available data. The conclusions should not be used as the sole basis for site-specific decisions.

14 Recommendations

Continued monitoring of the water levels and flow data during the operation of the scheme should be carried out to further develop the real-time database of hydrogeological information.

The ZOC of the source includes an extensive area of Extreme Vulnerability with a significant proportion of it comprising shallow rock. It is recommended therefore that an adequate barrier to Cryptosporidium is installed as part of the water treatment system for the supply. A hazard survey is also recommended.

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