Environmental Protection Agency

# Establishment of Groundwater Source Protection Zones

## Kilmacthomas Water Supply Scheme

## Ballyogarty Borehole

May 2010

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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 are delineated for the Ballyogarty Borehole source 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 Ballyogarty borehole source supplies the townlands surrounding the source as well the southwestern part of Kilmacthomas.

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 Ballyogarty borehole.
- To assist the Environmental Protection Agency and Waterford 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).

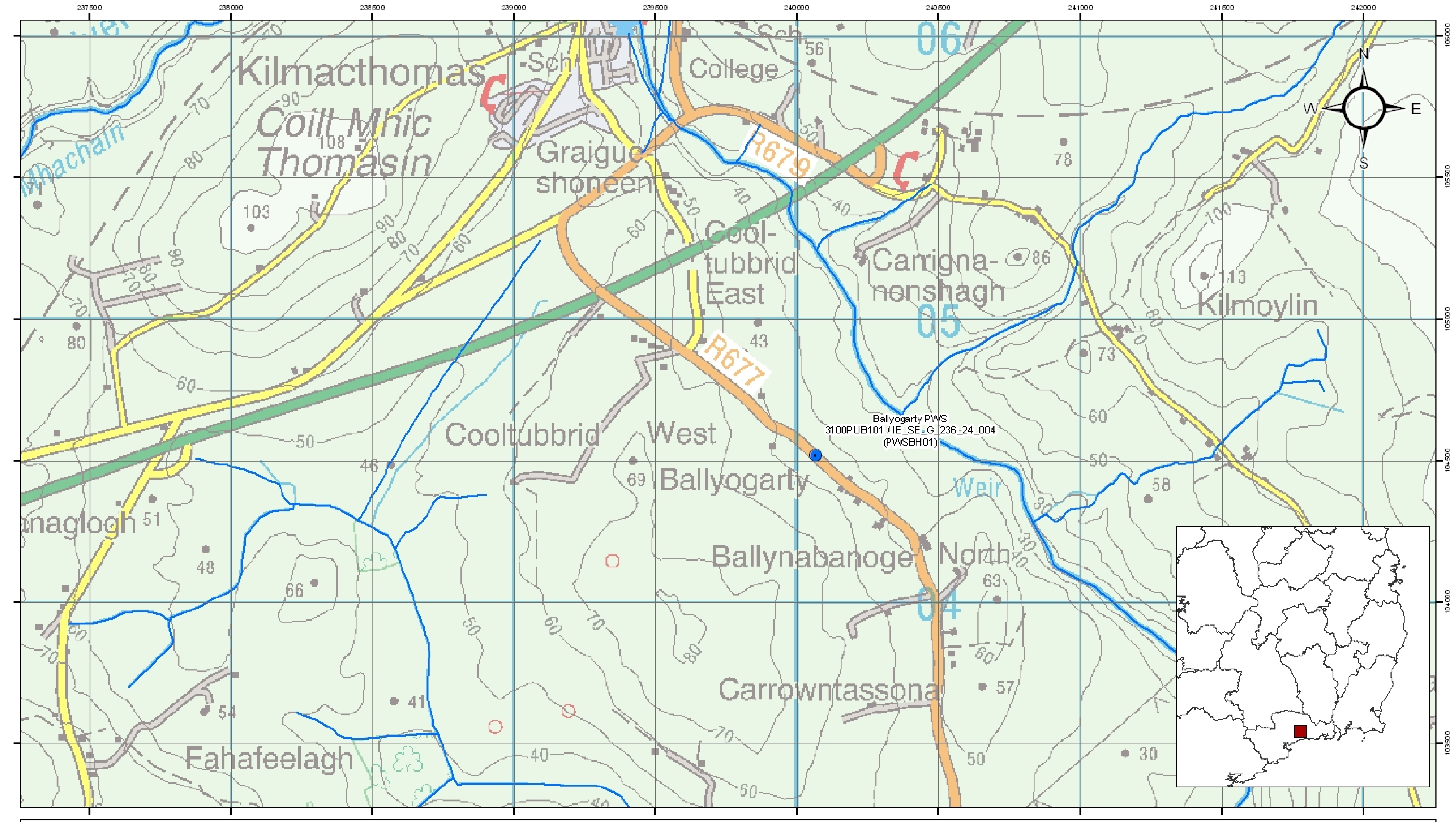
The maps produced are based largely on the readily available information in the area, a field walkover and on mapping techniques which use inferences and judgements based on experience at other sites. As such, the maps cannot claim to be definitively accurate across the whole area covered, and should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

# 2 LOCATION, SITE DESCRIPTION AND WELL HEAD PROTECTION

The Ballyogarty borehole (henceforth referred to as "the source") is located 1.7 km south of Kilmacthomas in the townland of Ballyogarty, as shown in Figure 1. The source is located in a 10 m by 10 m gated compound with concrete post and rail fencing, adjacent to the R677 from Kilmacthomas to Ballylaneen. The compound comprises a pumping house and adjacent metal shed. The borehole is located inside the treatment building and in this report is labeled borehole PWSBH01.

The source pumps directly into the water supply distribution main. There is no reservoir. Abstraction from the well is controlled by a pressure tank and cuts in and out frequently as pressure in the mains fluctuates with demand.

The mouth of the borehole casing for PWSBH01 inside the pumping house has a small lip above the floor level, but this is broken in places such that the borehole mouth is effectively open at floor level. A small protection of one course of bricks has recently been installed around the borehole mouth to prevent liquids on the pumping house floor from draining into the borehole. This wellhead protection was installed subsequent to the taking of Photograph 2 below.




# Figure 1 Ballyogarty PWS Site Location Map

PWS Abstraction

River



0 0.25 0.5 1 km

# 3 SUMMARY OF BOREHOLE DETAILS

No original borehole records were available for borehole PWSBH01, but basic borehole data have been obtained from the Geological Survey of Ireland (GSI) well database. The data are summarised in Table 3-1. The borehole was drilled in 1970. The uppermost section of the borehole is cased with a 9-inch internal diameter concrete pipe, which is set into the concrete floor of the pump house. An 8-inch diameter steel casing is visible down the borehole below 0.97 m below the top of the concrete casing. There are no data relating to the basal elevation of either casing.

The average abstraction from the source is 195 $m^3$/day, based on Waterford County Council data. The source caretaker indicated that the yield is very reliable and that the borehole has never suffered from a shortage of water.

**Table 3-1 Summary of Source Details**

| | |
|---|---|
| EU Reporting Code | IE_SE_G146_24_004 |
| Borehole Name | PWSBH01 |
| Grid reference | E240069 N104521 |
| Townland | Ballyogarty |
| Source type | Borehole |
| Drilled | 1970 |
| Owner | Waterford County Council |
| Elevation (Ground Level) | approx. 45 mAOD[1] |
| Depth | 21.9 m |
| Depth of casing | unknown |
| Diameter | 200 mm |
| Depth to rock | 5.6 m |
| Static water level[2] | 2.75 mbtc[3] |
| Pumping water level[4] | 5.97 mbtc |
| Consumption (Co Co records) | 195 $m^3$/day |

Note 1: mAOD = metres above ordnance datum; Note 2: water level measured on 10/11/2009 after 6 hour Recovery Test; Note 3: 'mbtc' = metres below top of casing & tc = top of 9-inch concrete pipe casing; Note 4: Water level measured on 19/10/2009.

**Photograph 1 Borehole PWSBH01 Pump House**

**Photograph 2 Borehole PWSBH01**

# 4 METHODOLOGY

Site visits, site walk-overs and field mapping (including a well survey, groundwater level survey, mapping of drainage indicators and logging of bedrock outcrops and subsoil exposures) of the study area were conducted between 19/10/2009 and 05/11/2009. An interview with the source Caretaker was carried out on 19/10/2009.

A pumping test comprising an initial recovery phase (following shut down of the PWS abstraction) and a constant discharge phase (following re-starting of the PWS abstraction), together with monitoring of field water quality parameters, was carried out on PWSBH01 on 10/11/2009. The locations of all of the point features investigated during the site visits and identified during the desk study are shown in Figure 2. A summary table of the point data collected during the site visits and field mapping is provided in Appendix No. 1.

# 5 TOPOGRAPHY, SURFACE HYDROLOGY AND LANDUSE

The site is in a small, roughly C-shaped sub-catchment of the Mahon River (Figure 1) in the townlands of Ballyogarty and Ballynabanoge, towards the base of the west side of the river valley. The river flows from northwest to southeast through the area.

The sub-catchment boundary is delineated by a low-lying ridge on the west side of the river running south from the river through the townlands of Cooltubrid East and West Ballyogarty before turning to run west – east and then north through Ballynabanoge North to finish abutting against the river. The sub-catchment containing the source lies on the east side of the ridge. The maximum elevation of the ridge is 80 mOD in Ballynabanoge, directly upslope and southwest of the source. The topographical gradient in the area ranges from 0.04 on the crest of the ridge to 0.06 in the vicinity of the borehole and the river. On the western side of the ridge the land slopes away to the northwest, southwest and southeast. The Mahon River has incised a 5 m to 10 m deep gorge into the valley floor to the east of the source.

Two small, unmapped, spring-fed streams drain into the Mahon River from the lower slopes of the ridge to the north and south of the borehole respectively. The stream to the north runs along the boundary of a conifer plantation in Cooltubrid East and has been artificially deepened. The stream to the south flows northeast out of Ballynabanoge North and has been culverted in the vicinity of the R677. The streams are short in length however, and the combined natural and artificial drainage density is considered to be low (i.e. less than 1 km per $km^2$).

Land use in the area is primarily agricultural, with lands used for livestock and bloodstock pasture and for arable cereal crops. There is a large conifer plantation along the crest of the ridge to the west of the source, as well as adjacent to the Mahon River to the north of the source in Cooltubrid East. The nearest farmyard to the source is located approximately 150 m to the west-northwest. The Mahon River is flanked on either side by a thin border of riparian woodland.

The population of the study area is low, with roughly 25 to 30 domestic residences and related farmyards in the study area. A number of recent domestic residences have been constructed adjacent to the R667 approximately 120 m to the south-southeast of the source.

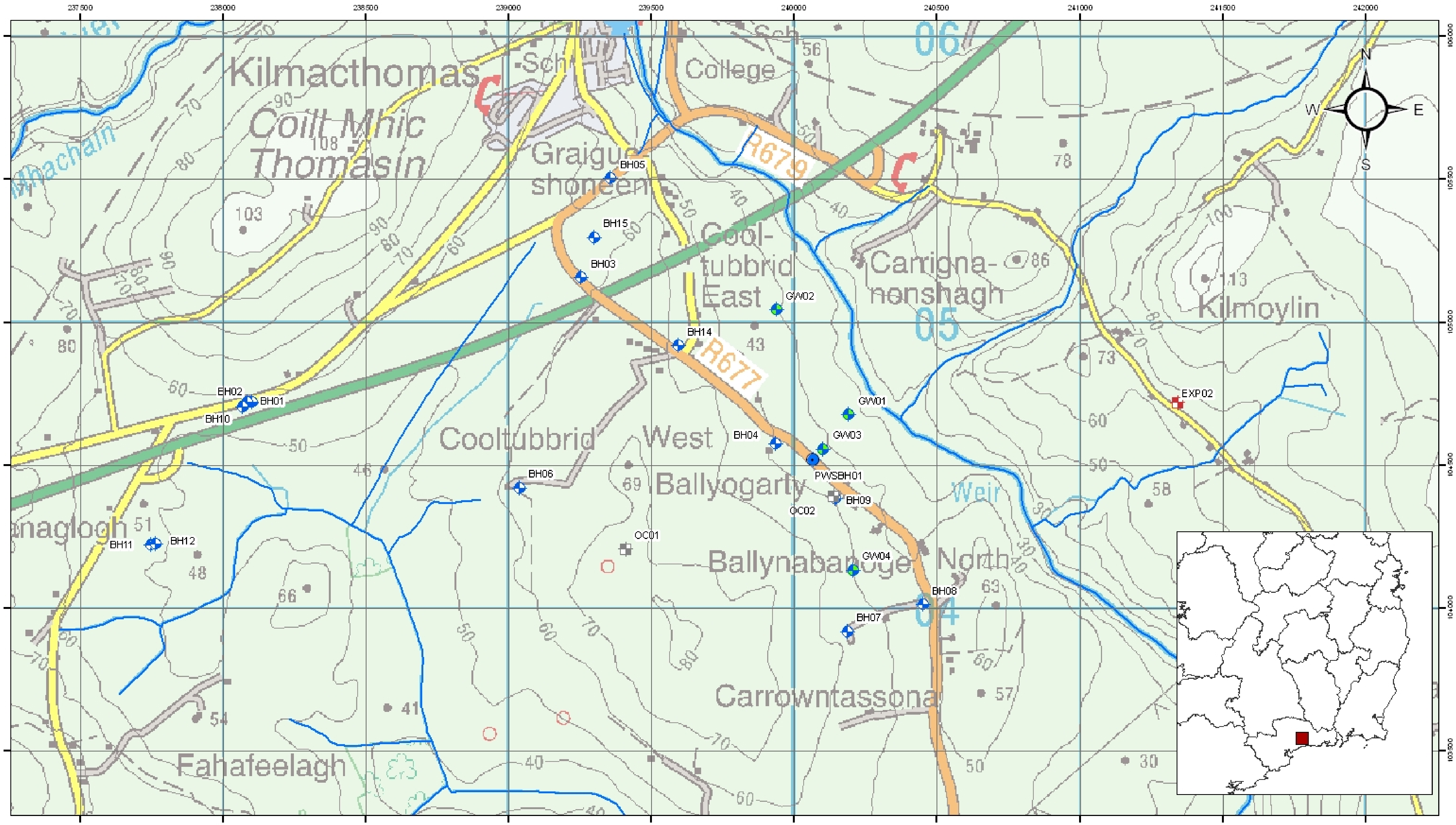



Figure 2 Data Points in the Vicinity of Ballyogarty PWS Site

PWS Abstraction
River
Bedrock Outcrop
Groundwater Borehole
Groundwater Spring
Subsoil Exposure

0 0.25 0.5 1 km

# 6 GEOLOGY

## 6.1 INTRODUCTION

This section briefly describes the relevant characteristics of the geological materials that underlie the Ballyogarty source. It provides a framework for the assessment of groundwater flow and source protection zones that will follow in later sections. The geological information is based on the bedrock geological map of East Cork – Waterford, Sheet 22, 1:100,000 Series (Geological Survey of Ireland (GSI), 2005) and accompanying memoir (Sleeman *et al,* 2005), the GSI Well and Borehole Databases and on bedrock outcrop and subsoil exposures encountered during site visits.

## 6.2 BEDROCK GEOLOGY

The bedrock map indicates that the majority of the study area is underlain by acidic volcanics and shale of the Campile Formation (CA). The bedrock is classified as Ordovician Volcanics for the purposes of the generalised rock unit map prepared to assist GSI aquifer classification. Outcrops of these rocks within the study area showed the beds were steeply dipping to the east and were well fractured, particularly at the ground surface. In the Cooltubrid East area and the northern part of Cooltubrid West, the bedrock is comprised of dark grey slates and thin siltstones of the Ross Member (CArs) of the Campile Formation.

A major fault is mapped running roughly northeast to southwest through Kilmacthomas, 1.2 km north of the source along the northern boundary of the Ross Member. The main fault is displaced by several cross faults in the Kilmacthomas area. Two of these cut through Cooltubrid East, the first from the north, which abuts against the second which trends southeast through the area and passes between the source and the Mahon River.

The bedrock geology of the area is shown in Figure 3. Figure 3 also shows the locations of a west-east schematic cross section through the study area, which is provided in Figure 9.

## 6.3 SUBSOILS GEOLOGY

According to GSI and EPA web mapping, the majority of the study area is underlain by till derived from acid volcanic bedrock material. The till is a component of the Ballyvoyle Till, which occurs throughout Waterford. The till is generally a massive, structureless, sandy – stony deposit with a well defined fabric (usually aligned north to south) (GSI, 2004).

Alluvial subsoils are mapped flanking the Mahon River, while a further band of alluvium is mapped running north to south adjacent to the west side of the R677 through Carrowntassona townland to the south side of the ridge.

Bedrock outcrop is mapped on the crest of the ridge to the west of the source and running north-south from the River Mahon on the southeastern limb of the ridge in Ballynabanoge north. Further isolated pockets of bedrock outcrop are mapped on a line north-south through the study area at between 50 m to 60 m AOD. The subsoil map of the area is shown in Figure 4.

***Subsoil Permeability***

The subsoils across County Waterford are currently being classified with respect to their permeability in the preparation of a Groundwater Vulnerability map for Waterford County Council, by TOBIN on behalf the Geological Survey of Ireland. The data were made available for the preparation of this report. Under the TOBIN/GSI investigations the subsoil permeability of the till units in the study area has been classed as '***Moderate Permeability***'.

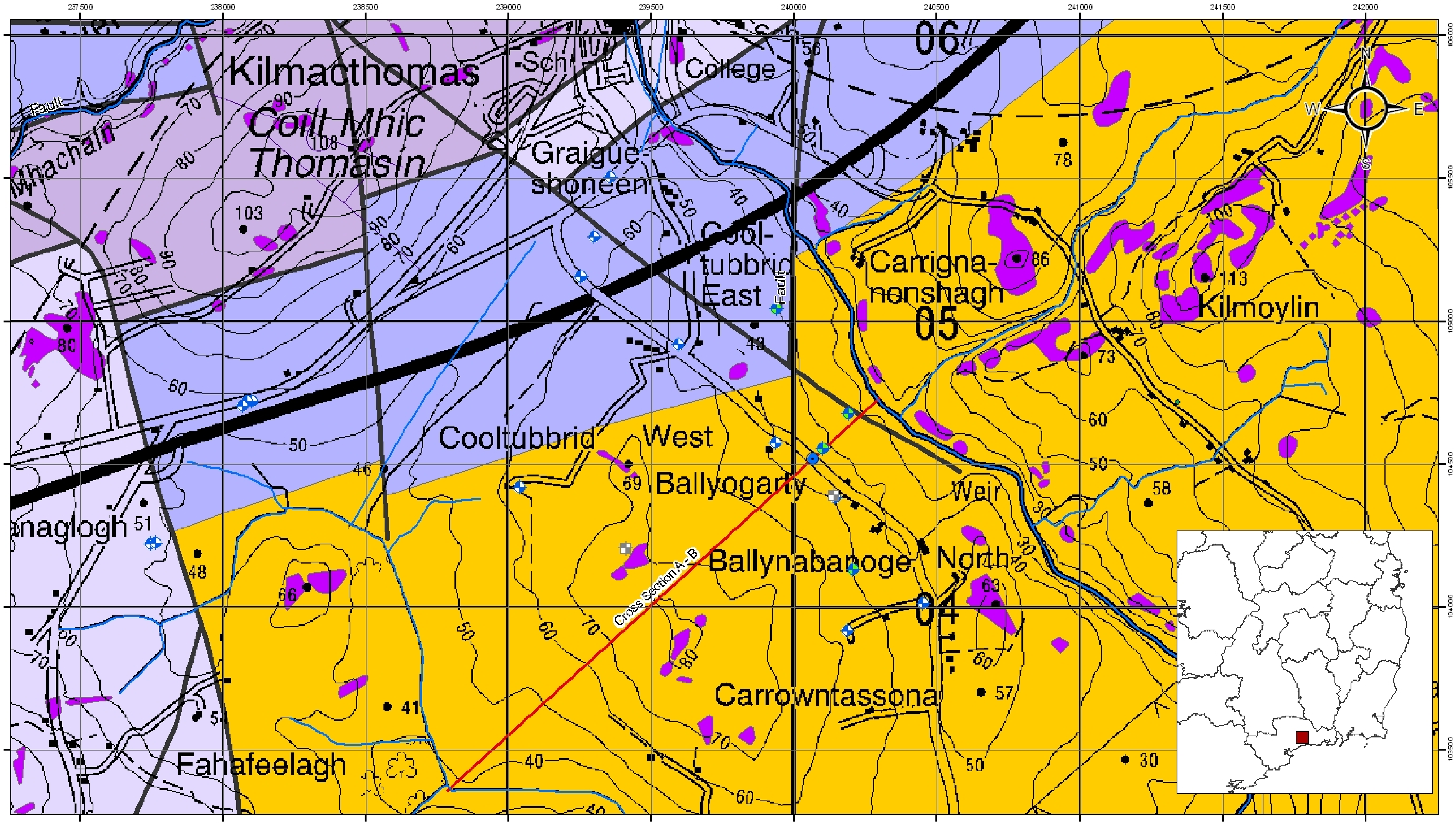



Figure 3 Bedrock Geology of Study Area

PWS Abstraction

River

Campile Formation (Rhyolitic lava, tuff & breccia, shale)

Kilmacthomas Formation (Green, grey and purple slate, siltstone)

in Campile Formation (Rhyolitic lava, tuff & breccia, shale)

Ross Member (Dark grey slate with thin siltstone)

Line of Cross Section A- B

See Fig 9

GSI Mapped Bedrock Outcrop

Fault

0 0.25 0.5 1 km

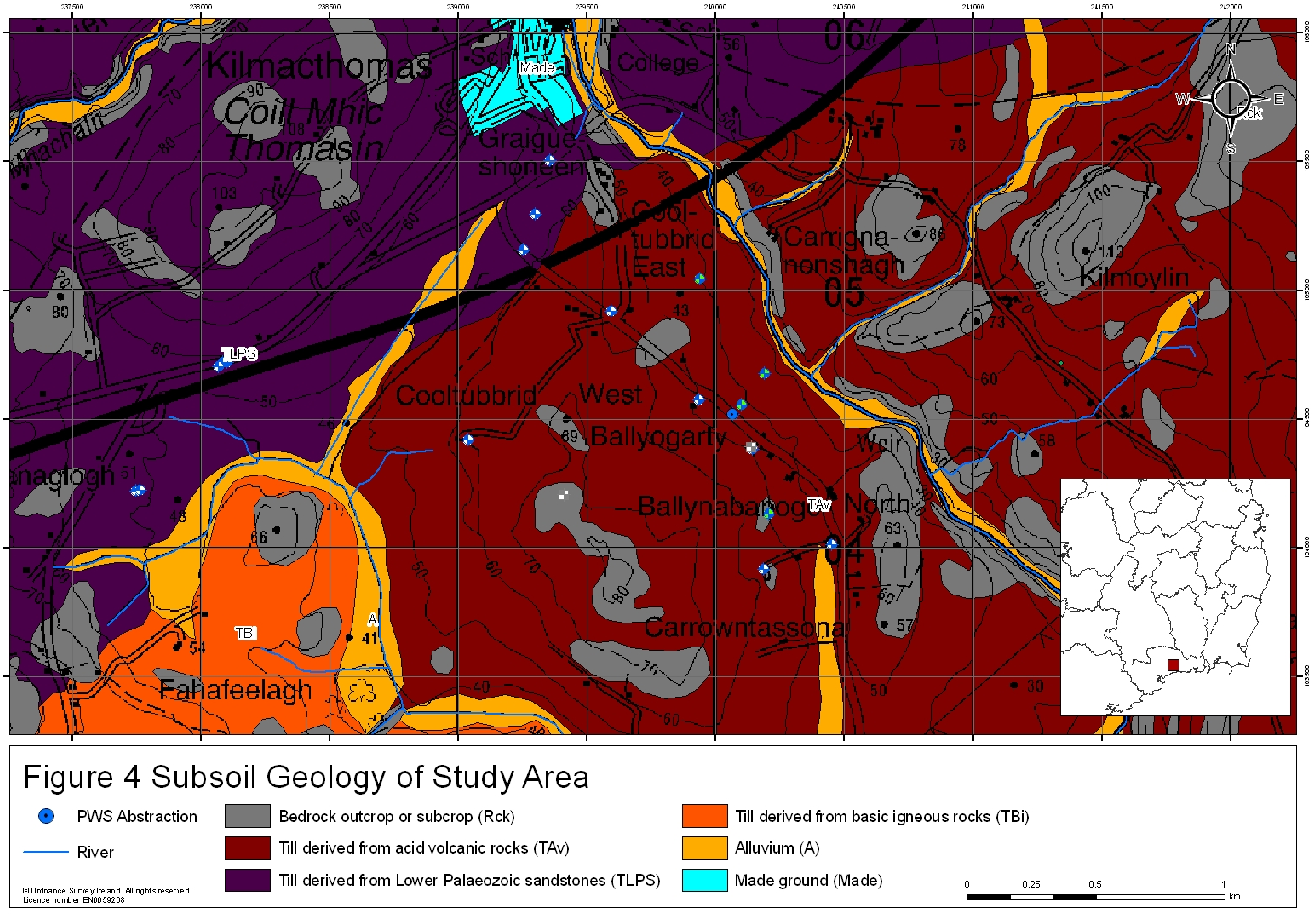



Figure 4 Subsoil Geology of Study Area

Subsoils at an existing trial hole in the townland of Shanakill on the east side of the Mahon River and in the same till unit as the study area were logged during the site visits and were also classified as '***moderate permeability'***. A small area of ***'high permeability'*** clayey SAND and SAND deposits occurs in the western part of Cooltubrid East, as recorded in the drilling of boreholes BH14 and BH15 respectively (RPS, 2009).

Indicators of poor drainage conditions such as rushes, iris and artificial drainage were encountered in the areas where deep poorly drained soils are mapped. Spring discharges were encountered in all of these areas, such that the poorly drained soils are considered to be associated with groundwater discharge rather than low permeability subsoils. Drainage density across the study area is low, which is a further indicator of moderate to high permeability.

Overall, outside the small area of high permeability, the subsoils are considered to have ***'moderate permeability'***.

***Depth to bedrock***

Depth to bedrock (DTB) has been interpreted across the study area based on bedrock outcrops mapped by the GSI, outcrops mapped during site visits, areas mapped as extreme groundwater vulnerability by the GSI, logged evidence from drilling of boreholes across the study area for the Kilmacthomas WSS (RPS, 2009) (boreholes BH01, 02, 10, 11, 12, 14 and 15) and anecdotal evidence from the borehole owners of the geological conditions encountered during the drilling of private boreholes (boreholes BH05, BH06, BH07 and BH08).

From the GWPS mapping, DTB is mapped as less than 3 m across the upper slopes of the ridge through Carrowntassona, Ballynabanoge North, Ballyogarty, Cooltubrid West and Cooltubrid East and on a north south line through the study area between 50 m and 60 mAOD. Anecdotal evidence at borehole BH06 in Cooltubrid West indicates that DTB is less than 3 m in the vicinity of the borehole and for this report the 3 m DTB contour has been extended into this area to include the borehole. Bedrock outcrop was encountered at outcrop OC02 (adjacent to borehole BH09) in the townland of Ballyogarty. For this report the 1 m and 3 m DTB contours have been extended into this area to incorporate outcrop OC02.

In the vicinity of boreholes BH14 and BH15, there is conflicting evidence of DTB. The driller's logs for the boreholes indicate DTB of 1.5 m and 3 m respectively. The driller's logs indicate that the length of casing used in the drilling of each borehole was 6 m. Both boreholes are located close to areas of DTB of less than 3 m. The consultants report indicates DTB was 18 m for each borehole. At borehole BH14 the log records 6 m of clayey SAND over brown CLAY overlying shale bedrock. At borehole BH15 the log records 6 m of SAND over plastic, yellow boulder clay, over grey shale bedrock. Given the uncertainty, it is considered that a conservative approach should be adopted in interpreting the DTB for this area. As such, a DTB of 6 m has been adopted for the area on the basis of the logged SAND and clayey SAND, the length of casing used and the location outside the mapped 3 m DTB contour.

A further small area with DTB between 5 m and 10 m has been mapped around the source, where a DTB of 5.6 m is recorded by the GSI. For this report DTB across the remainder of the study area is conservatively interpreted as between 3 m and 5 m.

## 6.4 SOILS

The soils across the majority of the study area are classified as deep, well drained, mineral soils (AminDW), derived from acid volcanic parent material (subsoils map on EPA website and An Foras Talúntais, 1980). Soils along the margin of the Mahon River are classified as alluvial mineral soils. A band of deep, poorly drained mineral soils (AminPD) derived from acid volcanic parent material, of varying width, runs between the alluvial soil and the well drained mineral soil.

# 7 GROUNDWATER VULNERABILITY

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

An interim groundwater vulnerability map was undertaken by RBD consultants and compiled by GSI. The groundwater vulnerability map for the area has been amended to take account of the local scale data collected during the desk study, site visits and field mapping stages of the project and data from the ongoing development of the regional scale County Waterford vulnerability map under the National Groundwater Protection Scheme.

The resulting proposed map reveals areas of extreme vulnerability on the ridge to the west of the source, and to the north and south of the source, at elevations between 50 m and 60 mAOD. Further areas of extreme vulnerability are mapped in the Ballynabanoge North townland adjacent to the River Mahon and flanking the River Mahon. High groundwater vulnerability has been delineated over the remainder of the study area. The proposed local scale vulnerability map derived for this report is shown in Figure 5.

# 8 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
- ⇨ Waterford Groundwater Protection Scheme (Hudson *et al*, 1997)
- ⇨ Kilmacthomas Water Supply Scheme: Preliminary Report – Hydrogeological Investigations (RPS, 2009)
- ⇨ Hydrogeological mapping by TOBIN Consulting Engineers October and November 2009.

## 8.1 GROUNDWATER BODY AND STATUS

The source and the surrounding area are located within the Tramore groundwater body (GWB), close to the southwestern boundary of the body. The Tramore GWB is currently classified at Good Status but is at risk of not achieving WFD objectives. The groundwater body descriptions are available from the GSI website: www.gsi.ie and the 'status' is obtained from the Water Framework Directive website: www.wfdireland.ie .

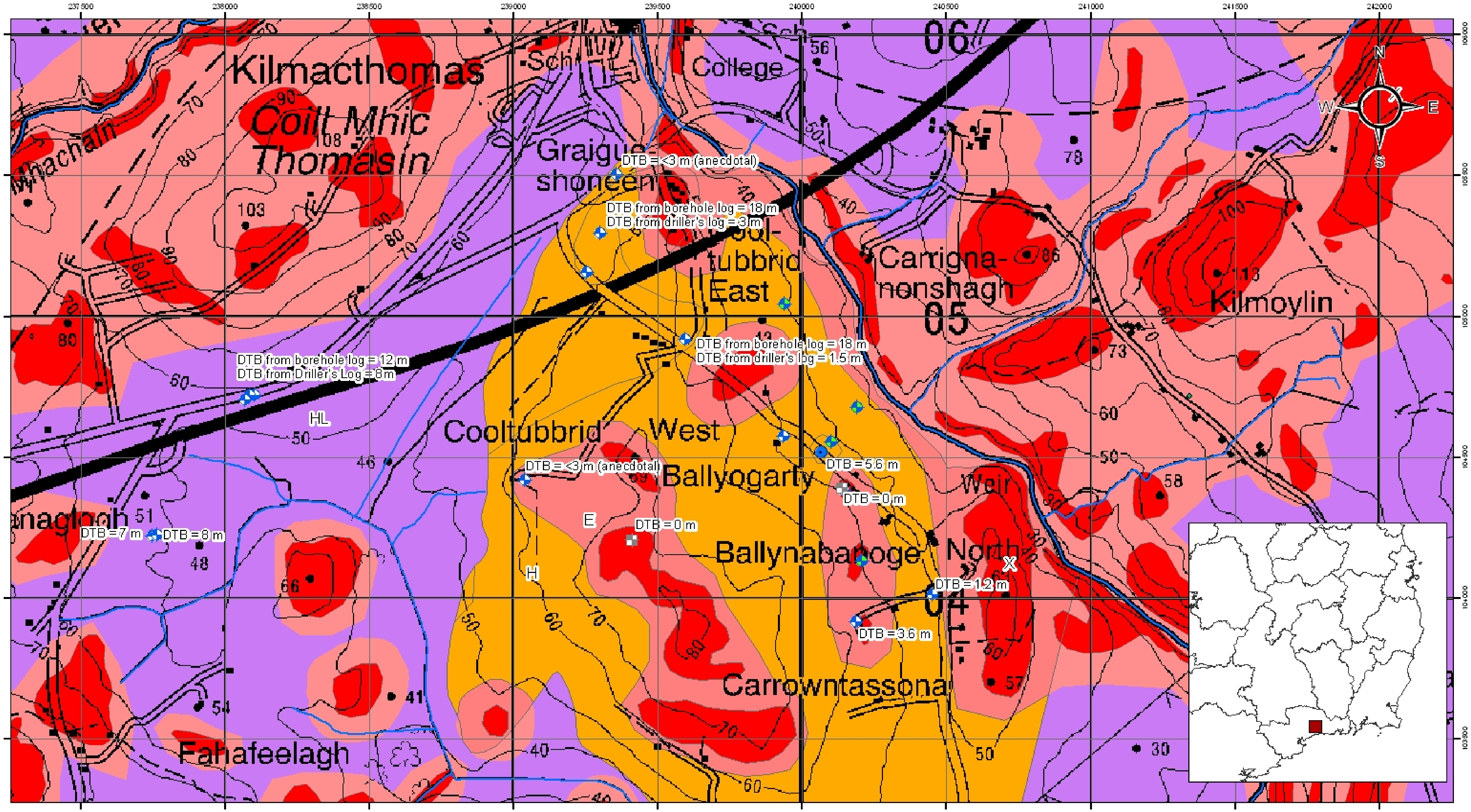
## 8.2 METEOROLOGY

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:*** 1,061 mm. The contoured data map of rainfall in Ireland (Met Éireann; 1961-1990 dataset) shows that the source is located between the 1,000 mm and 1,200 mm average annual rainfall isohyets. The closest meteorological station to the Ballyogarty Source is at Kill Garda Station, 5.7 km to the east-southeast where the average rainfall between 1961 and 1990 was 1061 mm/annum (Fitzgerald and Forrestal, 1996).

***Annual evapotranspiration losses:*** 548 mm. The closest synoptic weather stations to the study area are Kilkenny and Rosslare at 53 km north and 75 km east respectively. Average potential evapotranspiration (P.E.) at each site between 1961 and 1990 was 458.8 mm and 577.5 mm respectively, based on Met Éireann data. The contoured mean annual potential evapotranspiration for Ireland shows that Kilmacthomas lies close to the 500 mm/yr contour and is likely to better represented by Rosslare than by Kilkenny (France & Thornley, 1984). As such, P.E. for Kilmacthomas is taken as 577.5 mm/yr based on the Rosslare data. Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits giving an Actual Evapotranspiration of 548 mm.

***Annual Effective Rainfall:*** 513 mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this, or 513 mm/year. See section on Recharge which estimates the proportion of effective rainfall that enters the aquifer.




# Figure 5 Local Scale Groundwater Vulnerability Map

- PWS Abstraction
- River
- Extreme - Depth to bedrock < 1 m (X)
- Extreme Vulnerability (E)
- High Vulnerability (H)
- High to Low Vulnerability (HL) (Interim Value for unmapped area)
- Depth to Bedrock in metres
- Depth to Bedrock in metres

0 0.25 0.5 1 km

## 8.3 GROUNDWATER LEVELS, FLOW DIRECTIONS AND GRADIENTS

Groundwater levels were measured at the PWS borehole and in private boreholes across the study area in October/November 2009. Full details of the water level data collected are provided in Table A1.1 in Appendix 1.

Depth to groundwater in the private boreholes across the area varied between 1.95 m and 8.09 m below ground level (bgl). In the public supply borehole, the pumping water level was measured at a maximum of 5.76 mbgl (5.97 m below the top of the well casing) while resting water levels were recorded at 2.54 mbgl after a short recovery test. Winter artesian conditions occur occasionally in places, e.g. borehole BH07 is anecdotally reported to have overflowed in winter of 1999.

Approximate groundwater contours based on the available, measured groundwater level data are shown in Figure 6. The contours indicate that the groundwater flow direction is generally down slope towards the surface water courses. Flow directions are expected to approximately follow the local surface water catchments. Groundwater flow divides occur along the topographic catchment divide of the ridge enclosing the source.

Based on the approximate groundwater contours, the average hydraulic gradient in the vicinity of the source is approximately 0.044.

## 8.4 HYDROCHEMISTRY AND WATER QUALITY

Twenty samples were collected and analysed by the EPA between February 2001 and October 2008. Samples of untreated groundwater are collected from the untreated water tap in the source pump house. Biannual samples were collected until July 2007 with the frequency subsequently increasing to quarterly. The resulting data are presented in Table A1.2 in Appendix 1. Field water quality data (pH, alkalinity, DO, conductivity and temperature) were collected from borehole PWSBH01 during the pumping test on 10/11/2009. The field data are presented in Table A1.3 in Appendix 1.

Overall the source has a low level of mineralization as indicated by the low average electrical conductivity (182 µS/cm) and alkalinity (23.95 mg/l as $CaCO_3$) and low hardness (49.24 mg/l as $CaCO_3$). The hydrochemistry is mixed and is not dominated by any particular ion pair. The cations sodium, calcium and magnesium are present in equivalent amounts together with a minor component of potassium. The anion hydrochemistry is dominated by equivalent components of chloride and nitrate, a smaller but significant bicarbonate component and a minor sulphate component. The pH of the groundwater is low with a field measured average of 6.16.

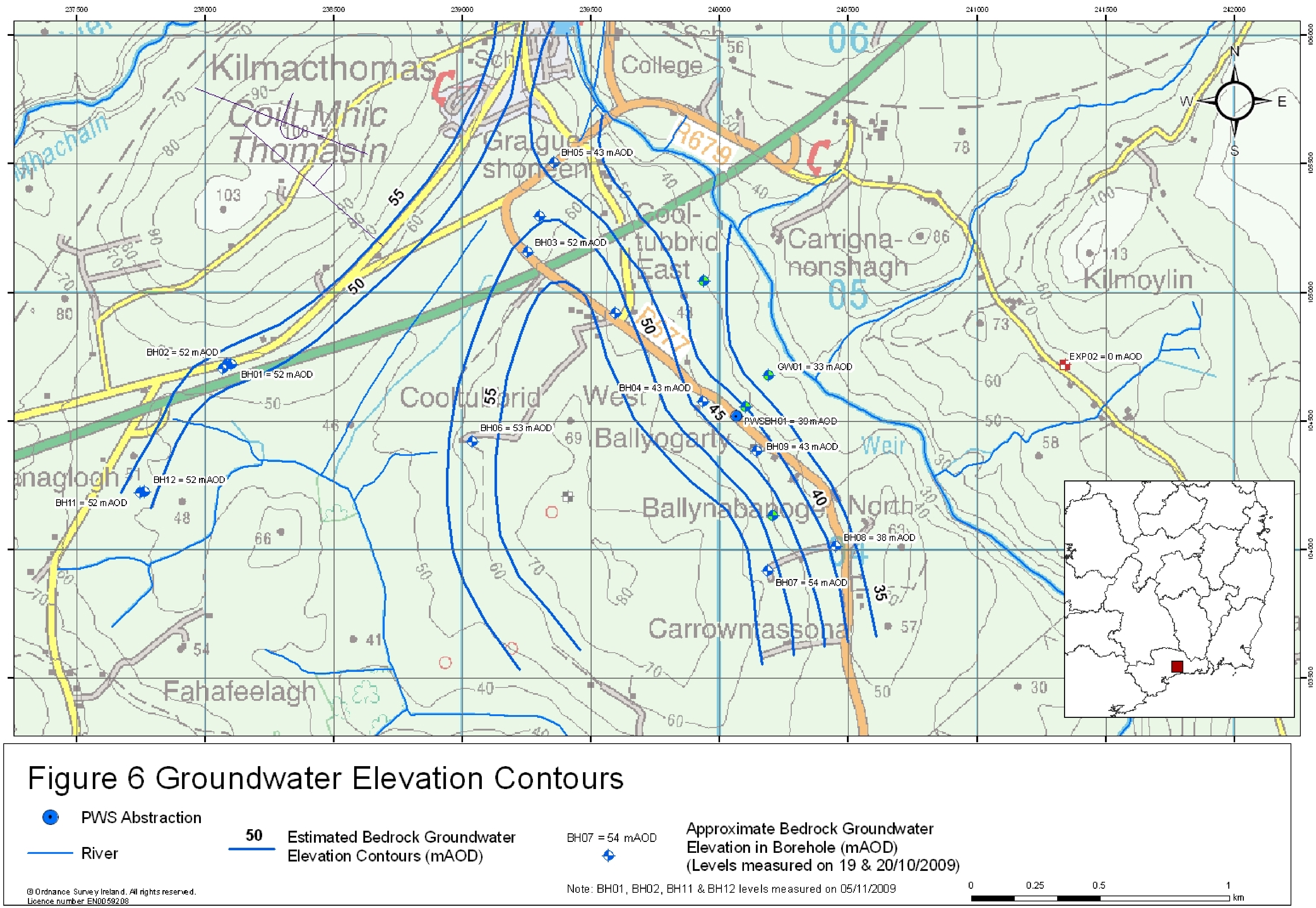



Figure 6 Groundwater Elevation Contours

Detectable levels of various heavy metals have been encountered over the monitoring period including arsenic, mercury, and cadmium.

The water quality of the source fails to meet the prescribed drinking water standards for three components and is in excess of the relevant groundwater threshold value (S.I. No. 9 of 2010 Groundwater Regulations) for a further three.

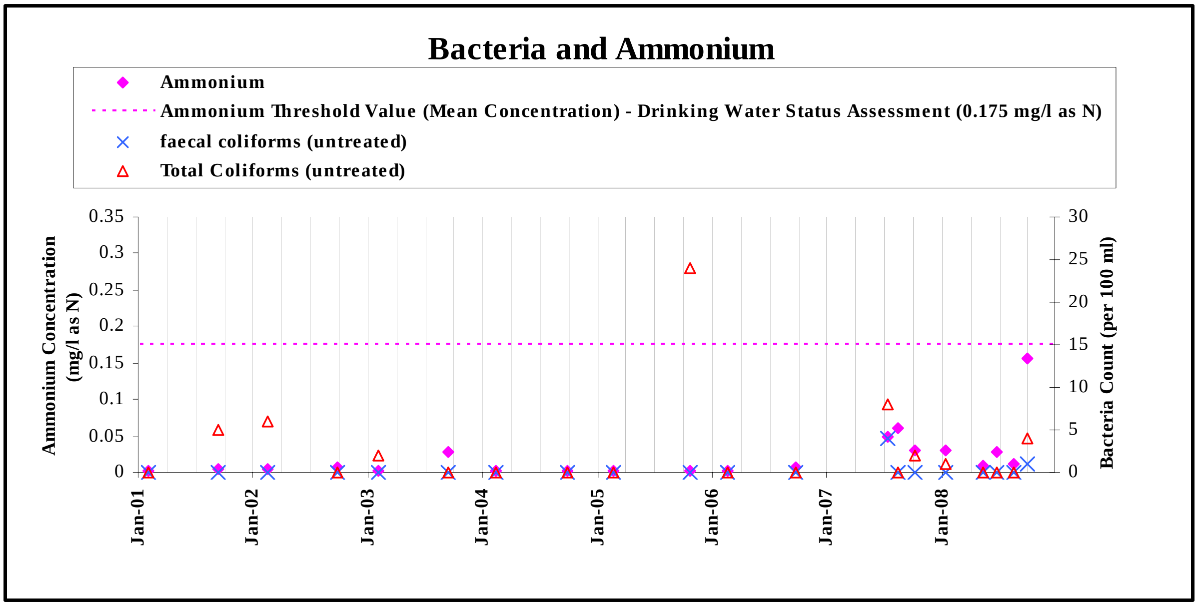



**Figure 7a Graph of Bacteria and Ammonia Concentrations at Borehole PWSBH01**

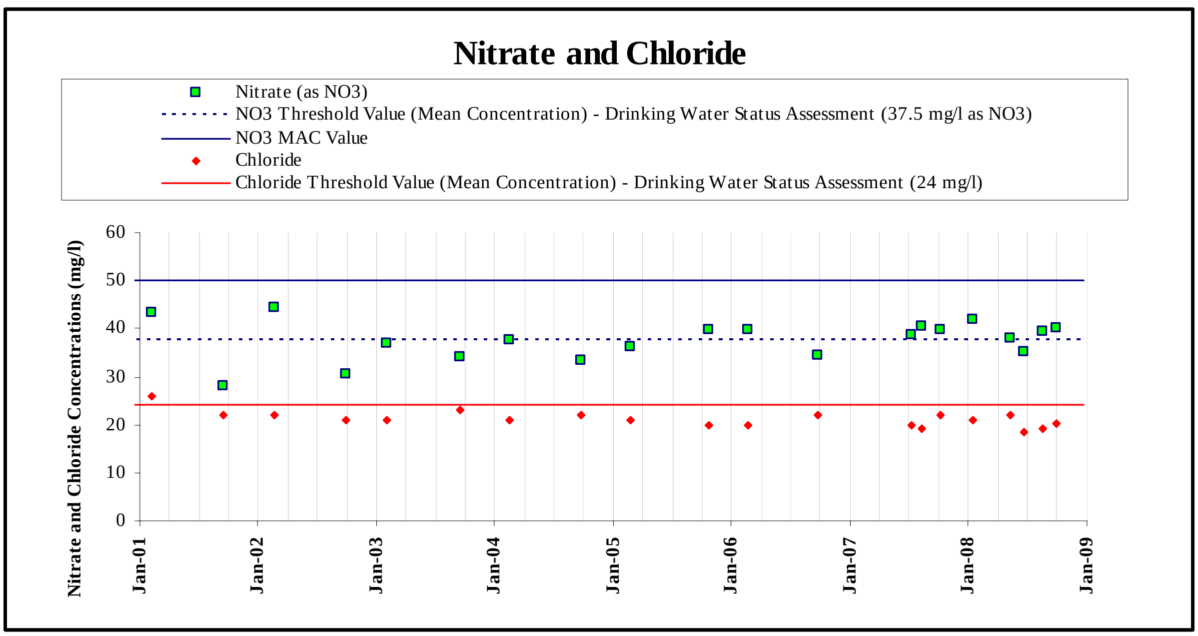



**Figure 7b Graph of Nitrate and Chloride Concentrations at Borehole PWSBH01**

Figure 7a shows the EPA measured concentrations of faecal and total coliforms and ammonia at the source. Faecal coliforms concentrations in the untreated groundwater were above the drinking water limit of zero counts per 100 ml on two occasions while total coliforms exceeded the same limit on eight occasions, two of which were coincident with the faecal events. The ammonium concentration was generally low but approached the threshold value (Groundwater Regulations, S.I. No. 9 of 2010) in October 2008 at a time when there were also total and faecal bacteria present. Detection of faecal coliforms correlated with total coliform and ammonium detections. Ammonium and total coliforms both occurred independently of the other parameters on other sampling dates.

Figure 7b shows the EPA measured concentrations of nitrate and chloride at the source. The average nitrate concentrations over the monitoring period was 37.6 mg/l as $NO_3$, which just exceeds the threshold value (Groundwater Regulations, S.I. No. 9 of 2010) of 37.5 mg/l as $NO_3$. Average chloride concentrations measured 21.15 mg/l which is below the Saline Intrusion threshold value (Groundwater Regulations, S.I. No. 9 of 2010) of 24 mg/l. Chloride exceeded the Saline Intrusion threshold value in February 2001, however the measured concentrations have been below the threshold value since that event.

Figure 7c shows the EPA measured concentrations of manganese and potassium and the potassium:sodium ratio at the source. Figure 7d shows the concentration of orthophosphate at the source.

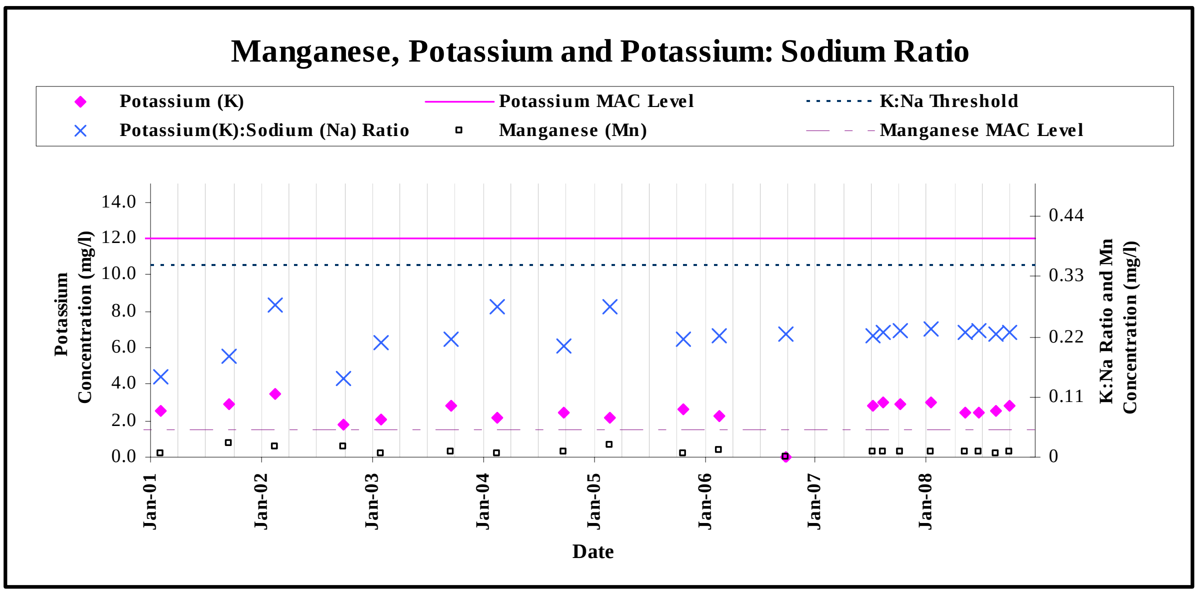



**Figure 7C Graph of Manganese, Potassium and Potassium:Sodium Ratio at Borehole PWSBH01**

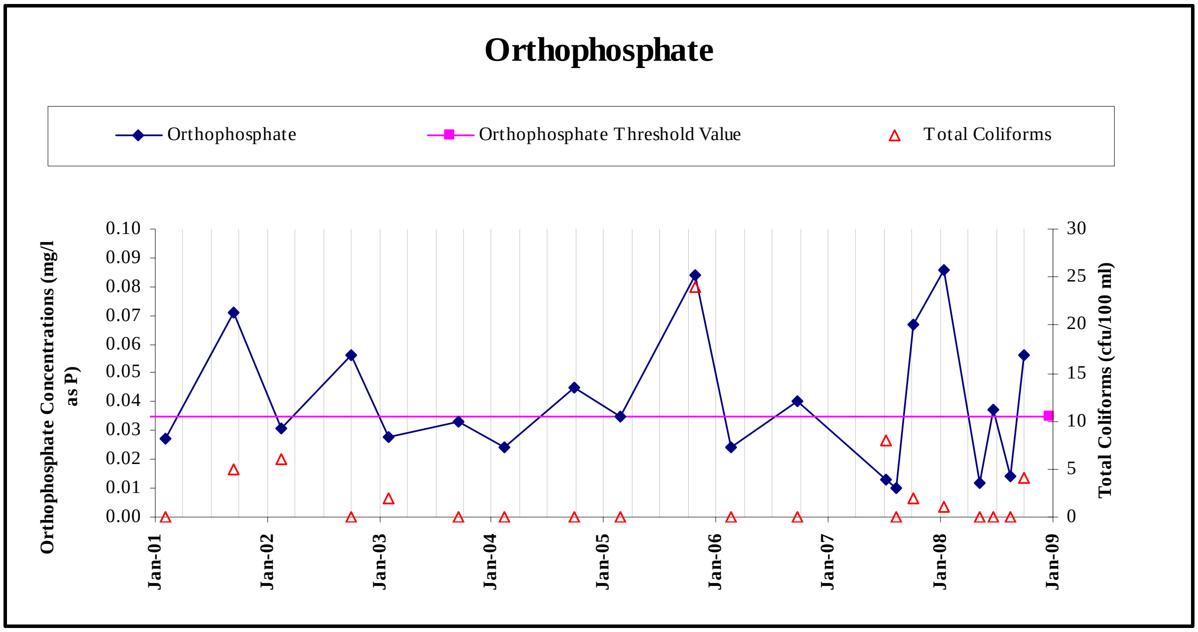



**Figure 7D Graph of Orthophosphate at Borehole PWSBH01**

The concentration of orthophosphate exceeded the threshold value (Groundwater Regulations, S.I. No. 9 of 2010) of 0.035 mg/l as P on ten occasions up to October 2008 and showed an average concentration over the monitoring period of 0.04 mg/l as P. Five of the phosphate exceedences correlate with total coliform exceedences while the remainder occur independently of peaks in other parameters.

The heavy metal arsenic exceeded the drinking water standard of 50 µg/l on all sampling occasions and had an average concentration of 58 µg/l, which is also in excess of the threshold value (Groundwater Regulations, S.I. No. 9 of 2010) of 7.5 µg/l. Arsenic treatment is in place at the source pumping house. Elevated arsenic also occurs at borehole BH05 and treatment is in place at that source as well. Further arsenic occurrence was detected at borehole BH10 (RPS, 2009).

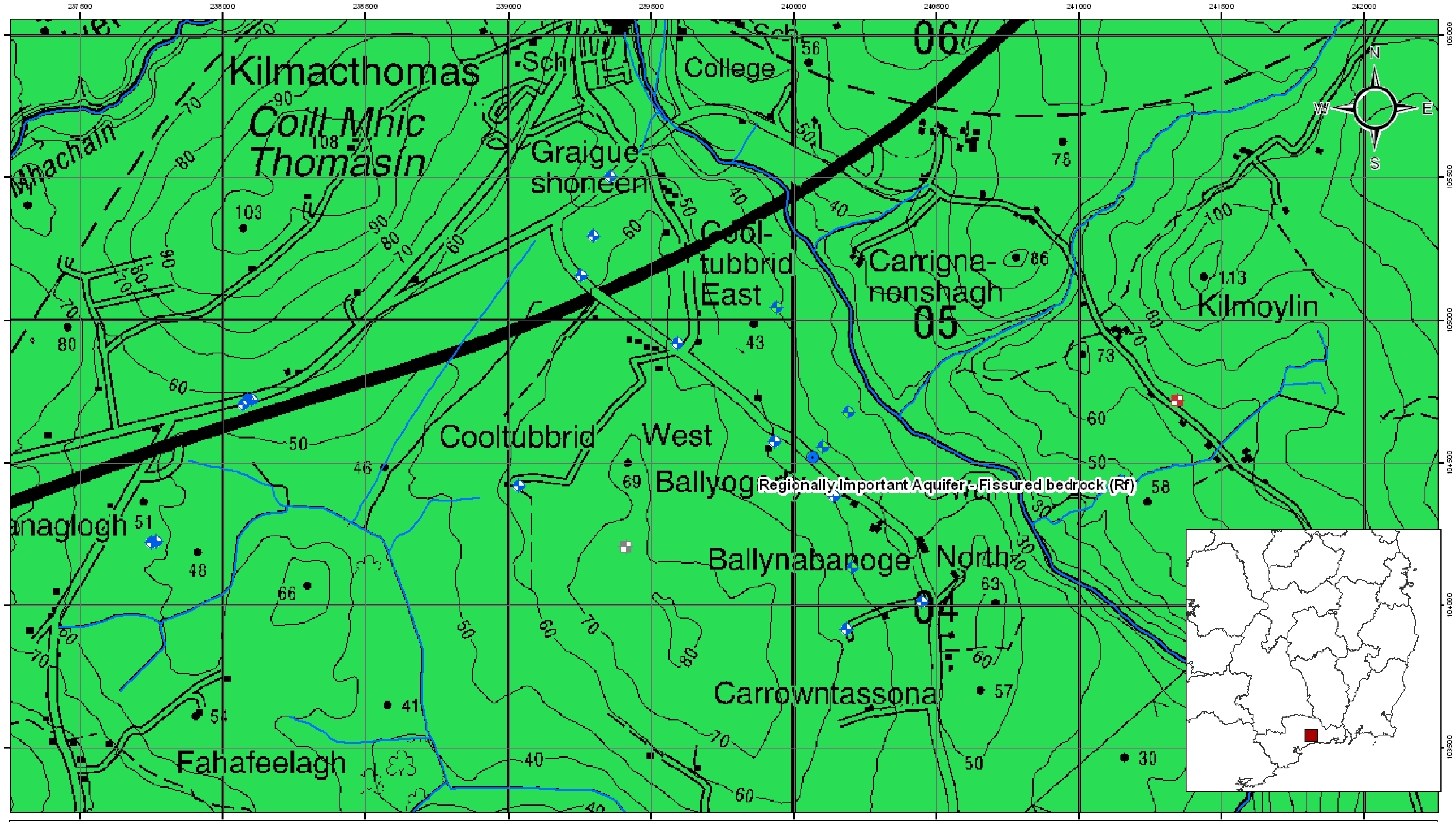
The remainder of the parameters measured do not exceed their respective drinking water standard and have average concentrations less than their respective threshold value (Groundwater Regulations, S.I. No. 9 of 2010).

In summary, nitrate, phosphate and bacteriological exceedences, and occasionally elevated ammonium concentrations, suggest contamination from an organic waste source. Given the land use in the area, the most likely sources are grazing animals, farmyard wastes and onsite waste water treatment systems upgradient of the source. The elevated levels of arsenic and detectable levels of other heavy metals are considered to be of natural origin, although may be being exacerbated by reducing conditions often associated with organic waste contamination.

## 8.5 AQUIFER CHARACTERISTICS

The groundwater source is located in the Tramore Groundwater Body. The GSI bedrock aquifer map of the area indicates that the Ordovician Volcanics are classified as a *Regionally Important Fissured Aquifer (Rf)*. This implies that the bedrock is generally highly productive. The bedrock aquifer map of the area is shown in Figure 8.

The Groundwater Body report indicates aquifer transmissivity in the Ordovician Volcanics ranges between 2 and 290 $m^2$/day, with an average of 108 $m^2$/day (GSI, 2004). The pumping test carried out on borehole PWSBH01 indicated a transmissivity of approximately 291 $m^2$/day in the vicinity of the source although the confidence in this result is low due to the conditions of the test (see Appendix 2). Further pumping tests in the Ordovician Volcanics at BH02 (BHB5), BH10 (BHB4) and BH11 (BHB2) for the Kilmacthomas Water Supply indicated a Transmissivity range of 13.5 $m^2$/day to 114 $m^2$/day (RPS, 2009). Aquifer storage is estimated at 0.01 in unconfined areas and 0.0001 in confined areas (GSI, 2004). Storativities ranging from 0.00155 to 0.0026 were encountered under confined conditions to the west of the source in the vicinity of boreholes BH02 and BH11 respectively (RPS, 2009). Aquifer thickness in the vicinity of boreholes BH02, BH10 and BH11 was estimated at between 40 and 52 m (RPS, 2009). Taken with the corresponding transmissivity values, hydraulic conductivities in the range of 0.39 to 2.6 m/d were calculated (RPS, 2009). Taking the same thickness range at borehole PWSBH01 results in an estimated hydraulic conductivity range of 5.6 to 7.2 m/d.




# Figure 8 Bedrock Aquifer Map

PWS Abstraction

Regionally Important Aquifer - Fissured Bedrock (Rf)

River

0 0.25 0.5 1 km

Based on the estimated bedrock aquifer transmissivity and the aquifer hydraulic gradients, the advective 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 (m²/day); $n_e$ = effective porosity (dimensionless)
i = hydraulic gradient; and, b = aquifer thickness.

The estimated groundwater velocity range in the bedrock aquifer, based on the available data is shown in Table 8-1.

**Table 8-1 Estimated Groundwater Velocity Range**

| Parameter | Units | Minimum | Maximum | Average | Data Source |
|---|---|---|---|---|---|
| T | $m^2/d$ | 13.5 | 291 | 108 | Boreholes PWSBH01, BH02, BH10 & BH11 |
| i | [-] | 0.044 | 0.044 | 0.044 | Section 8.3 |
| b | m | 40 | 52 | assume = 46 | Boreholes BH02, BH10 and BH11 |
| $n_e$ | [-] | 0.01 | 0.01 | 0.01 | (GSI, 2004) |
| v | m/d | 1.1 | 32.0 | 10.3 | |

## 8.6 RECHARGE

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 Ballyogarty, the main parameters involved in recharge rate estimation are: annual rainfall; annual evapotranspiration; and a recharge coefficient.

The majority of the area surrounding the source is mapped as high groundwater vulnerability with the Rf aquifer overlain by moderate permeability subsoils and well drained soils. Guidance Document GW5 recommends a recharge coefficient in the range of 0.35 to 0.80 for these conditions with an inner range of 0.5 to 0.7 (IWWG, 2005). The low drainage density of the study area indicates that recharge occurs readily. The steep slope of the sub-catchment containing the source is likely to promote a certain degree of runoff. Taken together it is considered that an inner range recharge coefficient of 0.60 should be used.

The extremely vulnerable areas in the study area are overlain by well drained soils or are classified as having depth to bedrock of less than 1 m. Based on the low drainage density, high slope and on Guidance Document GW5 these areas have been assigned recharge coefficients of 0.60 and 0.8 respectively.

Runoff losses are assumed to be 38% of potential recharge (effective rainfall). This value is based on an assumption of *c*. 20% runoff for 10% of the area (extreme vulnerability – rock close to surface) and 40% runoff for 90% of the area (extreme and high vulnerability).

The bulk ***recharge coefficient*** for the area is therefore estimated to be 0.62.

These calculations are summarised as follows:

| | | |
|---|---|---|
| Average rainfall (R) | | 1,061 mm/yr |
| Estimated P.E. | | 577 mm/yr |
| Estimated A.E. (95% of P.E.) | | 513 mm/yr |
| effective rainfall | | 513 mm/yr |
| Potential recharge | | 548 mm/yr |
| Recharge coefficient for extreme Vul (rock at surface) | 0.80 | 548 mm/yr |
| Recharge coefficient for extreme Vul (DTB 3 to 5 m) | 0.60 | 438 mm/yr |
| Recharge coefficient for high Vul | 0.60 | 438 mm/yr |
| Averaged runoff losses | 38% | 208 mm/yr |
| Bulk recharge coefficient | 0.62 | |
| **Recharge** | | **340 mm/yr** |

## 8.7 CONCEPTUAL MODEL

The current understanding of the geological and hydrogeological setting is given as follows:

- A schematic representation of the conceptual model is shown in Figure 9.

- The source under consideration in this report is comprised of one borehole (PWSBH01) in the Ballyogarty area of Kilmacthomas, located in Ordovician volcanic bedrock, classified as a *Regionally Important Fissured Aquifer (Rf)*.

- Abstraction rates from the source average 195 $m^3$/day.

- Depth to bedrock is considered to be less than 3 m on the ridges, deepening to up to 5 m downslope towards the surface water courses. At the source, the subsoil thickness slightly exceeds 5 m and as such, a pocket of subsoil around the source is mapped as between 5 m and 10 m thick.

- The subsoils of the area are considered to have a moderate permeability based on BS5930 assessment of subsoil samples and on indicators of good drainage across the study area.

- Local scale groundwater vulnerability mapping for the study area shows that the ridges and a few lower lying rock outcrops are classified as extremely vulnerable. The remainder of the study area is classified as having high groundwater vulnerability.

- Groundwater levels are deepest on the ridges at up to 8 mbgl. Levels rise to close to ground level close to and downgradient of the source. Spring discharges occur in places, especially downgradient of the source, between the source and the river. Winter artesian conditions occur occasionally at some bedrock boreholes.

- Groundwater flow is from the ridges down slope towards the river. Groundwater flow is via fractures, which are considered to be present throughout the effective thickness (up to 52 m) with occasional deeper fractures also likely. Flow paths are likely to be quite long, with groundwater discharge occurring close to and at surface water courses. Springs may occur close to breaks of slope where the shallow groundwater intercepts the ground surface Hydraulic gradients are estimated at approximately 0.044 in the vicinity of the source.

- The groundwater has a low level of mineralisation and is not dominated by any particular ion pair. This suggests a relatively short groundwater residence time. The pH is slightly acidic which may account for the detectable levels of many heavy metals in the groundwater.

- The untreated water quality has several parameters which exceed either the drinking water standard or groundwater threshold values (Groundwater Regulations, S.I. No. 9 of 2010). Occasional breaches of the drinking water standard have occurred for total and faecal coliforms, while the standard for arsenic has been breached on all sampling occasions. The average nitrate and phosphate concentrations are in excess of the groundwater threshold values (Groundwater Regulations, S.I. No. 9 of 2010). The nitrate and bacteriological exceedences, and occasional orthophosphate exceedences suggest contamination from an organic waste source. The arsenic is likely to be of natural origin although may be being exacerbated by reducing conditions often associated with organic waste contamination.

- A pumping test carried out at the source indicates that the transmissivity of the bedrock aquifer is 291 $m^2$/day. This is at the higher end of the regional range for the Ordovician Volcanics. Testing at other sites in the Kilmacthomas area has shown transmissivities ranging from 13.5 to 114 $m^2$/day and storativity of 0.00115 to 0.0026.

- Recharge is assumed to be 100% of potential in areas where bedrock is mapped as close to the ground surface. Elsewhere it is assumed to be 80% of potential recharge. This gives an averaged percentage of 83% for the whole study area and an annual actual recharge of 340 mm/yr.

- The limitations of the conceptual model are mainly related to a lack of information with respect to the following:

  - ⇨ Subsoil Permeability – only one subsoil exposure (trial pit) was encountered. Intrusive subsoil investigation points would help improve the subsoil permeability data and depth to bedrock, for instance in the Cooltubrid East area.

  - ⇨ The pumping test is considered to have been too short and suffered from pumping interference due to the operational requirements of the source. If further hydrogeological investigations are carried out in the vicinity of the source under the Kilmacthomas Water Supply Scheme, the results of any further, more reliable pumping tests should be taken into consideration with respect to the current conceptual model.

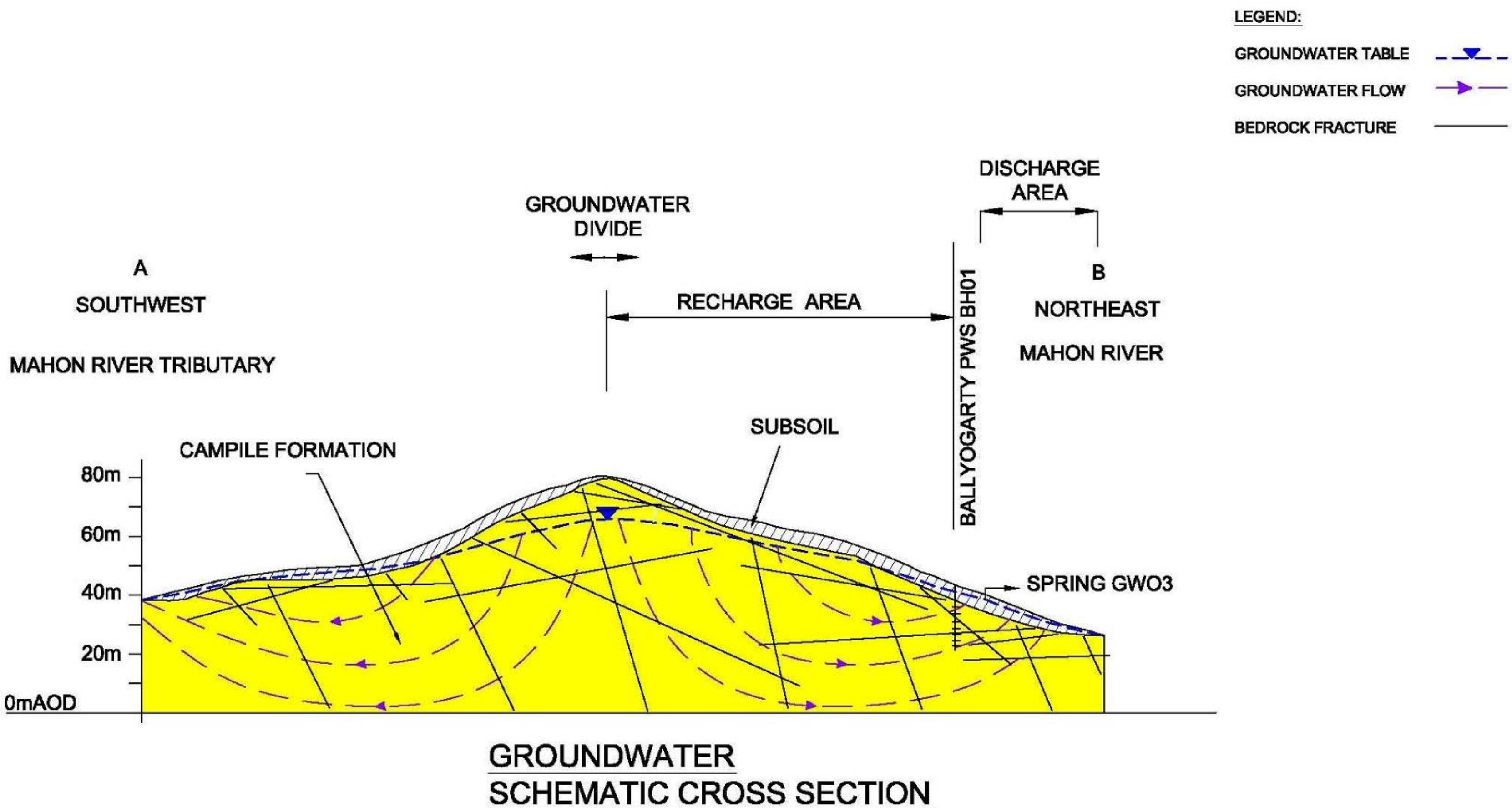



**Figure 9 Schematic Conceptual Model (refer to Figure 3 for Geological Map)**

# 9 DELINEATION OF SOURCE PROTECTION AREAS

This section describes the delineation of the areas around the source that are believed to contribute groundwater to it, and that therefore require protection. The areas are delineated based on the hydrogeological conceptual model, as described in Section 8.7 and presented in Figure 10.

Two source areas are generally delineated:

- Inner Protection Area (SI), designed to give protection from microbial pollution.
- Outer Protection Area (SO), encompassing the zone of contribution to the source.

## 9.1 OUTER PROTECTION AREA

The Outer Protection Area (SO) is bounded by the complete catchment area to the source, i.e. **the zone of contribution (ZOC)**, which is defined as the area required to support an abstraction from long-term recharge. 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. The shape and boundaries of the ZOC were determined using hydrogeological mapping, water balance estimations, and conceptual understanding of groundwater flow. The boundaries are described below along with associated uncertainties and limitations.

**The north east boundary** is the downgradient boundary of the ZOC. This delineates the maximum downgradient distance that the borehole can pump water from and is based on the uniform flow equation (Todd, 1980).

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

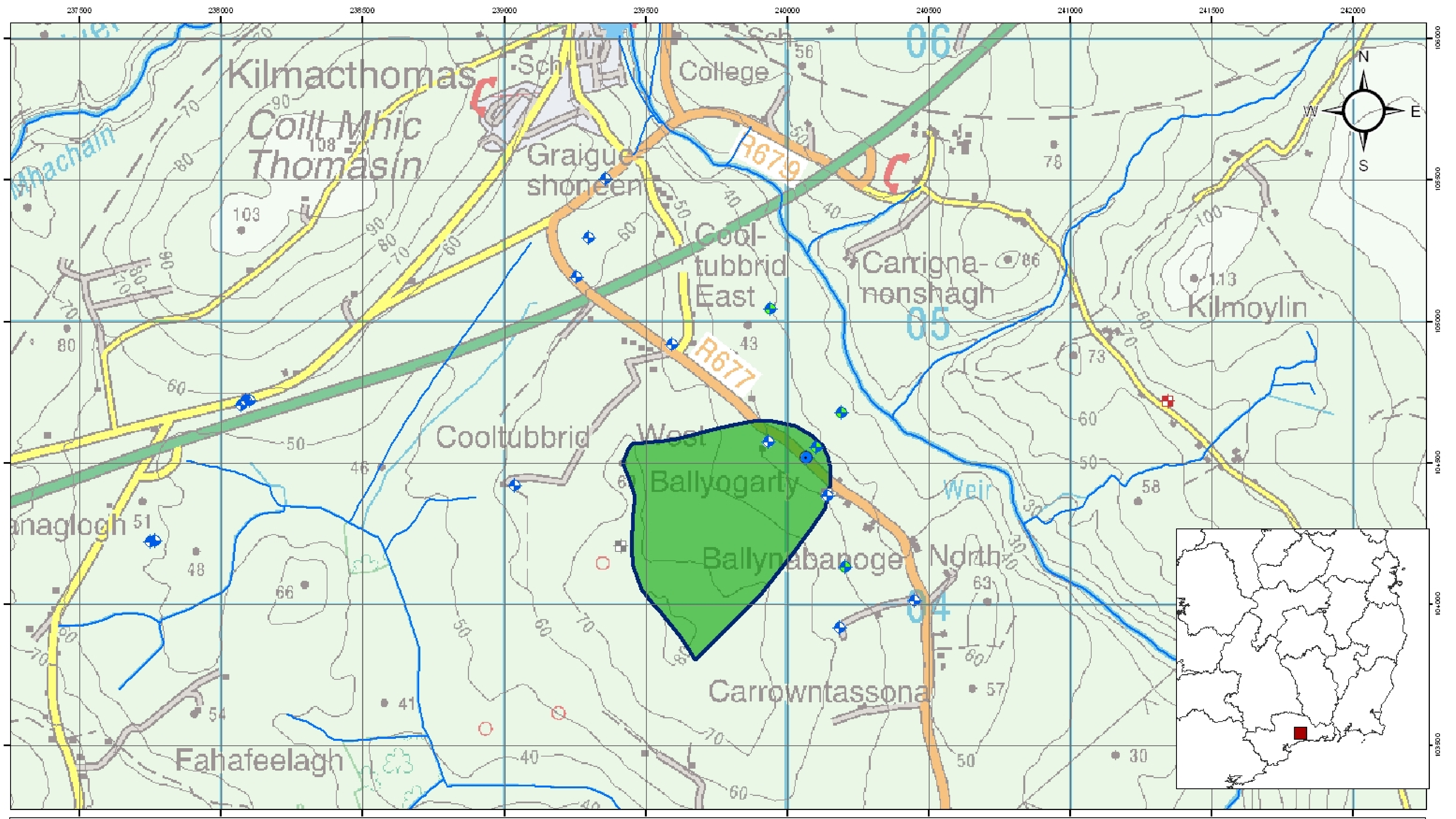
Q is the daily pumping rate +/- X%

T is Transmissivity (based on the aquifer hydraulic characteristics)

i is background non-pumping hydraulic gradient.

Where the pumping rate is 195 $m^3/d$, the transmissivity range is 13.5 to 291 $m^2/d$ and the hydraulic gradient is 0.044, the equation indicates that the possible down-gradient ZOC extent ranges from 2.5 to 52 m, depending on the transmissivity. In this case the boundary has been conservatively delineated at 52 m downgradient of the source.

**The northern and south eastern boundaries** are based on groundwater flow lines drawn perpendicular to the estimated groundwater elevation contours shown in Figure 7. The boundaries also take account of the C-shaped topographical catchment upgradient of the source. The topographical catchment and groundwater contours suggest that groundwater is likely to flow to the source from the west out of West Ballyogarty and from the south out of Ballynabanoge North.




# Figure 10 Source Protection Areas

PWS Abstraction

River

Ballyogarty PWS Zone of Contribution (ZOC)

Inner Source Protection Area (SI)

0 0.25 0.5 1 km

**The south western boundary** is delineated based on the intersection of the lateral boundaries with the groundwater flow divide mapped to the west of the source, which is based on the estimated groundwater elevation contours.

The total area of the ZOC has been calculated on the basis of a water balance. This approach calculates the recharge area footprint required to supply a recharge volume equal to the public water supply abstraction. The recharge area required to supply the Ballyogarty abstraction of 195 $m^3$/day, based on an annual recharge of 340 mm is 0.21 $km^2$. Overall the delineated boundaries describe a ZOC with an area of 0.41 $km^2$. This exceeds the 0.21 $km^2$ required by the water balance by 94%. The delineated ZOC represents a maximum likely ZOC for the source based on the available data and protects a recharge footprint equivalent to 380 $m^3$/day, which gives an adequate safety margin for abstraction at the Ballyogarty source in case of future increases in average abstraction. It also allows for uncertainties and variations in the flow direction.

## 9.2 INNER PROTECTION AREA

The Inner Source Protection Area (SI) 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 velocity multiplied by the 100 day time period gives the distance travelled by the groundwater during the TOT. This distance gives the lateral extent of the buffer which must be applied around the source to form the SI.

For the groundwater velocity range calculated in Section 8.5 of 1.1 to 32 m/day, the extent of the SI buffer zone is calculated at between 110 m and 3.2 km. The maximum calculated distance exceeds the longitudinal and lateral extents of the ZOC and is considered unrealistic as the maximum transmissivity may not be representative of the entire ZOC. Using the average calculated velocity of 10.3 m/d gives a distance of 1,030 m. This again exceeds the extent of the ZOC, however because it is based on the average transmissivity it is likely to be generally representative of the ZOC. As such, it indicates that groundwater at any point within the ZOC may reach the source in less than 100 days. This is not unreasonable for a highly transmissive fractured aquifer. As a result the entire ZOC has been classified as the inner protection zone (SI), shown in Figure 10.

There is no Outer Source Protection Area (SO).

# 10 GROUNDWATER PROTECTION ZONES

Groundwater protection zones are shown in Figure 11, and are based on an overlay of the source protection areas on the groundwater vulnerability. Therefore the groundwater protection zones are SI/E and SI/H.

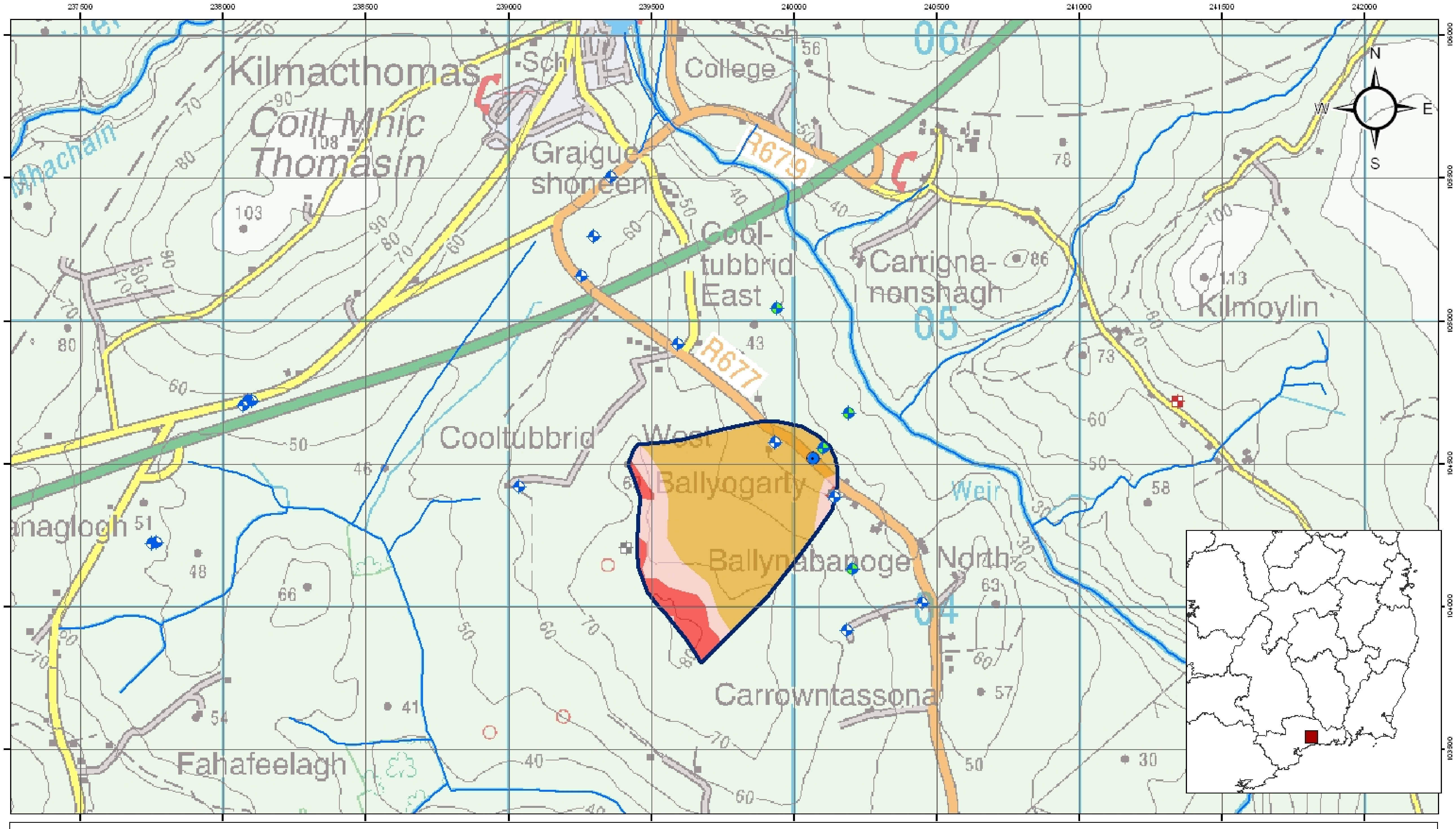



Figure 11 Source Protection Zones

PWS Abstraction
River
SI/X
SI/E
SI/H
Ballyogarty PWS Zone of Contribution (ZOC)

0 0.25 0.5 1 km

# 11 POTENTIAL POLLUTION SOURCES

The main potential sources of contamination within the ZOC are:

- Direct microbial contamination of the source by animals and birds. The main potential contaminants from these sources are faecal bacteria, viruses and cryptosporidium.
- All private residences within the ZOC are serviced by septic tanks or similar wastewater treatment systems which discharge to groundwater via percolation areas. The main potential contaminants from this source are ammonia, nitrates, phosphates, chloride, potassium, faecal bacteria, viruses and cryptosporidium.
- The majority of land within the zone of contribution is agricultural land, primarily arable with some pasture and forestry. At least one farming operation is active within the ZOC. Stockpiles of poultry manure awaiting spreading were observed in places within the ZOC and greater study area during the site visits. It is likely that landspreading of this and organic matter from other agricultural sources (e.g. cattle slurry) takes place within the delineated ZOC.
- Private home heating fuel tanks are likely to be located within the catchment area. The main potential contaminants from this source are hydrocarbons.
- Roadways are present within the ZOC. The main potential contaminants from this source are hydrocarbons and metals.

# 12 CONCLUSIONS

The untreated groundwater is currently impacted by microbial contamination, arsenic, nitrate, phosphate and very occasionally ammonia. Treatment is in place at the source to manage the arsenic and microbial contamination issues. The source of the contamination is likely to be groundwater pollution by organic matter. The sources of organic material are likely to be farmyard runoff, treated wastewater effluent and agricultural waste.

Due to the potentially high groundwater velocity within the study area it is possible that groundwater recharging anywhere within the ZOC could reach the source in less than 100 days. For this reason the entire ZOC has been classified as the Inner Protection Area (SI). The protection zones delineated in this report are SI/X, SI/E and SI/H.

The conclusions and recommendations of the report are based on current understanding of groundwater conditions and bedrock geology as inferred from the available data. The report should not be used as the sole basis for site-specific decisions.

Particular care should be taken when assessing the location of any activities or developments that might cause contamination of the Ballyogarty Source, particularly within the inner source protection zone (SI). Reference should be made to the guidelines contained within the DELG/EPA/GSI "Groundwater Protection Scheme" publication regarding the siting of certain activities, such as septic tanks and landspreading of organic wastes, within source protection areas.

# 13 RECOMMENDATIONS

Further investigations might usefully include.

- Two intrusive subsoil investigations across the study area to better assess the subsoil permeability of the full subsoil profile and the depth to bedrock;
- A larger scale pumping test may provide additional information on aquifer hydraulic properties.

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# APPENDIX 1

## POINT DATA & WATER QUALITY DATA

- TABLE A1.1 – POINT DATA FROM HYDROGEOLOGICAL MAPPING
- TABLE A1.2 – EPA WATER QUALITY DATA FOR BALLYOGARTY PWS SOURCE
- TABLE A1.3 – FIELD WATER QUALITY DATA FOR BALLYOGARTY PWS SOURCE

| Name | Type | Sub-type | X | Y | Description | GWL mbtc | GWL mbtc | GWL mbtc | Total Depth (m) | tc magl | GL mAOD | GWL mAOD | DTB | Exp Interval | Subsoil K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 19/10/2009 | 20/10/2009 | 05/11/2009 | | | | | | | |
| PWSBH01 | Groundwater | Borehole | 240069 | 104521 | Ballyogarty PWS borehole. BH is inside a small pump house. BH has a concrete casing at the ground surfcae (floor of pump house) with 9-inch internal dia. & 1-inch external dia.TC = top of 9-inch concrete casing (top of unbroken aprt of concrete rim). Driller & Year of drilling unknown. No drilling records available. Drilled in field with previously known good spring. | 5.97 | | | - | 0.215 | 44.5 | 38.75 | - | - | - |
| BH01 | Groundwater | Borehole | 238101 | 104722 | Trial Well drilled by Frank Seery for WF CoCo & RPS in 2008. Located in small WF CoCo plot between N25 and old Dungarvan road. Inflows at 10m, 18m& 13mbgl. Yield @ 30m approx 228m3/d. Bedrock = sandstone. TC = top of 6-inch steel casing. Observation well. RPS Name = BHB3 | | | 5.56 | 30 | 0.37 | 57 | 51.81 | 12 (Driller est = 8m) | - | GRAVEL & SAND) High |
| BH02 | Groundwater | Borehole | 238087 | 104722 | Production Well drilled by Frank Seery for WF CoCo & RPS in 2008. Located in small WF CoCo plot between N25 and old Dungarvan road. Inflows @ 40m 60m & 80mbgl. Overall yield at 80mbgl approx = 480m3/day. Bedrock = Shale. TC = top of 150mm blue plastic liner, which is 0.008m above top of 8-inch steel casing. RPS name = BHB5 | | | 5.71 | 96 | 0.38 | 57 | 51.67 | 12 (Driller est = 8m) | - | Gravelly CLAY) Moderate |
| BH03 | Groundwater | Borehole | 239255 | 105157 | Private borehole in factory landscaped gardens. Borehole is set in concrete chamber under a heavy duty manhole cover. TC = top of 6-inch steel casing. Drilled since 2005 (site not shown on 2005 orthophoto). Drillerbased in Waterford City. | | 6.04 | | - | -0.46 | 58 | 51.51 | - | - | - |
| BH04 | Groundwater | Borehole | 239935 | 104576 | Private borehole in farm yard. No data on construction or age available. Mouth of 6-inch steel casing to deformed to use as ref point. TC = rim of concrete chamber over mouth of borehole. TD estimated with dipper. | | 6.67 | | 17.2 | 0 | 50 | 43.33 | - | - | - |

| Name | Type | Sub-type | X | Y | Description | GWL mbtc | GWL mbtc | GWL mbtc | Total Depth (m) | tc magl | GL mAOD | GWL mAOD | DTB | Exp Interval | Subsoil K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 19/10/2009 | 20/10/2009 | 05/11/2009 | | | | | | | |
| BH05 | Groundwater | Borehole | 239357 | 105505 | Private borehole supplying Cruachan Housing estate on edge of castleconnell. Borehole set in concrete chamber beneath manhole cover in concrete patio in front of pump house, just off public pavement. Drilled by Pat Cusak of Waterford in 2003. Owner comments: 8-inch bore, pump at 33.5mbgl, TD slightly deeper. Not much liner. Rock Shallow. Arsenic conc approx = 15 ug/l. BH was switching on and off during visit. GWL range during on/off cycle approx 1.95 mbtc to 3.75 mbtc. Water treated for As & Fe. TC = top of 8-inch casing. | | 1.95 | | 35 | 0.17 | 45 | 43.22 | <3? | - | - |
| BH06 | Groundwater | Borehole | 239038 | 104421 | Private borehole in raised block chamber in farmyard. Drilled approx 1989.Rock close to surface, very little casing used. TC = top of 6-inch steel casing. | | 8.09 | | 39.6 | -0.1 | 61 | 52.81 | <3? | - | - |
| BH07 | Groundwater | Borehole | 240186 | 103918 | Private borehole in overgrown, disused farmyard. Drilled 1991. Driller's yield est = 1800gph (194m3/d), for 6.1m of drawdown.Typical pumping drawdown for private use = 3.6m. Owner said BH overflowed in winter of 1999. TC = top of 6-inch steel casing. | | 3.6 | | 15.24 | 0.21 | 57 | 53.61 | 3.6 | - | - |
| BH08 | Groundwater | Borehole | 240451 | 104013 | Private borehole in lawn adjacent to new house, from approx 2004. Formerly there was an old Co. Council dug well with Rock at approx 1.2mbgl adjacent to the road in front of the house, before road was widened. TC = top of 6-inch steel casing | | 7.73 | | 30.5 | 0.54 | 45 | 37.81 | 1.2 | - | - |
| BH09 | Groundwater | Borehole | 240144 | 104384 | Private borehole in lawn behind new house. Borehole drilled in 1970s and originally serviced an old farmhouse, now demolished. Rock outcrop (OC02) adjacent to borehole. Upper, exposed part of borehole casing damaged during rock excavation for new house, therefore reference point based on semi-broken casing-stick up. TC = top of 6-inch steel casing (broken & at an angle & on a sloping bank. LEngth of stick up = 0.8m. | | 6.56 | | - | 0.53 | 49 | 42.97 | 0 | - | - |

| Name | Type | Sub-type | X | Y | Description | GWL mbtc | GWL mbtc | GWL mbtc | Total Depth (m) | tc magl | GL mAOD | GWL mAOD | DTB | Exp Interval | Subsoil K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 19/10/2009 | 20/10/2009 | 05/11/2009 | | | | | | | |
| OC02 | Bedrock | Outcrop | 240138 | 104390 | Bedrock outcrop of fine grained, grey TUFF. Thinly laminated in some fragments but generally medium bedded. Frac set 1 trends 252degrees (WSW), vertical, spacing 0.2 to 0.3m, aperture <1mm; Frac set 2 trends 340 degrees (NNW, perpendicular to set 1), vertical, separation 0.1 to 0.2 m, aperture < 1mm. Some infilling of joints and fracs with quartz. Quartz veins range from 1 to 10mm aperture. Bedding dips east with dip of 50 degrees. | | | | | | | | 0 | | |
| GW01 | Groundwater | Spring | 240192 | 104677 | Spring in field downgradient of PWS. Large marshy area. Est. Q @ 2 to 3 l/s. A further spring (GW03) present just up slope between GW01 & PWS with similar Q. | | | | | | 33 | 33 | | | |
| EXP01 | Subsoil | Trial Hole | 242503 | 102913 | Site suitability trial hole encountered in field in townland of Shanakill on east side of Mahon River. Standing water in hole at 0.9mbgl. Landuse is pasture. Well drained on flattish shoulder in a larger slope towards mahon river, drain and rushy poorly drained ground approx 100m away to SW. Moderately soft, orange brown to brown (possibly very slight mottling of these colours), very gravelly, SILT. | | | | 2.25 | | | | - | 0 to 2.25 | SILT (moderate) |
| BH10 | Groundwater | Borehole | 238070 | 104704 | Trial Well drilled by Frank Seery for WF CoCo & RPS in 2008. RPS borehole BHB4. Couldn't open well cover. Adjacent to BH01 & BH02. Inflows at 18m and 30mbgl.Overall yield at 90mbgl = 600m3/d. Bedrock = Sandstone. | | | | 100 | | | | 12 | | SAND (high) |
| BH11 | Groundwater | Borehole | 237750 | 104221 | Trial Well drilled by Frank Seery for WF CoCo & RPS in 2008. RPS borehole BHB2. Production Well. Inflows @ 15 to 30m & at 42 m. Yield = 264 - 288m3/d. Bedrock = Shale with volcanics below 62mbgl. TC = top of 8-inch steel casing. 150mm blue plastic liner from 0.16mbtc. | | | 0.94 | 72 | 0.545 | 52 | 51.61 | 7 | | SAND (high) |

| Name | Type | Sub-type | X | Y | Description | GWL mbtc | GWL mbtc | GWL mbtc | Total Depth (m) | tc magl | GL mAOD | GWL mAOD | DTB | Exp Interval | Subsoil K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 19/10/2009 | 20/10/2009 | 05/11/2009 | | | | | | | |
| BH12 | Groundwater | Borehole | 237765 | 104225 | Trial Well drilled by Frank Seery for WF CoCo & RPS in 2008. RPS borehole BHB1. Inflows at 8m to 24mbgl & at 34 to 60mbgl. Yield = 264 to 288m3/d. Bedrock = Shale to 60mbgl with volcanic rock 60 to 100mbgl. Observation well. TC = top of 6-inch steel casing. | | | 0.74 | 100 | 0.47 | 52 | 51.73 | 8 | | SAND (high) |
| EXP02 | Subsoil | Exposure | 241344 | 104719 | TOBIN GWPS Project for GSI. Subsoil Exposure by OM. | | | | | | | | | | sandy SILT (moderate) |
| BH14 | Groundwater | Borehole | 239595 | 104919 | Trial Well drilled by Frank Seery for WF CoCo & RPS in 2008. RPS borehole BHA1. Unsuccessful. Backfilled. GW Inflow between 19 & 75mbgl. Yield = 72m3/d. Bedrock = Dark grey and brown shale | | | | | | | | 18 (Driller est @ 1.5mbgl) | | SAND (6m) over CLAY (12m)…clay may be weathered shale |
| BH15 | Groundwater | Borehole | 239300 | 105298 | Trial Well drilled by Frank Seery for WF CoCo & RPS in 2008. RPS borehole BHA2. Unsuccessful. Backfilled. GW Inflow between 36 & 52mbgl. Yield = 72m3/d. Bedrock = shale to 66mbgl, then volcanic rock to 75mbgl. | | | | | | | | 18 (driller est @ 3 mbgl) | | SAND (6m) over CLAY (12m)…clay may be weathered shale |
| GW02 | Groundwater | Spring | 239940 | 105045 | Spring in marshy area of field used for rough grazing. | | | | | | | | | | |
| GW03 | Groundwater | Spring | 240103 | 104557 | Spring in drain just downslope of PWSBH01 & near GW01 | | | | | | | | | | |
| GW04 | Groundwater | Spring | 240206 | 104134 | Spring in marshy area of field used for rough grazing. | | | | | | | | | | |
| OC01 | Bedrock | Outcrop | 239410 | 104206 | Outcrop of grey TUFF | | | | | | | | 0 | | |

# Table A1.2 - EPA Water Quality Data for Ballyogarty PWS Source

| | | | mg/l | mg/l Ca | mg/l Mg | mg/l K | mg/l Na | mg/l Cl | mg/l | mg/l $SO_4$ | mg/l $CaCO_3$ | mg/l $CaCO_3$ | uS/cm | ug/l Al | ug/l Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GSI Name** | **Date** | **Body** | **NO3** | **Ca** | **Mg** | **K** | **Na** | **Cl** | **NO2** | **SO4** | **Alk** | **Hard** | **Cond** | **Al** | **Fe** |
| **mg/l** | **Jan-82** | **Threshold** | **25** | **200** | **50** | **5** | **150** | **30** | **0.1** | **200** | | | **1000** | **200** | **200** |
| **mg/l** | **Jan-82** | **EU MAC** | **50** | **200** | **50** | **12** | **150** | **250** | **0.1** | **250** | | | **1500** | **200** | **200** |
| **GSI Name** | **Date** | **Body** | **NO3** | **Ca** | **Mg** | **K** | **Na** | **Cl** | **NO2** | **SO4** | **Alk** | **Hard** | **Cond** | **Al** | **Fe** |
| Ballyogarty | 14/02/2001 | | 43.4 | 11 | 6.1 | 2.5 | 17 | 26 | 0.001 | 8 | 32 | - | - | - | 50 |
| Ballyogarty | 24/09/2001 | | 27.9 | 10 | 6.4 | 2.9 | 16 | 22 | 0.001 | 12 | 28 | 51 | - | 50 | 50 |
| Ballyogarty | 27/02/2002 | | 44.3 | 13 | 6.7 | 3.5 | 13 | 22 | 0.001 | 7 | 20 | 60 | - | - | 60 |
| Ballyogarty | 07/10/2002 | | 30.6 | 9 | 6.0 | 1.8 | 13 | 21 | 0.001 | 11 | 20 | 47 | - | - | 60 |
| Ballyogarty | 10/02/2003 | | 36.8 | 9 | 5.6 | 2.1 | 10 | 21 | 0.001 | - | 20 | 46 | - | 50 | 50 |
| Ballyogarty | 24/09/2003 | | 34.1 | 10 | 6.0 | 2.8 | 13 | 23 | 0.001 | 9 | 20 | 50 | - | 50 | 50 |
| Ballyogarty | 23/02/2004 | | 37.6 | 9 | 4.2 | 2.2 | 8 | 21 | 0.001 | 8 | 20 | 41 | - | - | 50 |
| Ballyogarty | 04/10/2004 | | 33.2 | 9 | 5.8 | 2.5 | 12 | 22 | 0.001 | 9 | 20 | 47 | - | 50 | 50 |
| Ballyogarty | 01/03/2005 | | 36.3 | 12 | 4.3 | 2.2 | 8 | 21 | 0.001 | 8 | 20 | 47 | - | 50 | 50 |
| Ballyogarty | 01/11/2005 | | 39.9 | 11 | 5.3 | 2.6 | 12 | 20 | 0.001 | 9 | 20 | 48 | - | 50 | 50 |
| Ballyogarty | 28/02/2006 | | 39.9 | 10 | 5.6 | 2.2 | 11 | 20 | 0.001 | 7 | 20 | 48 | - | 50 | 50 |
| Ballyogarty | 03/10/2006 | | 34.5 | - | - | - | - | 22 | 0.001 | 9 | 20 | - | - | - | - |
| Ballyogarty | 19/07/2007 | | 38.6 | 13 | 6.0 | 2.8 | 12 | 20 | 0.050 | 8 | 44 | 52 | 153 | - | 2 |
| Ballyogarty | 21/08/2007 | | 40.5 | 13 | 5.5 | 3.0 | 12 | 19 | 0.050 | 8 | 50 | 52 | 203 | 2 | 29 |
| Ballyogarty | 15/10/2007 | | 39.7 | 14 | 5.8 | 2.9 | 13 | 22 | 0.050 | 8 | 30 | 48 | 205 | 2 | 2 |
| Ballyogarty | 23/01/2008 | | 41.8 | 13 | 6.0 | 3.0 | 15 | 21 | 0.050 | 8 | 40 | 50 | 159 | 2 | 2 |
| Ballyogarty | 16/05/2008 | | 38.0 | 11 | 6.3 | 2.4 | 12 | 22 | 0.003 | 7 | 8 | 45 | 196 | 11 | 10 |
| Ballyogarty | 01/07/2008 | | 35.3 | 10 | 11.3 | 2.4 | 12 | 18 | 0.043 | 9 | 10 | 47 | 180 | 8 | 5 |
| Ballyogarty | 26/08/2008 | | 39.4 | 12 | 11.3 | 2.5 | 12 | 19 | 0.043 | 4 | 18 | 54 | 184 | 5 | 5 |
| Ballyogarty | 08/10/2008 | | 40.2 | 12 | 11.3 | 2.8 | 12 | 20 | 0.043 | 6 | 19 | 54 | 176 | 10 | 5 |
| | Average | mg/l | 37.59 | **10.99** | **6.61** | **2.59** | **12.09** | **21.15** | **0.02** | **8.13** | **23.95** | **49.24** | **182.00** | **27.89** | **33.16** |
| | | mmol/l | 0.62 | 0.27 | 0.26 | 0.07 | 0.53 | 0.60 | 0.00 | 0.08 | 0.24 | mmol of CaCO3 = mmol of CO3-- | | | |
| | | MW | 61.00 | 40 | 25.31 | 39.1 | 22.99 | 35.45 | 47 | 96.066 | 100 | | | | |
| | | charge | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | | | | |
| | | meq/l | 0.62 | 0.55 | 0.52 | 0.07 | 0.53 | 0.60 | 0.00 | 0.17 | 0.48 | meq of CO3-- = meq of HCO3- | | | |
| | | | | | | | | | | | 0.48 | mmol HCO3- | | | |
| | | meq cations | 1.66 | | | | | | | | 29.22 | mg/l as HCO3- | | | |
| | | meq anions | 1.86 | | | | | | | | | | | | |

**Red colour denotes result in excess of MAC**

**Orange Colour denotes result in excess of EPA Threshold**

**Blue Colour Denotes result was less than the Detection Limit (DL), where DL is equal to the numeric value shown**

Source: available EPA data.

# Table A1.2 - EPA Water Quality Data for Ballyogarty PWS Source

| | | ug/l Mn | mg/l N | No./100ml | No./100ml | ug/l Ba | ug/l B | ug/l Cd | ug/l Cr | ug/l Cu | mg/l $F^-$ | ug/l Pb | ug/l Hg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GSI Name** | **Date** | **Mn** | **NH4** | **TC** | **F. coli** | **Ba** | **B** | **Cd** | **Cr** | **Cu** | **F** | **Pb** | **Hg** |
| **mg/l** | **Jan-82** | **50** | **0.15** | **0** | **0** | | **1000** | **5** | **30** | **30** | **1** | **10** | **1** |
| **mg/l** | **Jan-82** | **50** | **0.3** | **0** | **0** | **500** | **2000** | **5** | **50** | **500** | **1** | **50** | **1** |
| **GSI Name** | **Date** | **Mn** | **NH4** | **TC** | **F. coli** | **Ba** | **B** | **Cd** | **Cr** | **Cu** | **F** | **Pb** | **Hg** |
| Ballyogarty | 14/02/2001 | 7 | 0.003 | 0 | 0 | 50 | - | 0.3 | - | 7 | 0.1 | 1 | - |
| Ballyogarty | 24/09/2001 | 25 | 0.005 | **5** | 0 | 50 | 50 | 0.2 | 2 | 9 | 0.1 | 1 | - |
| Ballyogarty | 27/02/2002 | 20 | 0.005 | **6** | 0 | - | - | - | - | - | 0.1 | - | - |
| Ballyogarty | 07/10/2002 | 20 | 0.006 | 0 | 0 | - | - | - | - | - | 0.1 | - | - |
| Ballyogarty | 10/02/2003 | 7 | 0.003 | **2** | 0 | 50 | 50 | 0.2 | 1 | 21 | - | 1 | - |
| Ballyogarty | 24/09/2003 | 9 | 0.028 | 0 | 0 | 50 | 50 | 0.2 | 1 | 10 | 0.1 | 1 | - |
| Ballyogarty | 23/02/2004 | 8 | 0.003 | 0 | 0 | 50 | 50 | 0.2 | 1 | 5 | 0.1 | 1 | - |
| Ballyogarty | 04/10/2004 | 10 | 0.003 | 0 | 0 | 50 | 50 | 0.1 | 3 | 9 | 0.1 | 1 | - |
| Ballyogarty | 01/03/2005 | 22 | 0.003 | 0 | 0 | 50 | 50 | 0.2 | 1 | 8 | 0.1 | 1 | - |
| Ballyogarty | 01/11/2005 | 7 | 0.003 | **24** | 0 | 50 | 50 | 0.1 | 1 | 25 | 0.1 | 1 | - |
| Ballyogarty | 28/02/2006 | 11 | 0.003 | 0 | 0 | 50 | 50 | 0.2 | 1 | 15 | 0.1 | 2 | - |
| Ballyogarty | 03/10/2006 | - | 0.006 | 0 | 0 | - | - | - | - | - | 0.1 | - | - |
| Ballyogarty | 19/07/2007 | 10 | 0.050 | **8** | **4** | 35 | 3 | 0.4 | 1 | 5 | 0.1 | 1 | 0.05 |
| Ballyogarty | 21/08/2007 | 9 | 0.060 | 0 | 0 | 30 | 3 | 0.4 | 1 | 12 | 0.1 | 1 | 0.05 |
| Ballyogarty | 15/10/2007 | 10 | 0.030 | **2** | 0 | 30 | 3 | 0.4 | 1 | 8 | 0.1 | 1 | 0.05 |
| Ballyogarty | 23/01/2008 | 8 | 0.030 | **1** | 0 | 28 | 3 | 0.4 | 1 | 6 | 0.1 | 1 | 0.05 |
| Ballyogarty | 16/05/2008 | 8 | 0.010 | 0 | 0 | 33 | 17 | 0.2 | 1 | 7 | 0.1 | 1 | 0.01 |
| Ballyogarty | 01/07/2008 | 9 | 0.029 | 0 | 0 | 28 | 20 | 0.1 | 1 | 16 | 0.1 | 1 | 0.02 |
| Ballyogarty | 26/08/2008 | 7 | 0.012 | - | 0 | 32 | 20 | 0.1 | 1 | 27 | 0.1 | 2 | 0.02 |
| Ballyogarty | 08/10/2008 | 8 | 0.156 | **4** | **1** | 31 | 20 | 0.1 | 1 | 14 | 0.1 | 2 | 0.03 |
| | Average | **11.37** | **0.02** | **2.74** | **0.25** | **40.99** | **30.56** | **0.22** | **1.12** | **11.89** | **0.10** | **1.20** | **0.04** |

**Red colour denotes result in excess of MAC** 0.0069

**Orange Colour denotes result in excess of EPA Threshold** 0.0254

**Blue Colour Denotes result was less than the Detection Limit (DL), where DL is equal to the numeric value shown** 0.02

Source: available EPA data.

# Table A1.2 - EPA Water Quality Data for Ballyogarty PWS Source

TOBIN

| | | ug/l Ni | mg/l P | mg/l P | µg/l Se | µg/l Ag | µg/l Sr | ug/l Zn | ug/l Sb | ug/l As | [-] | [-] | °C | [-] | [-] | uS/cm (at 25oC) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GSI Name** | **Date** | **Ni** | **PO4** | **P** | **Se** | **Ag** | **Sr** | **Zn** | **Ant** | **As** | **K/Na Ratio (using mg)** | **K/Na Ratio (using meq)** | **Temperature** | **pH Field** | **pH Lab** | **EC_Lab** |
| **mg/l** | **Jan-82** | **20** | **0.03** | | | | | **100** | | **10** | **0.35** | | | | | |
| **mg/l** | **Jan-82** | **50** | **5** | **5000** | **10** | **10** | **5000** | **1000** | **10** | **50** | | | | **6.5-9.5** | **6.5-9.5** | **2500** |
| **GSI Name** | **Date** | **Ni** | **PO4** | **P** | **Se** | **Ag** | **Sr** | **Zn** | **Ant** | **As** | **K/Na Ratio** | | | | | |
| Ballyogarty | 14/02/2001 | 1 | 0.027 | - | - | 5 | - | 47 | 1.0 | 53.0 | 0.15 | 0.09 | 10.0 | - | 7.0 | 221 |
| Ballyogarty | 24/09/2001 | 1 | 0.071 | - | 1 | 50 | - | 66 | 1.0 | 94.3 | 0.18 | 0.11 | 11.4 | - | 6.2 | 193 |
| Ballyogarty | 27/02/2002 | - | 0.031 | - | - | - | - | 56 | - | - | 0.28 | 0.16 | 10.0 | - | 5.9 | 199 |
| Ballyogarty | 07/10/2002 | - | 0.056 | - | - | - | - | 52 | - | - | 0.14 | 0.08 | 11.4 | - | 5.7 | 190 |
| Ballyogarty | 10/02/2003 | 1 | 0.028 | - | 1 | 50 | - | 74 | 1.0 | 55.7 | 0.21 | 0.12 | 11.0 | - | 7.2 | 194 |
| Ballyogarty | 24/09/2003 | 1 | 0.033 | - | 1 | 50 | - | 32 | 1.0 | 62.9 | 0.22 | 0.13 | 12.0 | - | 6.2 | 190 |
| Ballyogarty | 23/02/2004 | 1 | 0.024 | - | 1 | 50 | - | 18 | 1.0 | 53.5 | 0.27 | 0.16 | 10.7 | - | 6.0 | 187 |
| Ballyogarty | 04/10/2004 | 1 | 0.045 | - | 1 | - | - | 57 | 1.0 | 64.0 | 0.20 | 0.12 | 11.4 | - | 6.0 | 184 |
| Ballyogarty | 01/03/2005 | 1 | 0.035 | - | 1 | - | - | 48 | 1.0 | 53.7 | 0.27 | 0.16 | 11.0 | - | 5.9 | 189 |
| Ballyogarty | 01/11/2005 | 1 | 0.084 | - | 1 | - | - | 28 | 1.0 | 54.0 | 0.21 | 0.13 | 13.2 | - | 5.8 | 198 |
| Ballyogarty | 28/02/2006 | 1 | 0.024 | - | 1 | - | - | 207 | 1.0 | 62.6 | 0.22 | 0.13 | 11.0 | - | 5.8 | 197 |
| Ballyogarty | 03/10/2006 | - | 0.040 | - | - | - | - | - | - | - | 0.23 | 0.13 | 12.1 | - | 5.8 | 191 |
| Ballyogarty | 19/07/2007 | 1 | 0.013 | - | - | 2 | 44 | 17 | 1.0 | 62.0 | 0.22 | 0.13 | 11.4 | 6.5 | 6.2 | 186 |
| Ballyogarty | 21/08/2007 | 1 | 0.010 | - | - | 2 | 38 | 35 | 1.0 | 53.0 | 0.23 | 0.14 | 11.8 | 6.2 | 6.1 | 189 |
| Ballyogarty | 15/10/2007 | 1 | 0.067 | - | - | 2 | 37 | 1 | 1.0 | 53.0 | 0.23 | 0.14 | 11.7 | 6.3 | 6.4 | 185 |
| Ballyogarty | 23/01/2008 | 1 | 0.086 | - | - | 2 | 37 | 22 | 1.0 | 45.0 | 0.23 | 0.14 | 11.2 | 6.7 | 6.3 | 196 |
| Ballyogarty | 16/05/2008 | 1 | 0.012 | 0.044 | - | 0 | 44 | 19 | 0.2 | 52.0 | 0.23 | 0.13 | 10.7 | 6.3 | 5.6 | 180 |
| Ballyogarty | 01/07/2008 | 1 | 0.037 | 0.100 | - | 1 | 36 | 30 | 0.3 | 55.7 | 0.23 | 0.14 | 5.6 | - | 5.7 | 168 |
| Ballyogarty | 26/08/2008 | 1 | 0.014 | 0.100 | - | 1 | 43 | 25 | 0.1 | 47.8 | 0.23 | 0.13 | 11.6 | 5.1 | 5.7 | 37 |
| Ballyogarty | 08/10/2008 | 1 | 0.056 | 0.280 | - | 1 | 39 | 29 | 0.1 | 55.5 | 0.23 | 0.13 | 11.2 | - | 5.8 | 175 |
| | Average | **0.95** | **0.04** | **0.13** | **1.00** | **16.62** | **39.74** | **45.39** | **0.80** | **57.51** | **0.22** | **0.13** | **11.03** | **6.16** | **6.07** | **182.43** |

**Red colour denotes result in excess of MAC**

**Orange Colour denotes result in excess of EPA Threshold**

**Blue Colour Denotes result was less than the Detection Limit (DL), where DL is equal to the numeric value shown**

Source: available EPA data.

# Table A1.3 - Field Water Quality Data for Ballyogarty PWS Source

| ID | Date | pH | Temp [pH] | EC | Temp [EC] | DO | Temp [DO] | Alkalinity | Comment |
|---|---|---|---|---|---|---|---|---|---|
| | | [-] | deg C | uS/cm | deg C | mg/l O2 | deg C | mg/l as CaCO3 | |
| PWSBH01 | 10/11/2009 | 5.14 | 10.6 | 190.2 | 10.9 | 84 | 11.5 | 13 | Measurements recorded using field electrodes and flow through cell at end of short pumping test on PWSBH01 on 10/11/2009. Measurements recorded after 188 minutes of pumping. Alkalinity measurment by acid titration. Alkalinity result is average of three measurments i.e., 15, 12 & 12 mg/l as CaCO3. |

# APPENDIX 2

## PUMPING TEST

- PUMPING TEST ANALYSIS & INTERPRETATION
- TABLE A2.1 – BOREHOLE PWSBH01 PUMPING TEST DATA

## Pumping test of borehole PWSBH01

Borehole PWSBH01 was subjected to a short pumping test on 10/11/2009. As the borehole was being pumped for public water supply, the test regime comprised an initial recovery phase following shut down of the public abstraction. The recovery was monitored between 00.30 and 02.30 and again between 06.50 and 07.00 on 10/11/2009. A constant discharge test (CDT) at 421 m$^3$/day was subsequently carried out on the source using borehole PWSBH01 as the pumping well. The CDT commenced at 07.01 on 10/11/2009 and was monitored until 09.53 on the same day, at which point the requirements of the scheme required the test to finish. Groundwater levels were monitored in borehole PWSBH01 throughout the test. The monitoring data collected is provided in Table A2.1. A graph of drawdown versus time for the CDT is shown in Figure A2.1.

The recovery data show that the borehole recovered from a dynamic water level of 3.27 m btc to 2.90 m btc during the first two hours of monitoring. A further water level rise of 0.15 m occurred over the following four hours to give a rest water level of 2.75 m btc. The time-drawdown graph for the CDT phase is shown in Figure A1.1. As can be seen from the graph the operational requirements of the water supply scheme interfered significantly with the test. The discharge fluctuated significantly during the test, which had a direct impact on drawdown in the pumping well.

The time-drawdown curves for the CDT phase do not show any early flattening off in drawdown which might indicate the presence of a recharge boundary (e.g.. the Mahon River) or a steepening of the drawdown curve which could indicate an impermeable boundary interacting with the source. Based on the depth to bedrock of 5 to 10 m in the vicinity of the source, as inferred from the hydrogeological mapping carried out for the project, the presence of moderate permeability till overlying the bedrock and on the presence of springs immediately downgradient of the source, the source aquifer is considered to be leaky-confined. Similar confined conditions were also encountered at boreholes BH02, BH10 and BH11 (RPS, 2009).

The pump test data were analysed using the Jacob Straight Line Method for a confined or leaky aquifer (Kruseman & DeRidder, 1990). The average discharge over the course of the CDT was used in the analysis and a straight line was fitted to the general trend of the fluctuating drawdown. Due to the deviation of the test from the ideal conditions of the analytical solution, the results of the analysis should be regarded as an approximate estimate of the aquifer transmissivity only. The estimated aquifer transmissivity based on the analysis is 291 m$^2$/day.

**Figure A2.1 Graph of CDT Drawdown versus Time**

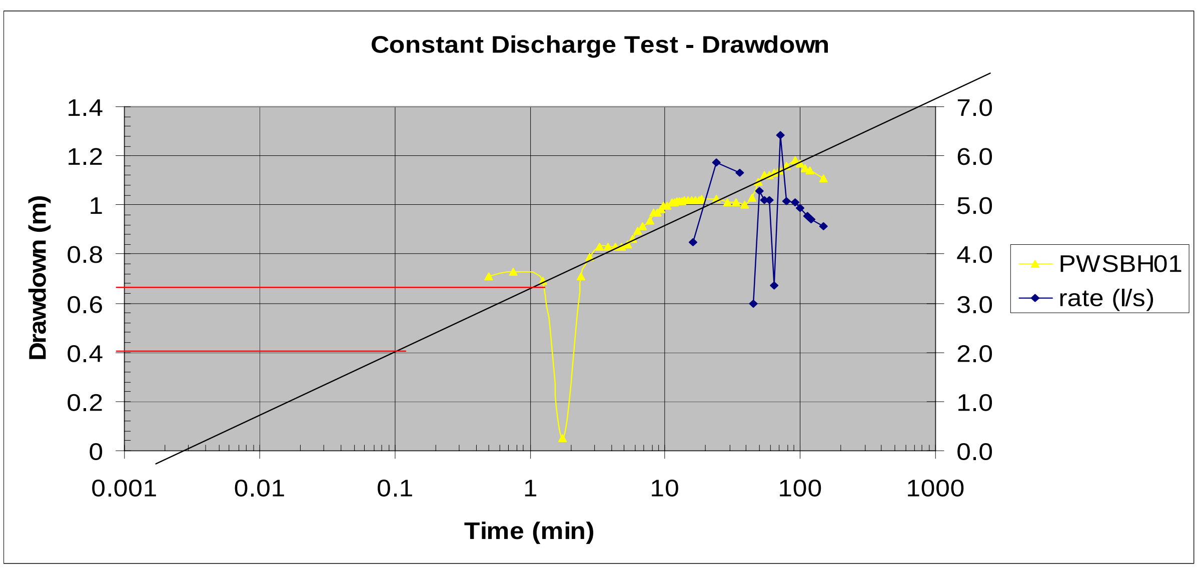

**Table A2.1 - Borehole PWSBH01 Pumping Test Data**
**- Constant Discharge Test -**
**Ballyogarty PWS**

| | | Water Level | | **Drawdown** | **Discharge** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | Corrected Time | mb datum | | m | Time | Corrected Time | | Flow Meter | | | | |
| min | | **PWSBH0** | **Comment** | **PWSBH01** | min | | Comment | m3 | Volume (l) | **rate (l/s)** | sec/100 l | **l/sec** |
| 0 | | 2.75 | | | 1.3 | 0.00 | Pump On, valve fully open at 9.5 min | 244623 | | | | |
| 0.25 | | 2.75 | | | 17.5 | 16.25 | | 244627.14 | 4140 | 4.2 | | |
| 0.5 | | 2.75 | | | 25.0 | 23.75 | | 244629.78 | 2640 | 5.9 | 20.84 | 4.8 |
| 0.75 | | 2.75 | | | 36.9 | 35.60 | | 244633.8 | 4020 | 5.7 | 21.35 | 4.7 |
| 1 | | 2.75 | | | 43.5 | 42.25 | | | | | 20.7 | 4.8 |
| 1.25 | 0 | 2.75 | Pump On | 0 | 45.8 | 44.55 | Scour open | 244635.4 | 1600 | 3.0 | 18.92 | 5.3 |
| 1.5 | 0.25 | | | | 50.9 | 49.60 | Scour closed sligtly | 244637 | 1600 | 5.3 | 19.38 | 5.2 |
| 1.75 | 0.5 | 3.46 | | 0.71 | 55.8 | 54.50 | | 244638.5 | 1500 | 5.1 | 19.68 | 5.1 |
| 2 | 0.75 | 3.48 | | 0.73 | 60.7 | 59.41 | | 244640 | 1500 | 5.1 | 19.93 | 5.0 |
| 2.5 | 1.25 | 3.44 | Pump Off | 0.69 | 65.6 | 64.38 | | 244641 | 1000 | 3.4 | 19.79 | 5.1 |
| 3 | 1.75 | 2.8 | | 0.05 | 71.9 | 70.62 | | 244643.4 | 2400 | 6.4 | 19.88 | 5.0 |
| 3.66 | 2.41 | 3.46 | Pump On @ 3.35min | 0.71 | 80.8 | 79.50 | | 244646.1 | 2700 | 5.1 | 19.91 | 5.0 |
| 4 | 2.75 | 3.54 | | 0.79 | 93.6 | 92.35 | | 244650 | 3900 | 5.1 | 20.12 | 5.0 |
| 4.5 | 3.25 | 3.58 | | 0.83 | 101.0 | 99.78 | Scour closed | 244652.2 | 2200 | 4.9 | 20.67 | 4.8 |
| 5 | 3.75 | 3.58 | | 0.83 | 113.6 | 112.35 | | 244655.8 | 3600 | 4.8 | 21.19 | 4.7 |
| 5.5 | 4.25 | 3.58 | | 0.83 | 120.7 | 119.45 | | 244657.8 | 2000 | 4.7 | 21.66 | 4.6 |
| 6 | 4.75 | 3.58 | | 0.83 | 150.7 | 149.40 | | 244666 | 8200 | 4.6 | 22.65 | 4.4 |
| 6.5 | 5.25 | 3.59 | Q increasing as pump valve opened | 0.84 | | | Pump off at 172 mins | | | **4.9** | **l/s** | **4.9** |
| 7 | 5.75 | 3.61 | | 0.86 | | | | | | **420.9** | **m3/day** | |
| 7.5 | 6.25 | 3.645 | | 0.895 | | | | | | | | |
| 8 | 6.75 | 3.665 | | 0.915 | | | | | | | | |
| 9 | 7.75 | 3.685 | | 0.935 | | | | | | | | |
| 9.5 | 8.25 | 3.72 | Pump valve fully open | 0.97 | | | | | | | | |
| 10 | 8.75 | 3.72 | | 0.97 | | | | | | | | |
| 10.5 | 9.25 | 3.735 | | 0.985 | | | | | | | | |
| 11 | 9.75 | 3.745 | | 0.995 | | | | | | | | |
| 11.5 | 10.25 | 3.745 | | 0.995 | | | | | | | | |
| 12.5 | 11.25 | 3.76 | | 1.01 | | | | | | | | |
| 13 | 11.75 | 3.76 | | 1.01 | | | | | | | | |
| 13.5 | 12.25 | 3.765 | | 1.015 | | | | | | | | |
| 14 | 12.75 | 3.765 | | 1.015 | | | | | | | | |
| 14.5 | 13.25 | 3.765 | | 1.015 | | | | | | | | |
| 15 | 13.75 | 3.77 | | 1.02 | | | | | | | | |
| 16 | 14.75 | 3.77 | | 1.02 | | | | | | | | |
| 17 | 15.75 | 3.77 | | 1.02 | | | | | | | | |
| 18 | 16.75 | 3.77 | | 1.02 | | | | | | | | |
| 19 | 17.75 | 3.77 | | 1.02 | | | | | | | | |
| 20 | 18.75 | 3.775 | | 1.025 | | | | | | | | |
| 25 | 23.75 | 3.775 | | 1.025 | | | | | | | | |
| 30 | 28.75 | 3.76 | | 1.01 | | | | | | | | |
| 35 | 33.75 | 3.76 | | 1.01 | | | | | | | | |
| 40 | 38.75 | 3.75 | Scour Valve Opened | 1 | | | | | | | | |
| 45 | 43.75 | 3.78 | | 1.03 | | | | | | | | |
| 50 | 48.75 | 3.845 | Scour Valve closed slightly | 1.095 | | | | | | | | |
| 55 | 53.75 | 3.87 | | 1.12 | | | | | | | | |
| 60 | 58.75 | 3.87 | | 1.12 | | | | | | | | |
| 65 | 63.75 | 3.88 | | 1.13 | | | | | | | | |
| 70.5 | 69.25 | 3.89 | | 1.14 | | | | | | | | |
| 80 | 78.75 | 3.91 | | 1.16 | | | | | | | | |
| 92.3 | 91 | 3.93 | | 1.18 | | | | | | | | |
| 100.0 | 98.75 | 3.92 | Scour Valve Closed | 1.17 | | | | | | | | |
| 110.0 | 108.75 | 3.9 | | 1.15 | | | | | | | | |
| 120.0 | 118.75 | 3.89 | | 1.14 | | | | | | | | |
| 150.0 | 148.75 | 3.86 | | 1.11 | | | | | | | | |
| 172.0 | | | pump off - recovery | | | | | | | | | |
| 172.4 | 0.35 | 3.12 | | 0.37 | | | | | | | | |
| 173.3 | 1.30 | | pump on | | | | | | | | | |
| 177.0 | 4.97 | 3.745 | | 0.995 | | | | | | | | |
| 178.8 | 6.75 | | pump off | | | | | | | | | |
| 179.0 | 6.97 | 3.21 | | 0.46 | | | | | | | | |
| 179.3 | 7.22 | 3.15 | | 0.4 | | | | | | | | |
| 179.5 | 7.47 | 3.1 | | 0.35 | | | | | | | | |
| 179.75 | 7.72 | 3.07 | | 0.32 | | | | | | | | |
| 180 | 7.97 | 3.06 | | 0.31 | | | | | | | | |