Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Watergrasshill Water Scheme

November 2012

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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, well field or spring, in which water and contaminants may enter groundwater and move towards the source. Knowledge of where the water is coming from is critical when trying to interpret water quality data at the groundwater source. The Source Protection Zone also provides an area in which to focus further investigation and is an area where protective measures can be introduced to maintain or improve the quality of groundwater.

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

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

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1 Introduction

Groundwater Source Protection Zones (SPZ) have been delineated for the Watergrasshill Water Scheme 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.

The Watergrasshill Scheme comes from a spring source (IE_SW_G_004_04_028) which flows by gravity to a pumphouse. The objectives of the study were:

- To outline the principal hydrogeological characteristics of the Watergrasshill area where the spring is located.
- To delineate source protection zones for the spring.
- To assist the Environmental Protection Agency (EPA) and Cork County Council in protecting the water supply from contamination.

SPZs 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 SPZ are presented in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

2 Methodology

The methodology applied to delineate the SPZ consisted of data collection, desk studies, site visits and field mapping and subsequent data analysis and interpretation.

An initial interview with the caretaker of the supply scheme and field mapping of the study area were undertaken on 22/11/2011 and 2/12/2011.

While specific fieldwork was carried out in the development of this report, the maps produced are based largely on the readily available information and mapping techniques using inferences and judgements from experience at other sites. As such, the maps may not 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.

3 Location, Site Description and Well Head Protection

The spring is located approximately 1.7 km east of Watergrasshill, north of the Midleton Road, in the townland of Skahanagh South (Figure 1). The pumphouse is located approximately 300 m southwest of the spring in the townland of Meenane.

The spring is accessed from a laneway running north from the third class Midleton Road. The entrance to the laneway is approximately 130 m west of Meenane Bridge. The spring itself is approximately 210 m north of the road. The pumphouse and borehole, meanwhile, are located by the road and approximately 90m west of Meenane Bridge.

There are two collection chambers at the spring. Based on the orientation of the chambers it appears that there may be two separate sources feeding into the spring discharge area. Two springs are noted on the historic 25 inch Ordnance Survey of Ireland map at these locations. A schematic of the spring chambers is shown on Figure 2 below. The larger and older chamber is in the eastern section of the spring (Photo 1). A newer, smaller chamber is located approximately 10 m north of the larger chamber (Photo 2). The chamber to the north could not be accessed because of wet ground due to the overflow.

The spring water is collected in the collection chambers and is piped to a common distribution chamber (Photo 3). This chamber has metal covers that can be lifted to sample the spring and inspect the quality of the water. The chamber is 1.4 m in width, 6.9 m in length and 0.45 m deep. The walls of the distribution chamber are made of concrete block. From this chamber the water is piped and flows under gravity to the pump house. Not all of the water that discharges at the spring is collected for use in the supply. The overflow runs off to a stream which is a tributary of the Butlerstown River. The stream flows to the southwest. There is no weir on the overflow and it is not measured.

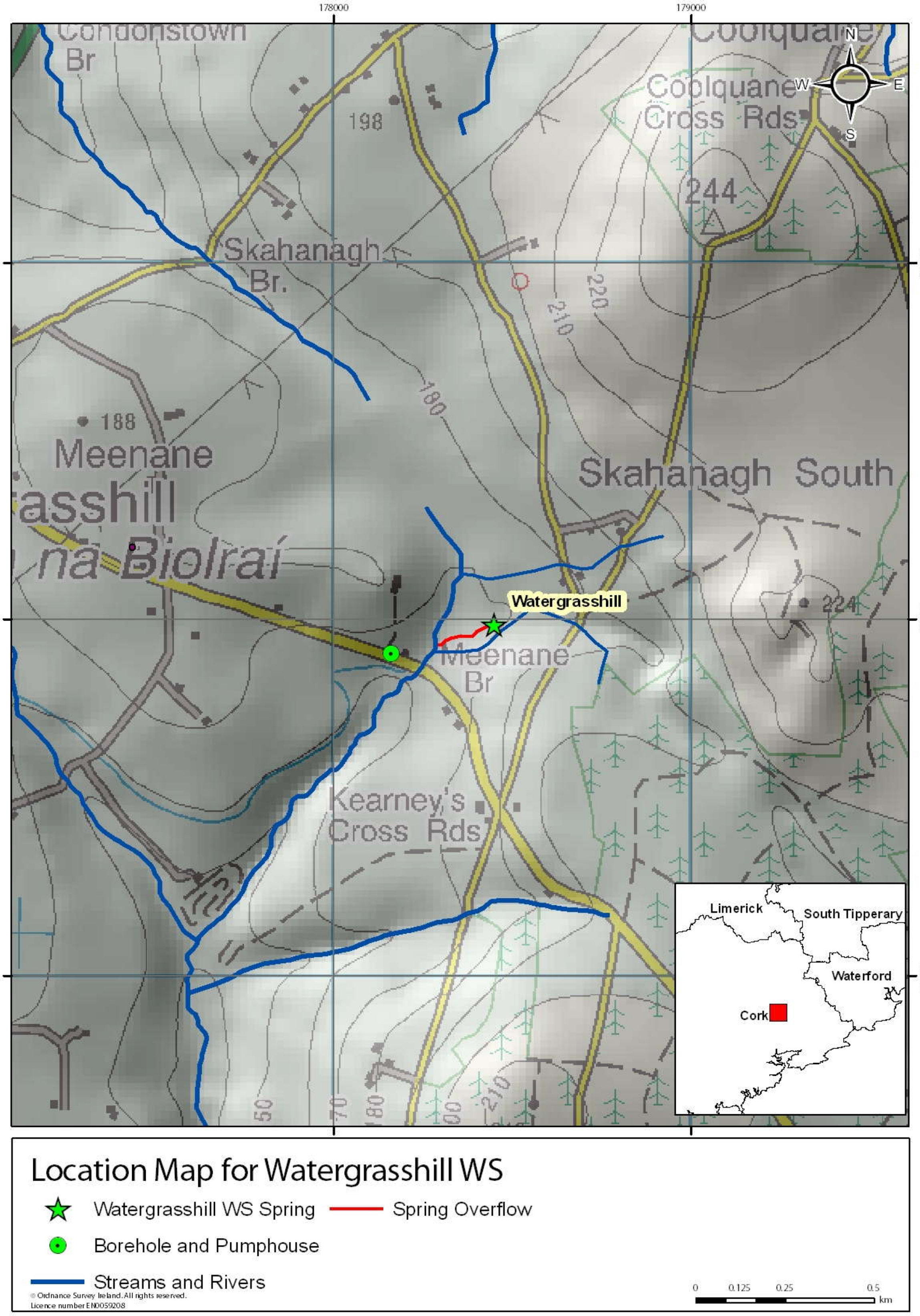

Figure 1: Location Map

Photo 1: Larger Eastern Collection Chamber

Photo 2: Smaller Northern Collection Chamber

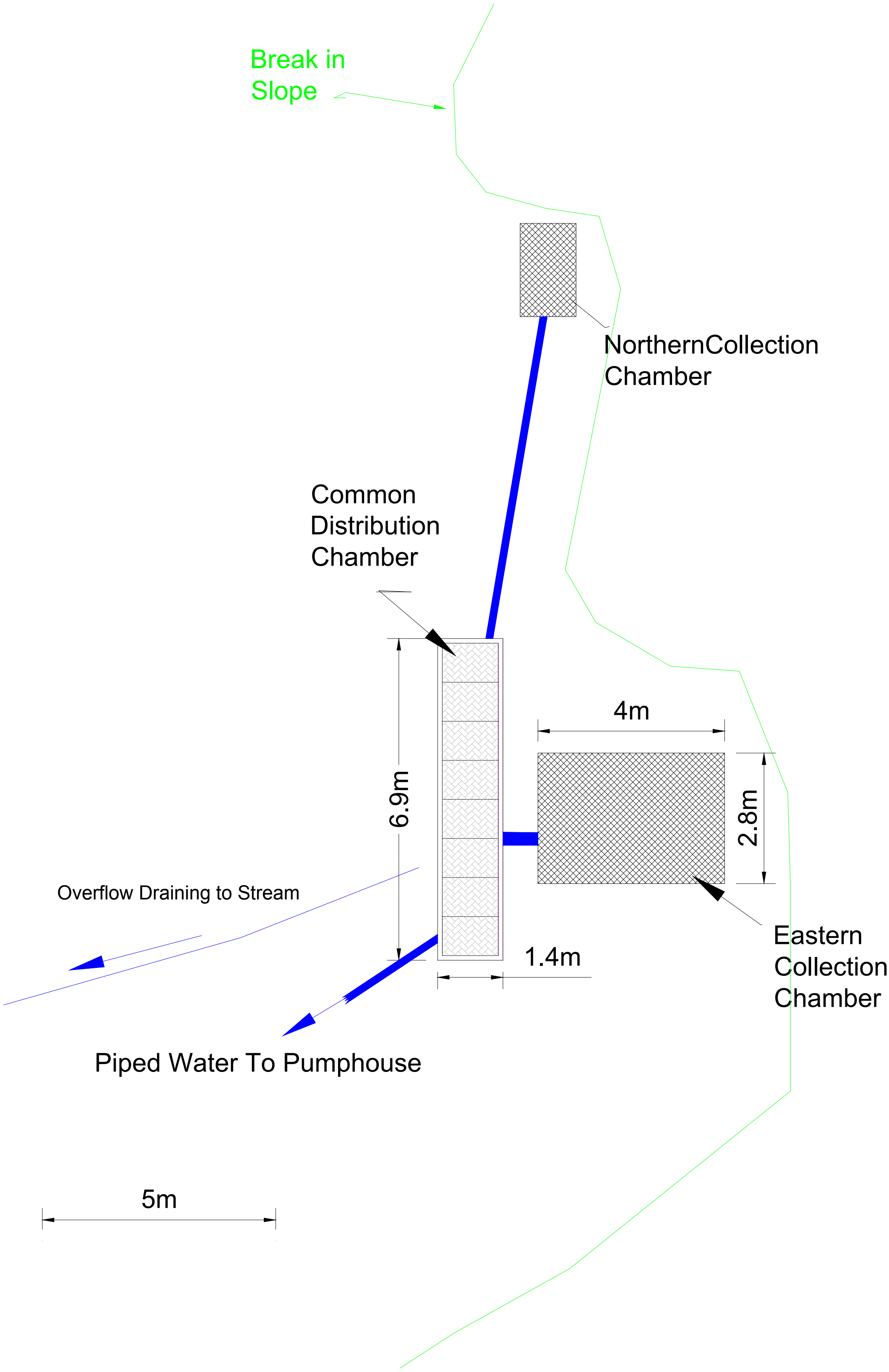

Figure 2: Schematic of Spring Chambers

Photo 3: Distribution Chamber for both Collection Chambers

Photo 4: Standby Borehole (Photo taken in 2004)

4 Summary of Spring and Borehole Details

The scheme supplied all of the water for the village and surrounding areas of Watergrasshill up to June 2010. The average demand was 200 m^3/d. With the expansion of the village in the mid 2000's, the spring occasionally struggled to meet the increasing demand in the drier summer months. To meet the increasing demands, a borehole was installed in 2002, beside the pumphouse to augment the supply. The borehole is located on the western side of the stream in a separate sub-catchment to the spring. It was capable of providing 75 m^3/d and was only used as an emergency supply. Between 2002 and 2010 the caretaker indicated that it was only used during very dry periods. It would activate on a float switch whenever the spring could not supply the required volume of water. Generally it would pump for a few hoursduring peak demand. It was last used in the summer of 2008.

The borehole was installed flush to ground level and is sealed with concrete at the surface. The well head was covered by concrete blocks (Photo 4).

There is no log for the borehole and the information was provided by the caretaker. A 152 mm (6") steel casing was installed to bedrock at 10 m below ground level (bgl). The borehole was advanced at the 152 mm diameter to its completion depth at 100 m bgl. The borehole was fitted with 76 mm (3") uPVC liner from ground level to the base of the hole. The length of slotted liner is unknown.

In June 2010 the Knockraha Surface Water Supply Scheme came on-line to provide approximately 60% of the supply for the Watergrasshill area. The Knockraha surface water supply currently supplies 150 m^3/d of the water demand for Watergrasshill. This is more than half the village's current water needs of 250 m^3/d. The Knockraha Surface Water Scheme is supplied by three surface water intakes. The closest point is approximately 3.8 km downstream on the same tributary that the spring flows into.

The spring now supplies 90–100 m^3/d of the demand. Since the introduction of the surface water scheme, the spring is capable of supplying the requirements for the remaining 40% of the Watergrasshill area without the need for the borehole supply. The borehole at the pumphouse was subsequently capped and is no longer accessible.

The spring water supply is piped by gravity towards the pumphouse where it is filtered though limestone chips to correct for pH before being treated by chlorination in the pumphouse. The water is then pumped to the Spring reservoir for distribution to the network. The reservoir is approximately 420 m to the west, towards Watergrasshill. Table 4-1 provides a summary of the spring and borehole details as currently known.

Table 4-1: Spring Details

	Spring	BH
EU Reporting Code	IE_SW_G_004_04_028	-
National Drinking Water Code	0500PUB1216	0500PUB1216
Grid ref.	178449, 83986	178447, 83981
Townland	Skahanagh South	Meenane
Source type	Spring	Borehole
Owner	Cork County Council	Cork County Council
Elevation (Ground Level)	~169 m OD	~163 m OD
Depth	-	100 m
Depth of casing	-	9.1 m
Diameter	-	152 mm (6")
Diameter of liner		76 mm (3")
Depth to rock	-	9.1 m
Static Water Level	-	Unknown
Pumping Water Level	-	Unknown
Consumption (Co. Co. records)	90-100 m^3/d	Not in use
Pumping test summary: (i) abstraction rate	-	No Data
(ii) specific capacity	-	No Data
(iii) transmissivity	-	No Data

5 Topography, Surface Hydrology & Land use

The local high point (244 m OD) in the surface water catchment is approximately 1.3 km northeast of the spring. The land slopes to the south and southwest from this point. These lands drain into the headwater tributaries of the Butlerstown River. Running south of the topographic high point is a ridge that marks the boundary between the Glashaboy River Catchment to the west and the Owenacurra River Catchment to the east. The spring is located in the Glashaboy River Catchment. Further south along the ridge is another local high point c. 224 m OD. This marks the eastern boundary of a sand and gravel quarry. From here the land slopes to the west towards the spring at a similar topographic gradient (c. 0.06). The removal of sands and gravels has reduced the topographic gradient within the quarry area.

The spring originates at a break in slope where the sand and gravel deposits in and around the quarry thin out and the underlying bedrock is close to the surface. The spring overflows to a tributary of the Butlerstown River which flows southwards.

Figure 3 shows the surface water drainage. To the north of the spring is a stream (Unmarked Stream) that is not identified on the Ordnance Survey of Ireland (OSI) 1:50,000 Map. It rises to the north of the quarry and flows to the west into the Butlerstown River tributary, north of the spring overflow. Some other, smaller, spring seeps were noted draining into this stream (Photo 5).

There is another surface water drain to the east and south east of the spring flowing from east to west. The drain has been extended to the east in recent times (Photo 6 and Fig 3) and is approximately 3 m deep where it passes near the spring. There was very little flow in the drain during any of the site visits.

In the western end of the quarry towards the entrance most of the sand and gravel has been removed, and several groundwater seeps were observed in the floor and sidewalls of the quarry. These seeps are collected in a pond in the lowest area of the quarry to the south of the site entrance. The quarry operator had excavated a ditch to drain this water into the settlement ponds near the quarry entrance. The settlement ponds drain into a pond to the north of the quarry entrance at a lower topographic gradient to theone to the south of the entrance. This ponded area appears to drain towards the source.

The land use in the area is primarily agricultural grassland. The sand and gravel quarry is located300 m to the east directly up hydraulic gradient of the spring. It has been a working quarry since the 1960s. The present site is approximately 0.34 km^2. It was initially a small local quarry covering less than an acre but the quarry activity intensified in the 1990s. The quarry is bounded to the south and west by the Coilte owned Monbaun Forest Park. The public entrance to the park is at approximately 3 km^2 to the southwest of the quarry. There is also a small area of private forestry northwest of the spring. The grassland to the northwest has dry bank walls and no ditches which is indicative of well drained land.

Photo 5: Spring entering Stream

Photo 6: Ditch recently excavated south of the quarry

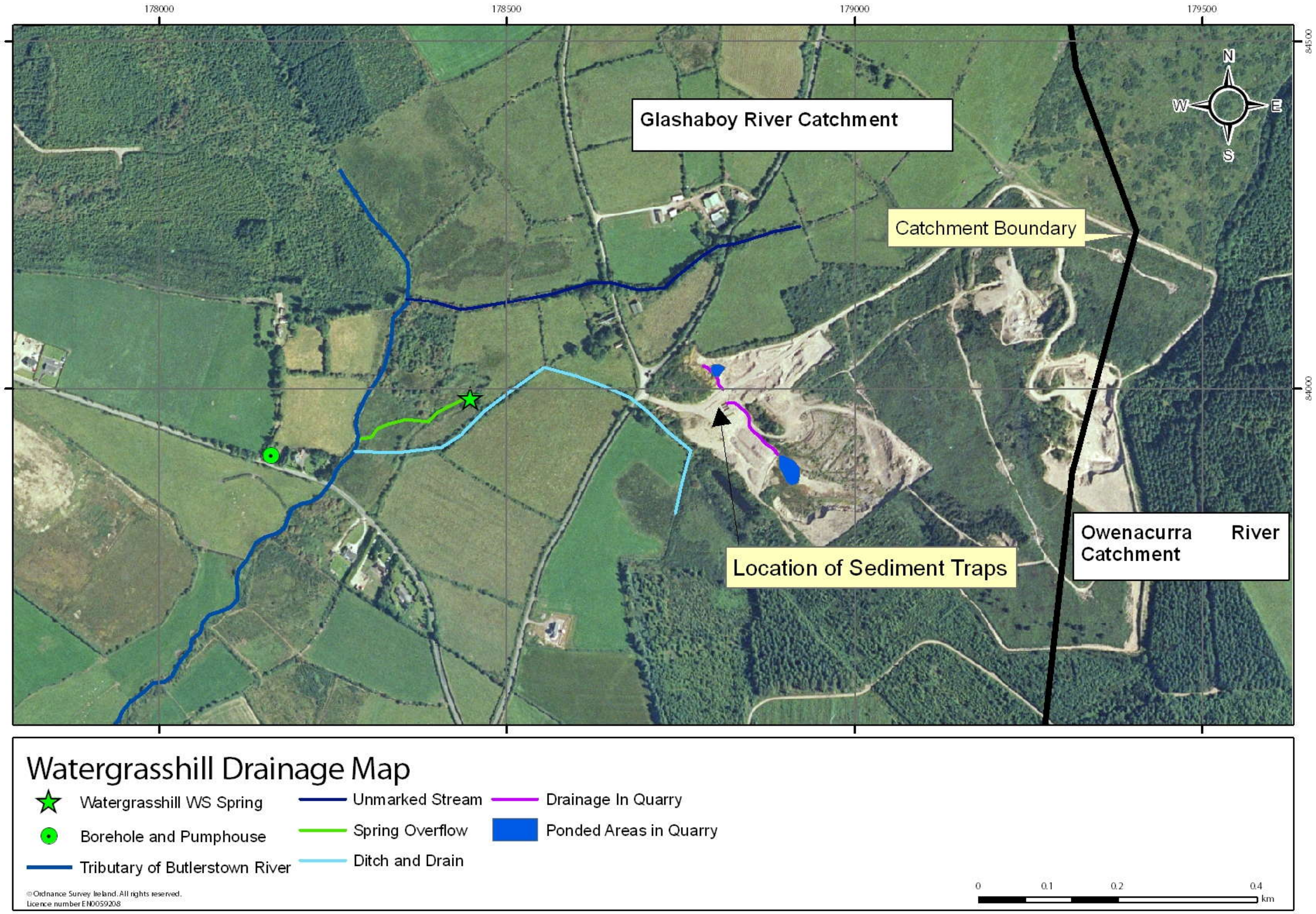

Figure 3: Local Drainage

6 Hydrometeorology

Establishing groundwater SPZs requires an understanding of general meteorological patterns across the area of interest. Meteorological information was obtained from Met Éireann.

Annual rainfall: 1230 mm. The contoured data map of rainfall in Ireland (Met Éireann website, data averaged from 1961–1990) shows that the source is located close to the 1200 mm average annual rainfall isohyet.

Annual evapotranspiration losses: 400 mm. Average potential evapotranspiration (P.E.) is estimated to be 470 mm/yr based on the contoured data map of potential evapotranspiration in Ireland (Met Éireann website, data averaged from 1971–2000) which shows that the source is located close to the 470 mm average annual evapotranspiration isohyet. Actual evapotranspiration (A.E.) is then estimated as 85% of P.E., to allow for seasonal soil moisture deficits.

Annual Effective Rainfall: 830 mm. The annual average effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this, or 820 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:

- Geology of East Cork - Waterford. Bedrock Geology 1: 100,000 Map series, Sheet 22, Geological Survey of Ireland (A.G. Sleeman and B. McConnell 1994).
- Forest Inventory and planning system – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map, Teagasc (Meehan, 2002).
- Geological Survey of Ireland (2004) 1st Draft Ballinhassig GWB Description.

7.2 Bedrock geology

The spring is underlain by rocks from the Ballytrasna Formation which is part of the Old Red Sandstone Rock Unit group. The formation comprises purple mudstone and sandstone. The contact with the older Gortanimill Formation, comprising sandstone and siltstone, but also part of the Old Red Sandstones, is mapped approximately 850 m to the northwest.

The Devonian rocks here were folded during the Variscan Mountain Building Event into a series of anticlines and synclines. The folds generally trend east – west. Widespread north-south faulting is usually associated with this event but there are no known faults mapped in the area.

The bedrock geology is shown on Figure 4 below.

7.3 Soil and Subsoil geology

The soil and subsoil distributions are illustrated in Figures 5 and 6, respectively. According to the EPA and GSI Web Mapping sites, the soil is classified in the quarry as Acid Mineral Shallow Rocky or Peaty Soil (AMinSRPT). Where the gravel is exposed, the soil is absent. To the north of the quarry and around the spring, the soils are Acidic Mineral Deep Well Drained (AMinDW) and to the south of the quarry Acid Mineral Poorly Drained Peaty Soil (AMinPDPT).

Based on observations made during this study the subsoils in the quarry are mostly sands and gravels derived from Devonian parent material (GDSs) with varying amounts of silts and clays. The extent of the sands and gravels were delineated in the field based on the geomorphology of the ground in and around the quarry and the high dry banks visible on aerial photographs. The EPA and GSI map details for this area are currently being updated to reflect these field observations.

A hydrogeological report commissioned by the Watergrasshill Residents Association (S.M. Bennet. 2007) estimated that the original thickness of sand and gravel measured between 5 and 20 m. The report is included in Appendix 1. Based on observations during field mapping in 2011/2012, the sands and gravels are small grained, being comprised mostly of sands and pebble gravels, but with some cobbly deposits. They are at least 8 m deep from examination of pit faces, but may be up to 15–20m deep based on the depth of the pit faces and on the amplitude of the high, dry banks backed up against the rock walls The sand and gravel unit seems to comprise a fan feature, formed at the ice margin as ice lay to the northwest of the locality, and deposited either into a glacial outwash river or into a proglacial lake. Photos 7 and 8 below show the types of sands and gravels encountered.

In the remainder of the catchment, the subsoils are mainly tills derived from Devonian Sandstones (TDSs)

Photo 7: Cobble Sands and Gravels near Quarry Entrance

Photo 8: Sand and Pebble Gravels at Top of the Quarry

7.4 Depth to Bedrock

There were no available details on depth to bedrock in the quarry planning files. In the report by S.M Bennet, it was noted that bedrock was visible on the quarry floor during a site visit on 09/03/2007, when reinstatement of an estimated 2 m of material was underway at the quarry floor (Bennet 2007). During the site visit to the quarry in December 2011, no bedrock was visible. Rock is visible in the stream bed approximately 400 m northeast of the spring and 100 m north of the quarry (Photo 9).

Photo 9: Bedrock in Unmarked Stream north of the Spring and Quarry

8 Groundwater Vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target', which in this case is the bedrock aquifer. 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).

The vulnerability map is shown in Figure 7. The vulnerability at the spring is extreme. To the east and in the quarry it is classified as high. The sands and gravels are characterised as having high permeability on the GSI vulnerability maps. The quarry is flanked north and south by areas of moderate vulnerability. The moderate vulnerability areas are mapped based on local mapping of the tills and the interpreted increasing depth to bedrock on either side of the sand and gravel bank. At the highest and most easterly portion of the quarry the vulnerability is extreme.

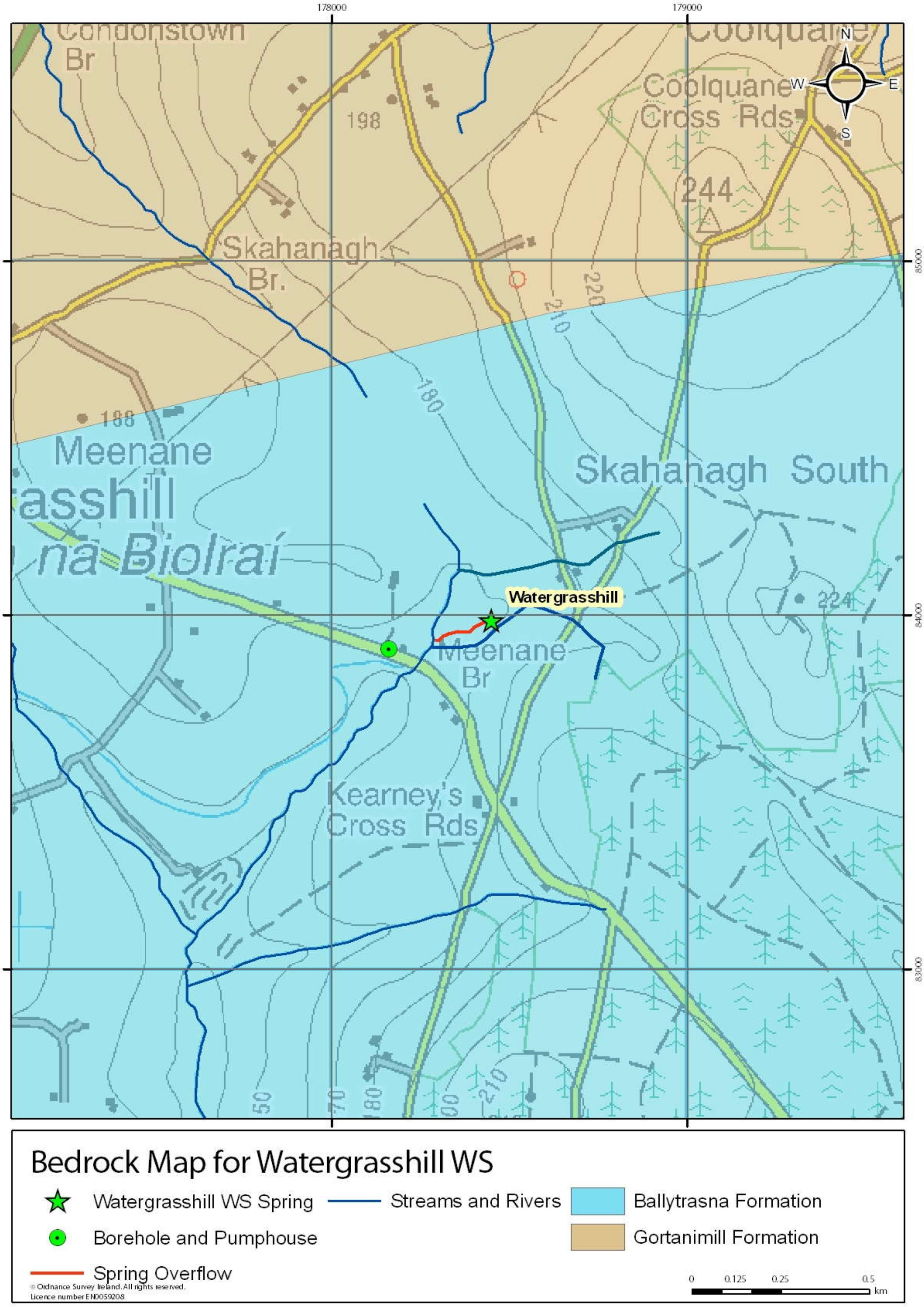

Figure 4: Bedrock Map

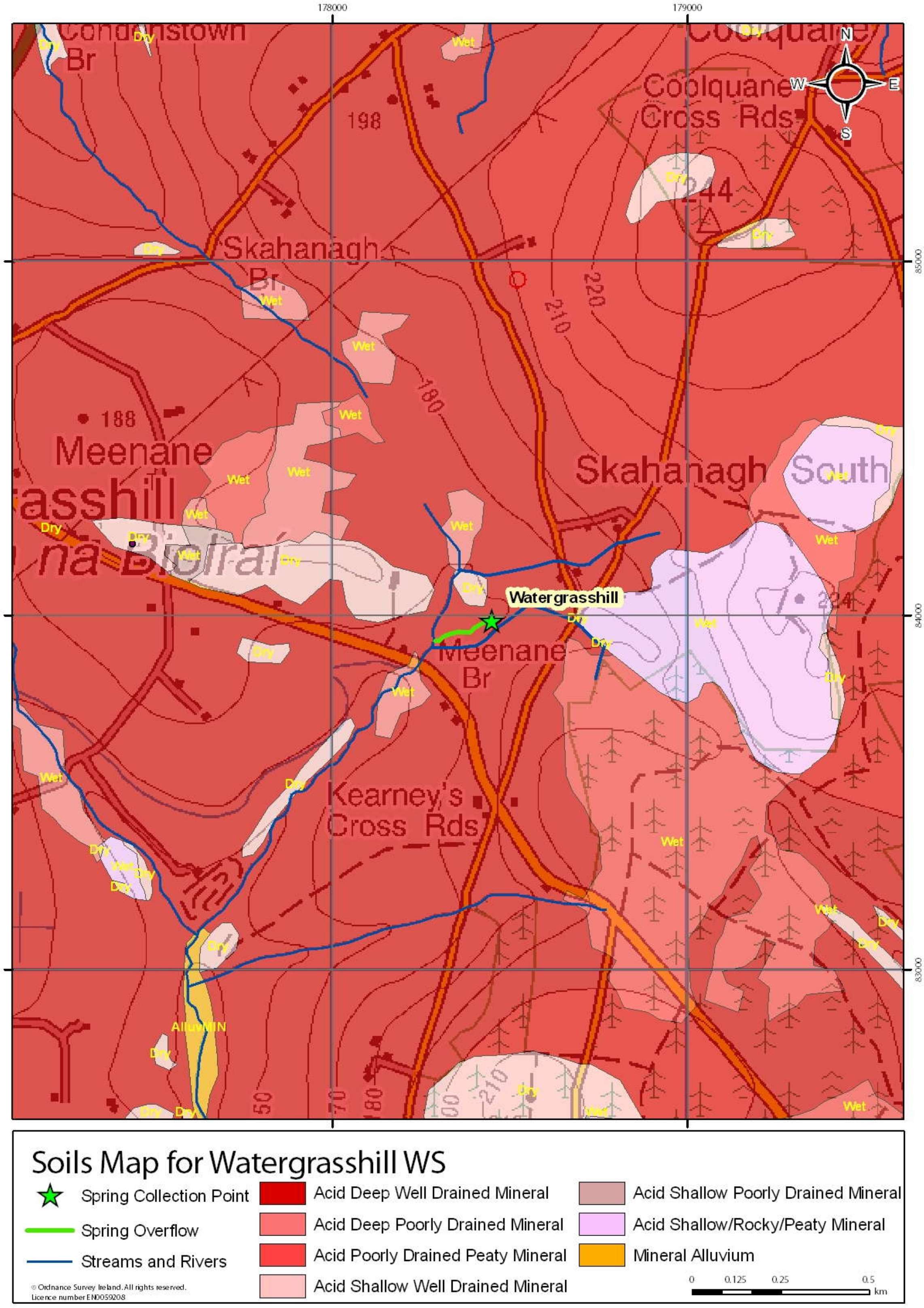

Figure 5: Soils Map

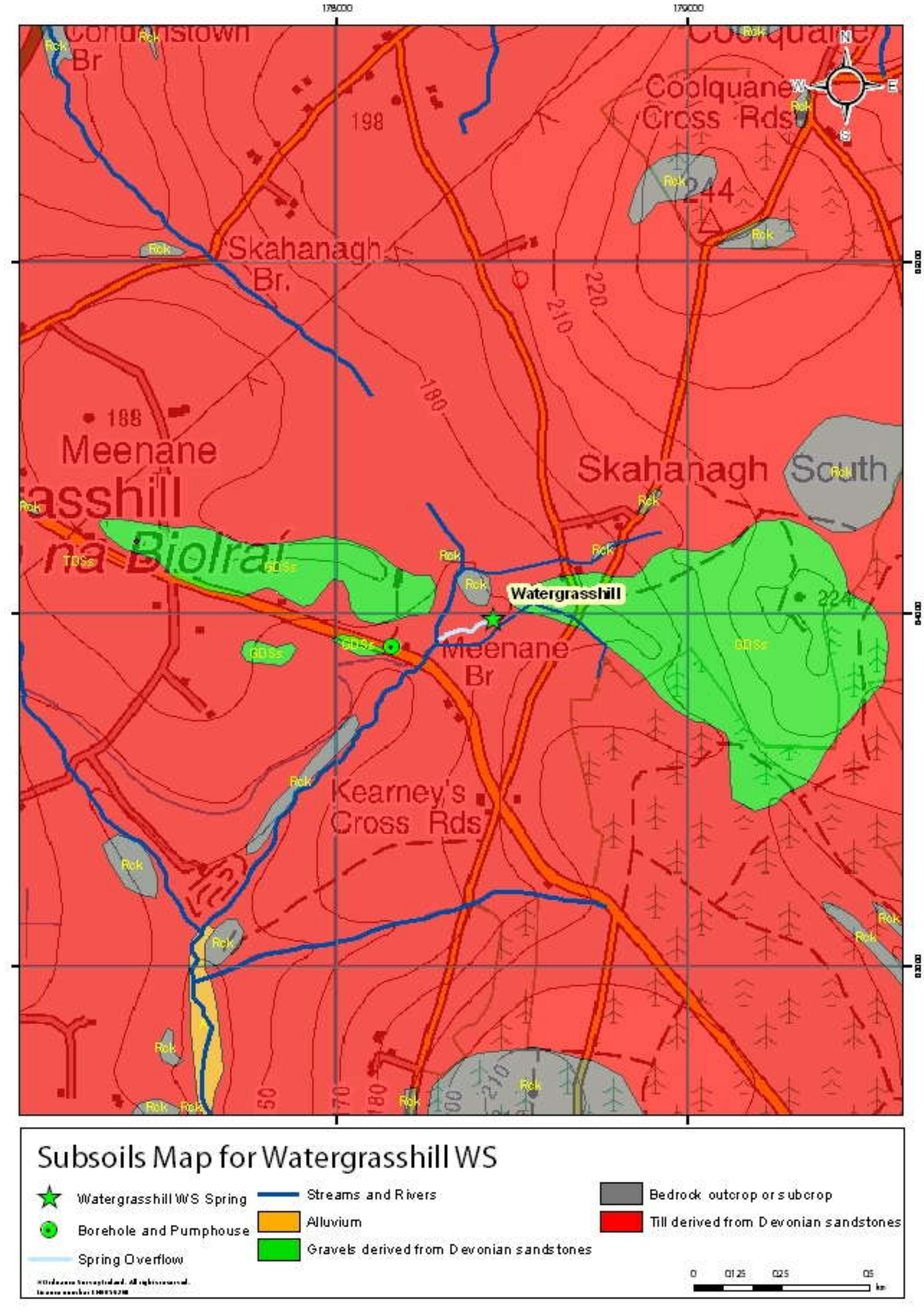

Figure 6: Subsoils Map

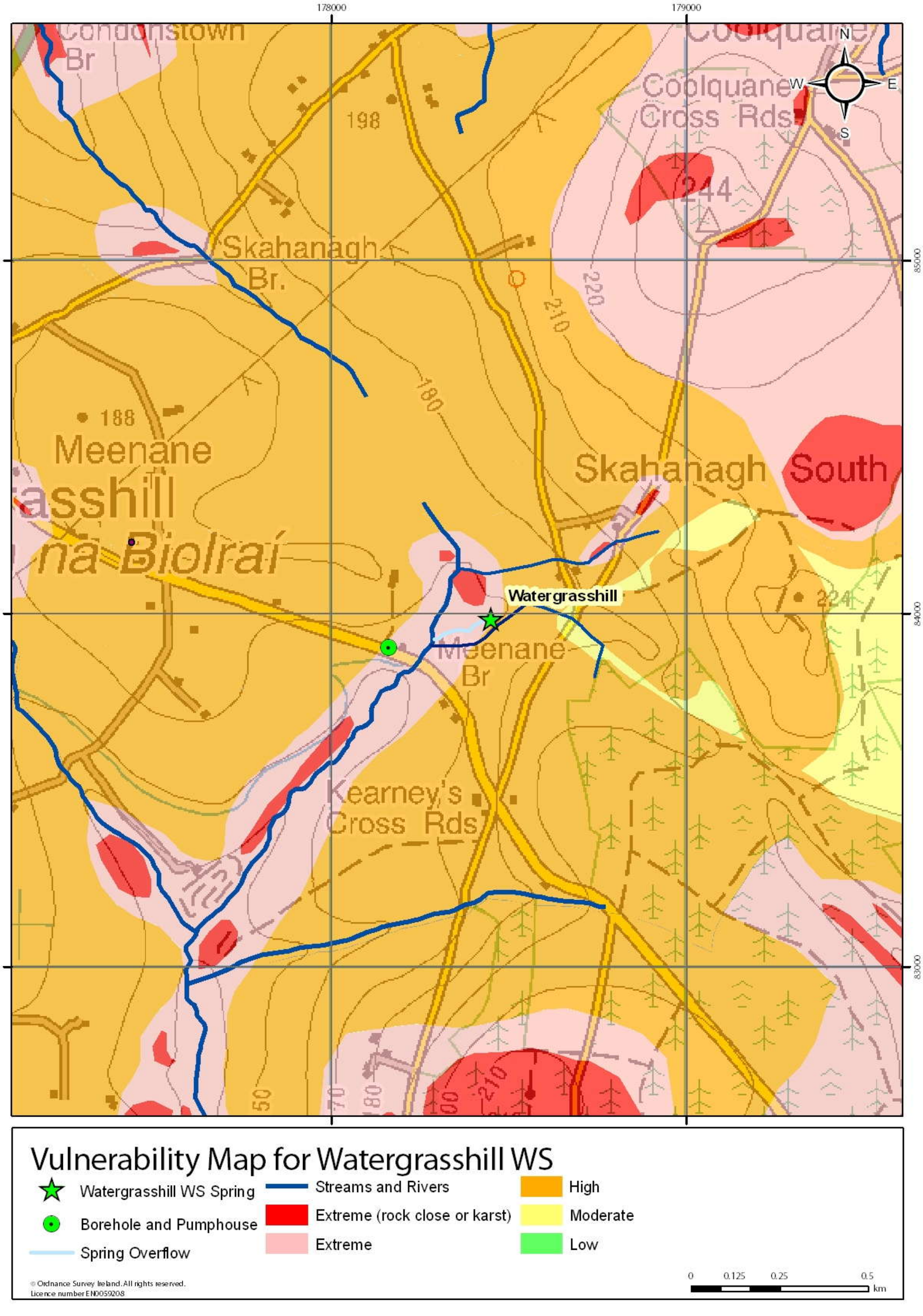

Figure 7: Vulnerability Map

9 Hydrogeology

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

- GSI Website and Database
- County Council Staff
- EPA website and Groundwater Monitoring database
- Local Authority Drinking Water returns
- The Ballinhassig Groundwater Body initial characterisation report
- The Hydrogeological Report by S.M. Bennet & Co. Ltd. (2007).

9.1 Groundwater Body and Status

The spring is located within the Ballinhassig_1 Groundwater Body (IE_SW_G_004) which has been classified as being of Good Status. The groundwater body description for the Ballinhassig Groundwater Body is available from the GSI website: www.gsi.ie and is provided in Appendix 2. The 'status' is obtained from the Water Framework Directive website: www.wfdireland.ie/maps.html.

9.2 Groundwater Levels, Flow Directions and Gradients

During the site inspection on 2/12/2011, a number of wells were dipped on private land and in the quarry. The data are shown in Table 9–1 and on Figure 11. There are no construction details for any of the wells, although the landowner for wells-1 and 2 indicated that bedrock was encountered close to the surface at those locations. The water levels in the bedrock wells are closer to the surface than the water level in the wells installed in subsoil (sand and gravels). Well-4 is located on a haul road at the northern end of the quarry land. The water level is very close to the surface and it is assumed that the borehole is installed in the bedrock. This information and the topography were used to delineate the northern boundary of the sand and gravel deposit.

Table 9-1: Groundwater Levels in Boreholes

Name	**Water Level (m btc)**	**Estimated Water Level (m OD)**	**Subsurface Deposit Well Situated in**
Well-1	2.55	188	Sandstone (bedrock)
Well-2	1.58	192	Sandstone (bedrock)
Well-3	4.90	171	Gravel (subsoil)
Well-4	1.92	214	Sandstone (bedrock)
Well-5	11.50	207	Gravel (subsoil)

Based on the topography and surface water drainage, it is assumed that rainwater infiltrates the soils and subsoils, with recharge of the groundwater system greatest where the subsoils are predominantly sands and gravels. The recharge percolates through the subsoils to shallow bedrock. Because this zone is more permeable than the underlying competent bedrock, and because of the topographic gradient, the infiltrating water flows down-gradient westwards discharging at the springs where the subsoils thin out and where the bedrock is close to the surface. The topographic gradient in the catchment is estimated at 0.06 though it reduces locally within the quarry where the sand and gravels have been removed. Well-5, which is located in the eastern part of the quarry lands, has a depth to water of 11.5 m below the top of the casing (btc) which is estimated to be c. 207 m OD. It is close to the top of the catchment. The spring is estimated to be c. 168 m OD The hydraulic gradient from this point to the spring is estimated as 0.04. This is naturally less steep than the topographical gradient.

9.3 Hydrochemistry and Water Quality

The spring has been included in the EPA operational chemical network since 2008. The raw water sample is taken from the distribution chamber where the water is collected from the two spring collection chambers. There is also a treated sample point in the pumphouse. The laboratory results have been compared to the EU Drinking Water Council Directive 98/83/EC Maximum Admissible Concentrations (MAC) and, where relevant, mean values have been compared to the Threshold Levels in the European Communities Environmental Objectives (Groundwater) Regulations 2010 adopted in Ireland (S.I. No. 9/2010) as part of the implementation of the Water Framework Directive 2000. The EPA data are graphed in Figures 8 to 10 and are summarised below.

- The water has a calcium bicarbonate hydrochemical signature and is moderately soft (Average Total Hardness 35 mg/l $CaCO_3$). The average conductivity is 107 µS/cm. The pH was lower than the MAC range of between 6.5 and 9.5, on 10 occasions from a total of 11 analyses. The average pH is 5.3 which indicates mildly acidic water, probably related to the siliceous nature of the gravel material it filters through and/or groundwater discharge from the sandstone bedrock beneath the gravels. The raw water is filtered through limestone chips to bring the pH to potable quality.
- Faecal Coliforms were detected three times in 12 EPA analyses. Ammonium values were not recorded above the Threshold Level (0.175 mg/l) and were only above the detection limit on three of the twelve occasions.

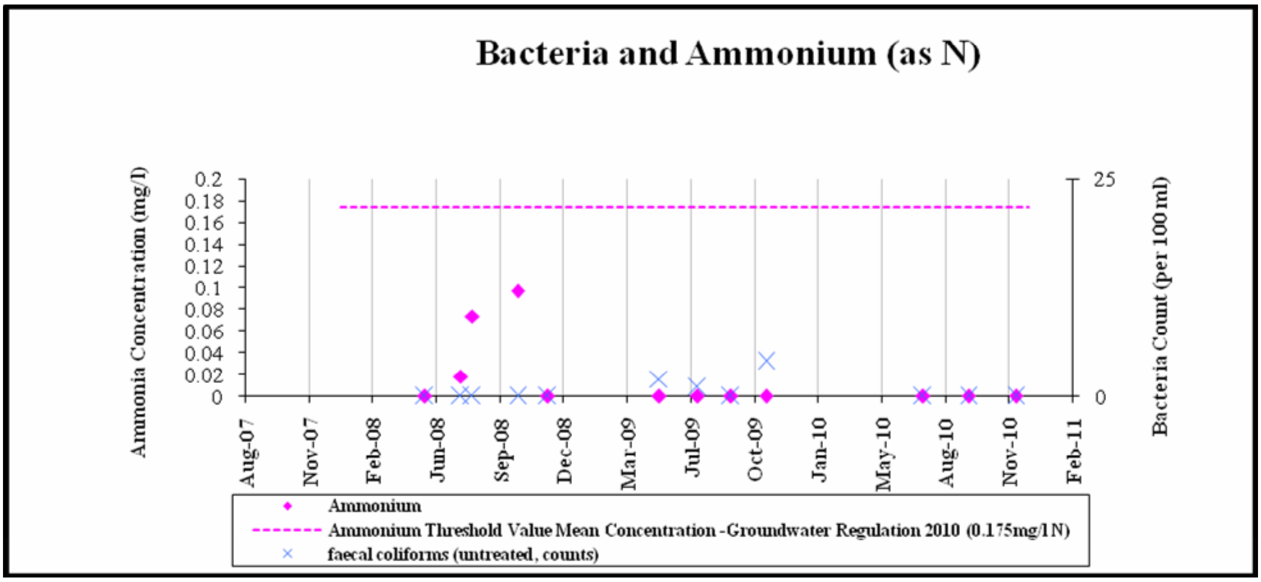

Figure 8: Key Indicators of Agricultural and Domestic Contamination: Bacteria and Ammonium

- The nitrate (as NO_3) level ranges from 4.7 mg/l to 8.9 mg/l, with a mean of 6.7 mg/l. The values are well below the MAC (50 mg/l) and Threshold Value of 37.5 mg/l.
- Chloride can be a constituent of organic wastes, sewage discharge and artificial fertilisers, and concentrations higher than 24 mg/l (Groundwater Threshold Value, Groundwater Regulations S.I. No. 9 of 2010) may indicate contamination, with levels higher than 30mg/l usually indicating significant contamination (Daly, 1996). Chloride concentrations range from 7 mg/l to 19 mg/l with a mean of 14 mg/l.
- Turbidity exceeded the drinking water standard limit of 1 NTU only three of five monitoring events it was recorded above the limit of detection. Exceeding values coincided with faecal coliforms on only one of these events.
- Total Coliforms were detected on 11 of the 12 monitoring events. This is likely due to the presence of very fine clay particles from the gravels entering the spring after periods of heavy rainfall.

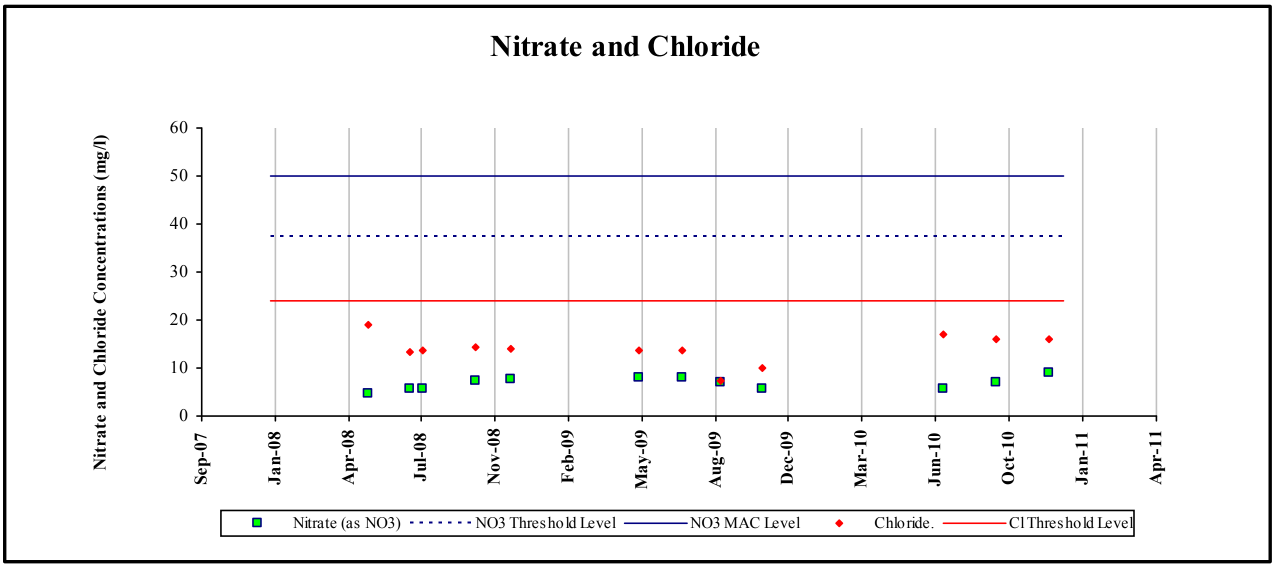

Figure 9: Key Indicators of Agricultural and Domestic Contamination: Nitrate and Chloride Graph

- The sulphate, potassium, sodium, magnesium and calcium levels are within normal ranges. The potassium: sodium ratio has never been above the threshold value of 0.35.

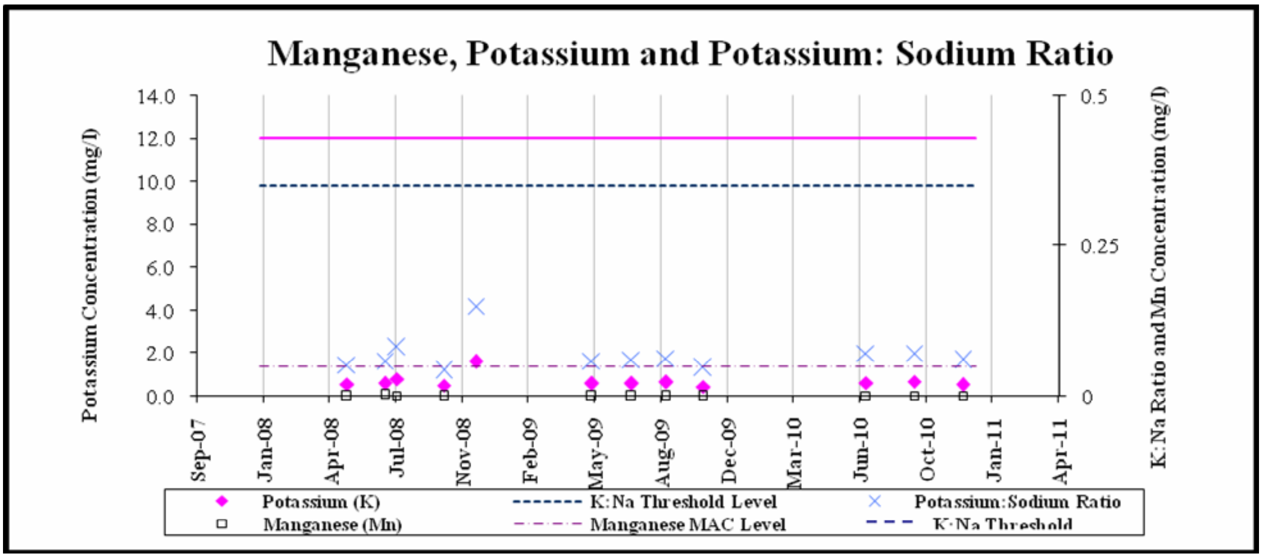

Figure 10: Key Indicators of Agricultural and Domestic Contamination: Manganese, Potassium and K/Na ratio

- The concentrations of iron and manganese are within the normal range. .
- Other trace metals were within either the normal range for good quality drinking water or were not detected. Similarly, organic compounds and herbicides have not been detected.

In summary, the water is mildly acidic and with the exception of three incidents of low levels of faecal coliform detection, one in 2008 and two in 2009, the quality is generally very good, which is likely to be a function of the limited pressures in the zone of contribution to the well and the filtration that occurs as rainfall drains through the thicker sand and gravel sequences remaining in the quarry and present in the surrounding lands.

The pH, electrical conductivity and temperature were measured on the 2/12/2011 in the spring, in the stream tributary of the Butlerstown River at Meenane Bridge and in the Unmarked Stream tributary to the north of the spring. The field parameters were measured again on the 26/4/2012 after a period of heavy rainfall. The more consistent temperature of the spring is indicative of groundwater while the more variable temperature of the stream is indicative of changes from Winter to Spring surface water temperatures.

The pH at the spring was acidic in February but was more or less neutral in April after a period of heavy rainfall which appears to be buffering the groundwater pH. Electrical conductivity (EC) data is similar for the spring and the streams with the exception of SW-3 in February which had a much lower EC than both the spring and the other surface water monitoring points. The data are presented in Table 9-2 and shown in Figure 11.

Table 9-2: Spring and Surface Water Field Measurements

	pH		**Electrical Conductivity** (µS/cm)		**Temperature (°C)**	
	2/12/2011	26/4/2012	2/12/2011	26/4/2012	2/12/2011	26/4/2012
Spring	5.96	7.01	135	120	10.0	9.9
Stream (SW-1)	6.93	7.69	141	131	9.3	8.9
Stream (SW-2)	6.99	7.78	143	130	9.5	8.9
Stream (SW-3)	7.22	7.64	89	146	7.1	8.3

9.4 Aquifer Characteristics

The groundwater resource comes from the bedrock aquifer and from an area of sand and gravels. Usually, a sand and gravel deposit needs to have a surface area of more than 1 km^2 and have at least 5m of saturated thickness to be classified by the Geological Survey of Ireland as a locally important gravel aquifer (Lg). The extent of these sand and gravels is estimated at 0.34 km^2 and is not large enough to be considered an Lg aquifer. At the quarry, a significant portion of the sand and gravel has also been removed at the process area near the entrance. The saturated thickness is unknown but on average, based on field observations and the water level recorded in Well 5, it is estimated at approximately 5 m. The gravels provide storage and filtration thus enhancing the quality and quantity of water reaching the spring.

The gravels are underlain by the Ballytrasna Formation. It is classified as an aquifer that is moderately productive only in local zones (Ll). The rocks have been folded and then eroded by glaciers. Most of the groundwater flow that will contribute to the spring from the bedrock will be in the top 15 m of the formation where the rock is weathered and broken. The GSI report for the Ballinhassig GWB indicates that transmissivity values are likely to range between 2-20 m^2/d. The hydraulic conductivity, K (coefficient of permeability), can be calculated by dividing the transmissivity by the assumed depth of the aquifer. This gives a range of K of 0.133-1.33 m/d. The effective porosity for this upper 15 m of the bedrock is estimated to 1-2%.

Misstear et al (2007) suggests a porosity of between 20 and 50% for sands and gravels with a hydraulic conductivity (coefficient of permeability) range of 1 to 100 m/d. Fetter (2001) suggests a similar porosity range and hydraulic conductivity ranges of between 8.6 m/d and 86 m/d. A hydraulic conductivity (K) value of 50 m/d was calculated by K.T. Cullen (1982) for the Brinny Sand & Gravel aquifer in the Lee Valley, while a GSI report on the Coachford Water Supply Scheme, located approximately 30 km to the southwest also in the Lee Valley, also derived the K value of 50 m/d and an effective porosity of 30% based on particle analysis. However, these are alluvial gravels while the deposits in Watergrasshill are glacial and not as well sorted or permeable. Therefore a more conservative K value of 30 m/d was chosen. Allowing for the less porous glacial gravels, an effective porosity of 20% was chosen.

The exact thickness of the sand and gravel deposits is unknown. Based on the visual inspections during the site visit an average saturated thickness of 5 m was estimated. Assuming a K value of 30 m/d and thickness of 5 m, gives a likely transmissivity of the order of 150 m^2/d.

The hydraulic parameters are presented in Table 9.3.

Table 9-3: Average Hydraulic Parameters

	Sand and Gravel	Shallow Bedrock
Transmissivity (m^2/d)	150	2-20
Hydraulic Conductivity (m/d)	30	0.13-1.33
Effective Porosity (%)	20	2

The velocity of water moving through this aquifer to the borehole has been estimated using Darcy's Law:

$$v = \frac{Ki}{n}$$

where v is the groundwater velocity (m/d)

K is the hydraulic conductivity (m/d)

i is the groundwater gradient

n is the estimated effective porosity

The velocity was calculated for the sand and gravel layer and the bedrock layer. The hydraulic gradient is estimated at 0.04 (Section 9.2). The velocity calculated ranged from 6 m/d in the sand and gravel to 0.3-2.7 m/d in the shallow weathered bedrock. To be conservative the velocity for the fastest layer, the sand and gravel, was chosen.

The aquifer parameters are summarized in Table 9-4.

Table 9-4: Indicative Parameters for the Watergrasshill Source

Parameters	Sand and Gravel	Shallow Bedrock
Transmissivity (m^2/d)	150	2-20
Hydraulic Conductivity (m/d)	30	0.13-1.33
Effective Porosity (%)	20	2
Groundwater gradient	0.04	0.04
Velocity (m/d)	6	0.3-2.7

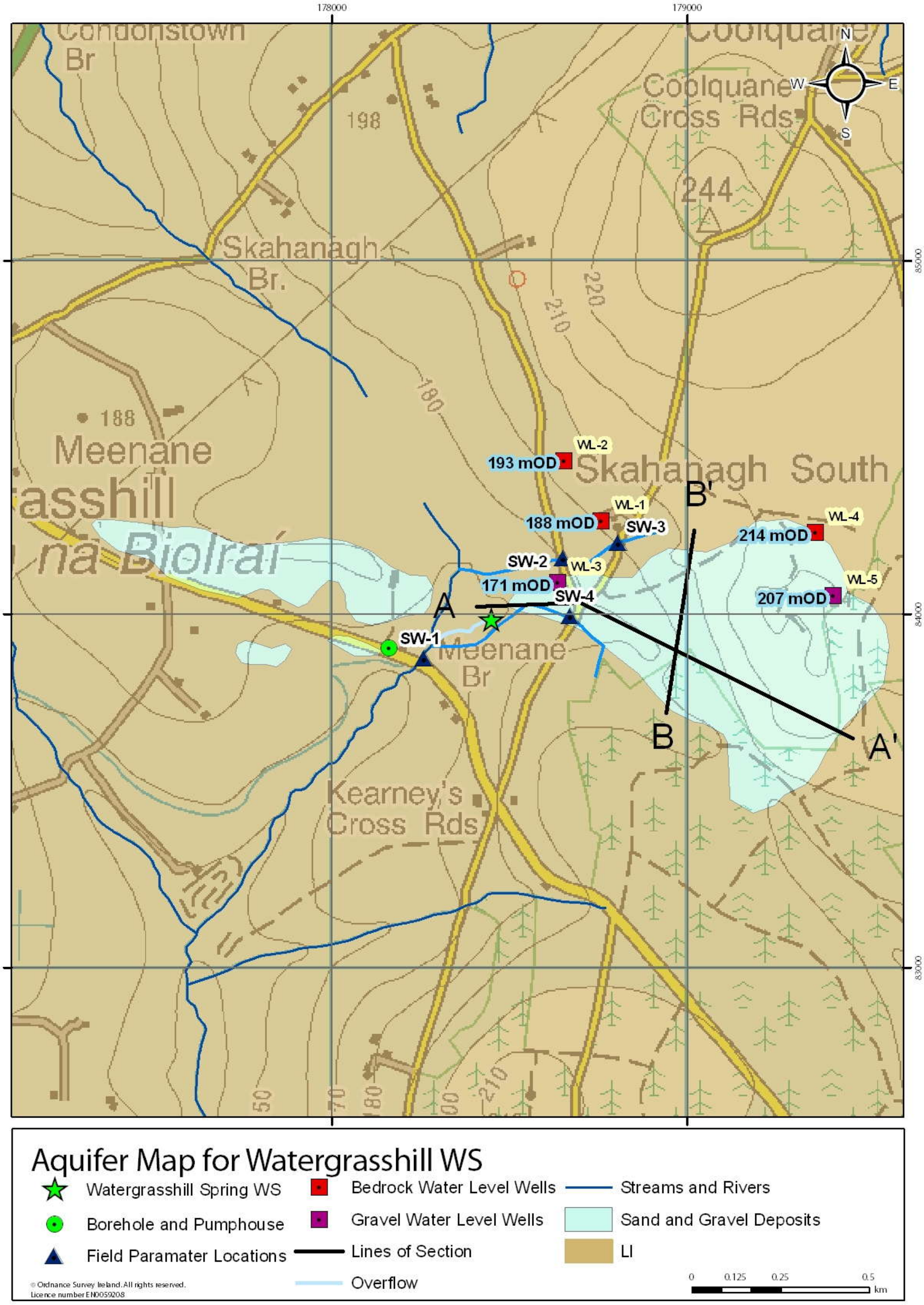

Figure 11 Bedrock Aquifer Map with mapped Sand and Gravel Deposits

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

The spring source is fed by a discharge that emerges at a break in slope where a sand and gravel deposit pinches out and where the underlying bedrock comes close to the surface.

From topographic considerations, recharge is expected to come from rainfall infiltrating the shallow subsoils to the southeast of the spring and rainfall infiltrating the sands and gravels to the east.

Recharging water percolates mainly through the sands and gravels and into the weathered shallow sandstone bedrock. To the southwest of the spring, where the sands and gravel are absent, water recharges the weathered shallow bedrock through the overlying tills. In the wetter months the shallow bedrock is saturated and most of the flow to the spring is along the sand and gravel. In the drier months the water level drops and the flow to the spring may be limited to the bedrock.

Schematic representations of the conceptual model are shown in Figures 12 and 13. The lines of section are shown on Figure 11. Figure 12 is a cross section from east to west from the eastern margins of the catchment to the spring. Figure 13 is a cross section from southeast to northwest. The representations are based, in field observations and in part, on a survey drawing of the quarry which forms a significant portion of the catchment. The drawing was obtained from a search of the Cork County planning files for the quarry. The drawing is included in Appendix 3.

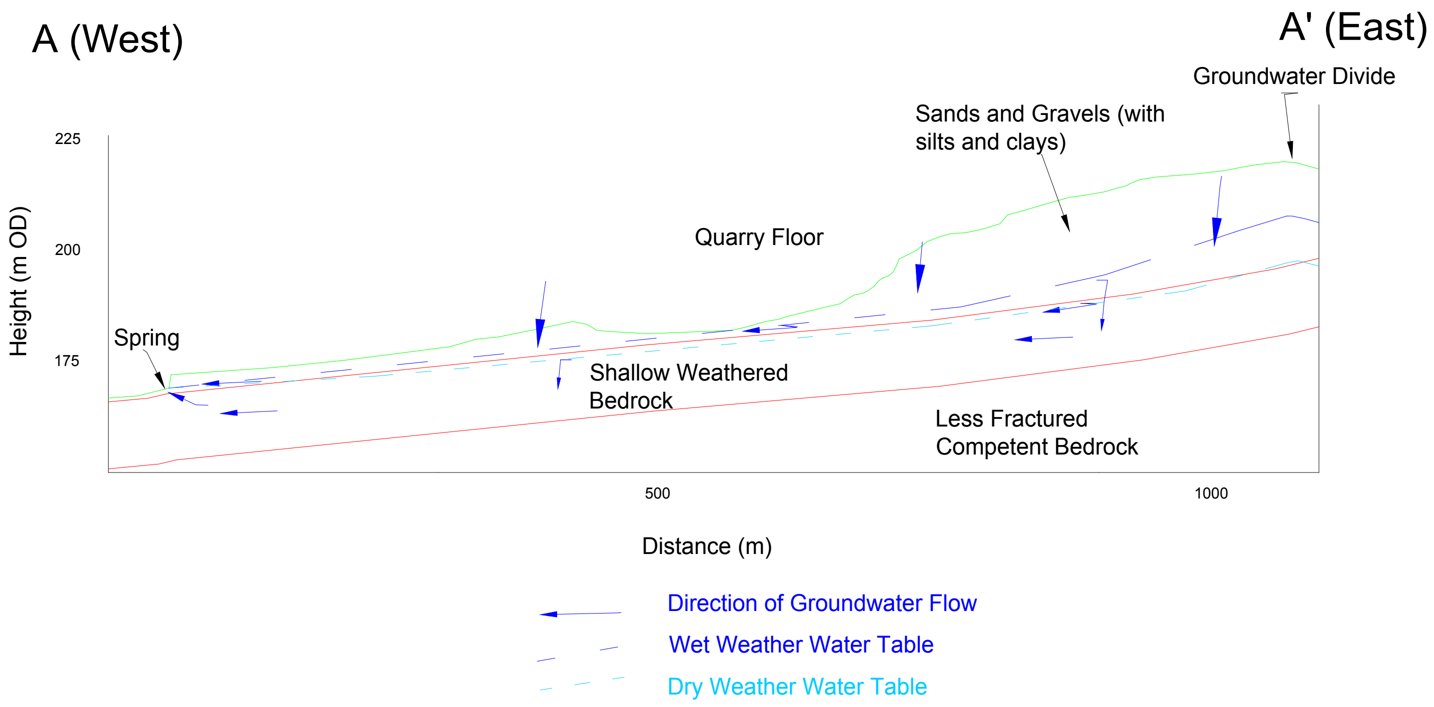

Figure 12: Cross Section from East to West (A-A')

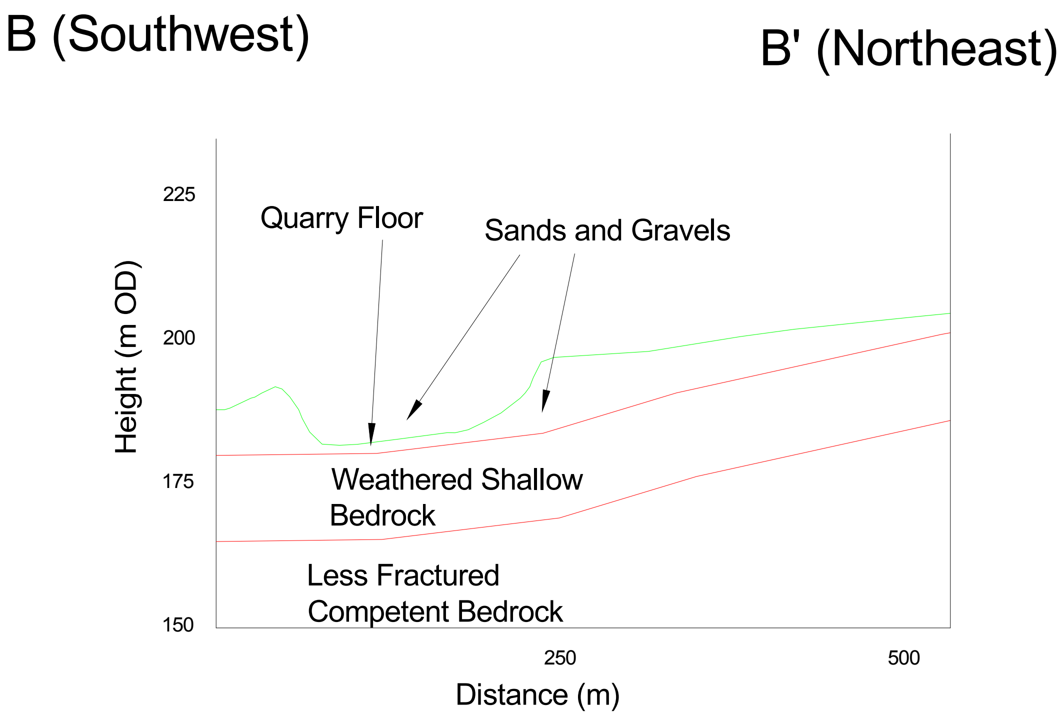

Figure 13: Cross Section from Northeast to South West (B-B')

10.2 Boundaries of the ZOC

The boundaries of the area contributing to the spring are considered to be as follows (Figure 14). (A ZOC was not delineated for the borehole because it is not in use.)

The northern, eastern and southern boundaries are primarily based on the topography, location of the sand and gravel deposit, conceptualised groundwater flow-lines, which flow to the west in the direction of the tributary of the Butlerstown River, and the location of the surface water features.

The western boundary is the downgradient boundary. Groundwater will not flow back upgradient to the spring. However, an arbitrary downgradient distance of 30 m was chosen based on the standard used for springs by the GSI in order to protect the source.

The size of the ZOC comprises the entire hydraulic area draining to the spring and includes for water abstracted for supply as well as the excess/overflow discharging to the Butlerstown River stream tributary.

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 Watergrasshill therefore, the main parameters involved in recharge rate estimation are: annual rainfal; annual evapotranspiration and a recharge coefficient. The recharge is estimated as follows.

Potential recharge is equivalent to 830 mm/year (i.e. Annual Effective Rainfall as outlined in Section 6).

Actual recharge: 830 mm/yr. Much of the recharge is assumed to come through the gravels. Much of the soils and subsoils have been removed in the quarry. Given that there is little standing water or drainage features in the remainder of the quarry 80% of the rainfall is assumed to recharge the aquifer.

To the south of the quarry the vulnerability ranges from moderate to high. The soil is well draining and the thickness of the till is expected to be relatively shallow. This gives an overall recharge coefficient of 0.6.

Runoff losses are assumed to be 20% of the potential recharge (effective rainfall). This value is based on an assumption of 25% runoff for the areas of high and moderate vulnerability south of the quarry and 15% runoff for sands and gravels (High vulnerability). The **bulk recharge** coefficient for the area is therefore estimated to be 80%.

Runoff losses: 166 mm. Runoff losses are assumed to be 20% of potential recharge.

These calculations are summarised as follows:

Average annual rainfall (R)	1230 mm
Estimated P.E.	469 mm
Estimated A.E. (95% of P.E.)	400 mm
Effective rainfall	830 mm
Potential recharge	830 mm
Runoff losses	20%
Bulk recharge coefficient	80%
Assumed Recharge	**664 mm**

Using the water balance calculation, a recharge of 664 mm/yr and the current abstraction rate of 100 m^3/d would require a recharge area of 0.055 km^2. The maximum previous yield of 200 m^3/d would require an area of 0.110 km^2. The ZOC accounts for the topography for the entire hydraulic area from which water is likely to reach the springs. This results in a ZOC area of 0.494 km^2 and is approximately 882% larger than the area required by the recharge calculations to sustain the current abstraction rate. This is the area of the ZOC described above, and shown in Figure 14.

The recharge over the area contributing to the source should equal the discharge at the source. The discharge at the source is unknown and an assessment was made of the likely available recharge based on the topography and field mapping of the area. Several recharge and abstraction scenarios were modelled and potential zones of contribution calculated to determine the best fit for the observed field conditions. Bulk recharge coefficients tested were 1, 0.8 and 0.6. The recharge cap of 200mm/yr for poorly productive aquifers was also applied (Groundwater Working Group 2005). The discharge rates used were the previous abstraction of 200 m^3/d and a discharge of 300 m^3/d including an average overflow of 100 m^3/d. The relevant calculations are included in Appendix 4. The calculations show that in the low flow summer months, that a discharge greater than 200 m^3/d is unlikely to be sustainable with the delineated ZOC of the hydraulic catchment.

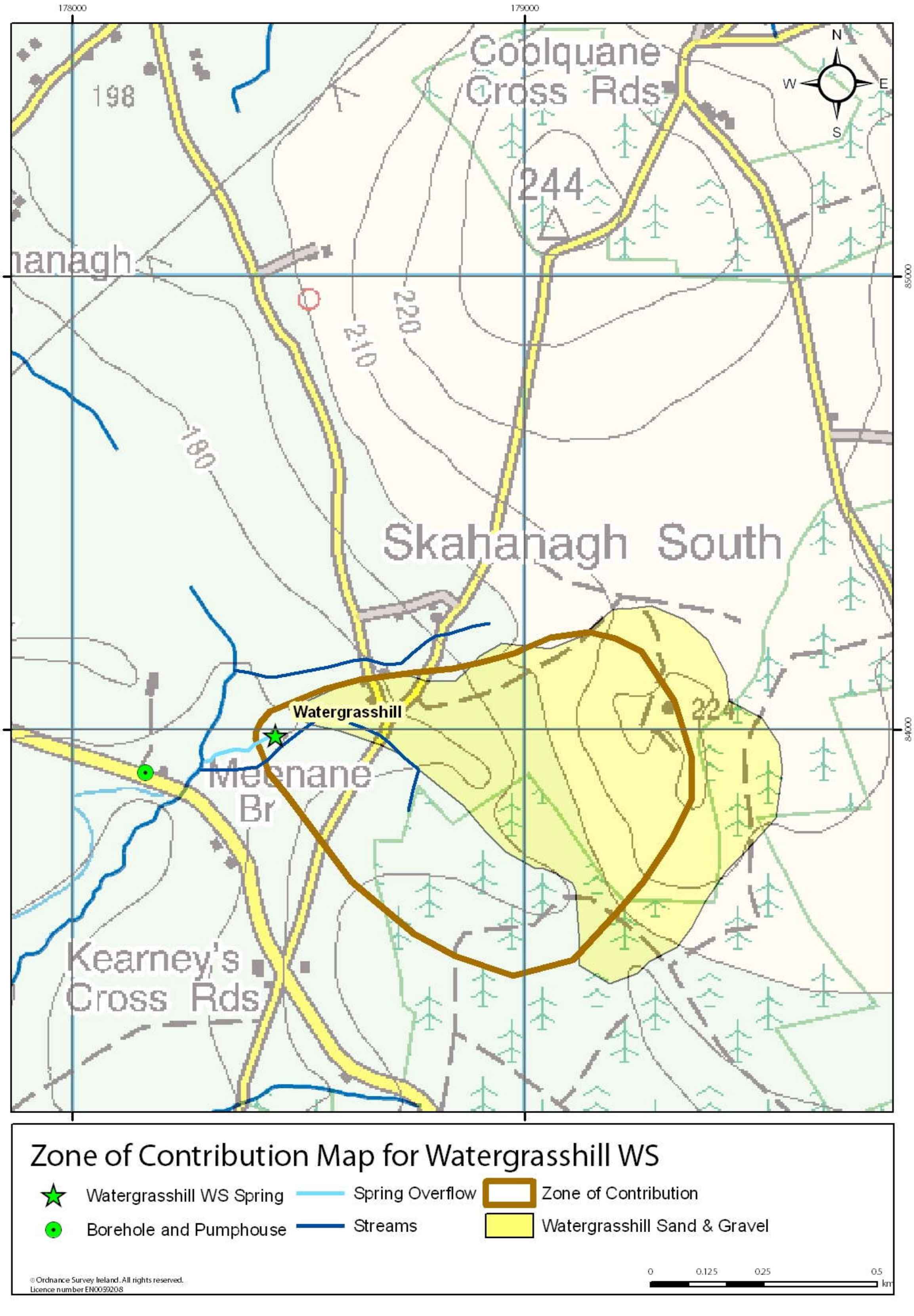

Figure 14: Zone of Contribution

11 Source Protection Zones

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

The Inner Protection Area (SI) is designed to protect the source from microbial and viral contamination and it is based on the 100-day time of travel to the supply (DELG/EPA/GSI 1999). Recharge occurs through the sand and gravels overlying weathered bedrock in the northern and northeastern portion of the ZOC through the thin tills overlying weathered bedrock in the southern and southwestern portion of the ZOC. The inner source protection area was delineated taking account of variations in recharge rates in both of these areas. Over the sand and gravel area the most conservative aquifer parameters, presented in Section 9.4 were applied in delineating the source protection area. The maximum groundwater velocity for the sands and gravels is 6 m/d. Hence, the 100-day time of travel was calculated at 600 m. For the area of tills overlying bedrock south of the quarry, the maximum velocity is 2.7 m/d and a 100-day time of travel of 270 m was calculated. The Inner Protection Area is illustrated on Figure 15.

The groundwater Source Protection Zones are shown in Figure 16 and are listed in Table 11-1. They include SI/E, SI/H and SI/M. The majority of the ZOC is designated as SI/H and SO/H.

Table 11-1 Source Protection Zones

Source Protection Zone		**% of total area (km^2)**
SI/E	Inner Source Protection area / <3 m subsoil	1.1% (0.006 km^2)
SI/H	Inner Source Protection area / High vulnerability	33.3% (0.165 km^2)
SI/M	Inner Source Protection area / Moderate vulnerability	2.7% (0.013 km^2)
SO/H	Outer Source Protection area / High vulnerability	58.4% (0.289 km^2)
SO/M	Outer Source Protection area / Moderate vulnerability	4.5% (0.022 km^2)

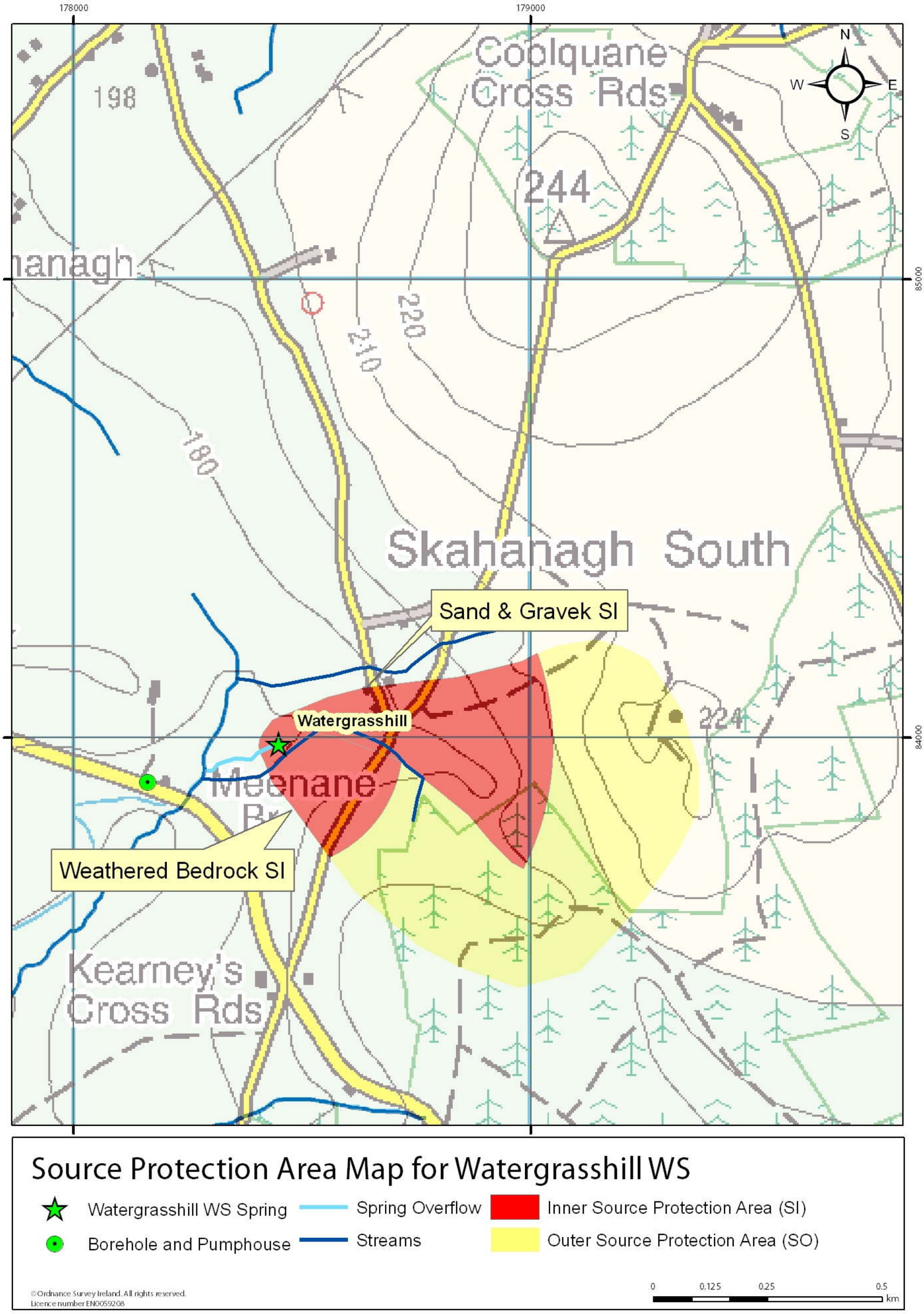

Figure 15: Inner and Outer Source Protection Areas

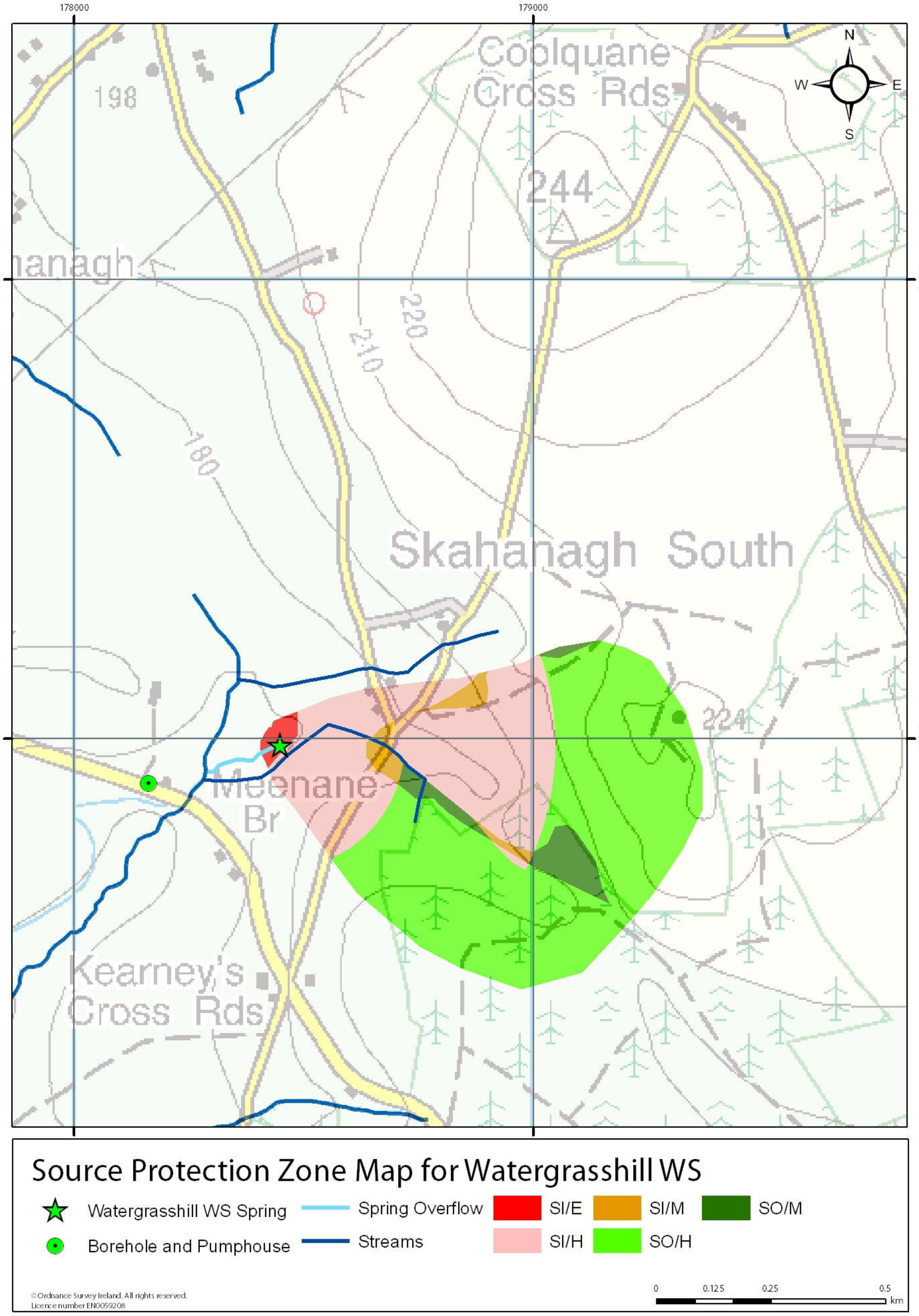

Figure 16: Source Protection Zones

12 Potential Pollution Sources

The spring chambers are located at the end of a laneway 190 m north of the road. The entrance to the site is fenced with access via a gate. The two concrete collection chambers are not accessible. The distribution chamber has steel covers that are unlocked and easily accessible.

At the water treatment plant the ground surface in the compound is fenced off and comprises hardcore gravels.

The land use within the Inner Source Protection Area includes the sand and gravel quarry, grassland for cattle and horses and forestry. The main potential microbial pollution source is lands directly east of the spring which were being used for grazing horses during the site inspections in 2012. Faecal coliforms have been detected twice in 2008 and once in 2009.

The Watergrasshill Community Association (WCA) has been involved in issues regarding the protection of the spring water supply for many years. The main issue of concern has been the operation of the quarry immediately up hydraulic gradient of the spring which is located within the Inner Source Protection Area for the water supply. While the quarry had been operational on a small scale since the 1960's the quarry owners expanded operations substantially in the early to mid 2000's, with a quarry footprint in 2007 estimated at 34.4 ha The quarry owner applied for registration of the quarry as required under the 2000 Planning and Development Act Section 261. The WCA objected to the registration on the basis that if the quarry footprint (>5Ha) the development needed an Environmental Impact Assessment. The WCA commissioned a report by Hydrogeological Consultant, Shane Bennet. Mr. Bennet concluded that recharge to the spring was coming directly from the quarry area and that the recharge to the spring had been reduced because of increased quarrying activity which resulted in a loss of groundwater storage and increased evaporation of the exposed water table. It was also concluded that the quarry operation had increased the vulnerability in the source protection area of the spring which could potentially result in groundwater pollution from quarry activities.

Mr Bennet's findings are consistent with the observations during the current assessment. While the quarry is currently not active, the reactivation of quarry activities poses a significant threat to the chemical quality and quantity of the spring supply.

While the quarry is currently not operating, fly tipping of waste has been occurring in more recent times at the quarry entrance (Photo 10). Given that this activity is occurring in the Inner Source Protection Area to the supply it has the potential to impact on water quality if the waste is not removed or if further dumping occurs.

In summary, given the current land use, the potential risk for contamination from land use is moderate. If the quarry reopens, the potential risk of contamination is likely to increase to high.

Photo 10: Fly Tipping at Quarry Entrance

13 Conclusions

The spring supply to the Watergrasshill Scheme provides 100 m^3/d of the total demand of 250 m^3/d with the balance of the supply being provided by the Knockraha Surface Water Scheme. That scheme commenced operation in July 2010. Prior to 2010, the spring supplied all of the water supply demand and was augmented occasionally by a borehole supply which is no longer in use.

The spring is piped under gravity to a pumphouse where the water is filtered through limestone chips to correct for pH and is chlorinated. The current yield is sustainable and the water quality is generally good reflecting the current lack of land use pressures within the zone of contribution (ZOC).

There is a disused quarry located in the inner source protection area of the quarry. Should this quarry become active in the future it poses a significant risk to the quality and quantity of water discharging at the spring.

The removal of sands and gravel from the quarry in the past has resulted in a loss of storage and subsoil filtration capacity of the recharge to the spring. Further losses of storage and filtration will occur if more of the sand and gravels are removed.

The groundwater vulnerability at the source is extreme. In the majority of the ZOC, the vulnerability is high with small areas of moderate vulnerability flanking a sand and gravel quarry. The former production area of the quarry lies in the Inner Source Protection Area to the supply. The ZOC encompasses an area of 0.494 km^2.

The source protection zones are based on the current understanding of the groundwater conditions and the available data. Additional data obtained in the future may require amendments to the protection zone boundaries.

14 Recommendations

The following actions are recommended:

- Because of the potential to impact on the storage and filtration of the groundwater emerging at the spring, a detailed assessment of the impact of recommencement of quarry operations on the sustainability and water quality of the supply should be carried out before a decision on the feasibility of re-activating the quarry is considered by Cork County Council.

15 References

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APPENDIX 1

Hydrogeological Report S.M. Bennet & Co. Ltd., 2007

HYDROGEOLOGICAL REPORT

Date of Issue: 30th March, 2007

In Respect of:
Potential Hydrogeological Impact of Proposed Quarry Works
at Watergrasshill, County Cork

Conducted by:
Mr. Shane Bennet, *Hydrogeologist,*
S.M.Bennet & Co. Ltd., *Hydrogeological & Environmental Engineers*
Grove Hill,
Bishophill Road,
Ballymore Eustace,
Co. Kildare.

On Behalf of:
Mr. B. Curtin,
C/o J. Noonan, Noonan Linehan Carroll Coffey,
54 North Main Street,
Cork.

SMB Ref: rt-30.03.07-wghl-ck-3.07

TABLE OF CONTENTS

FIGURES

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Tel: +353 45 863211;
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Grove Hill, Bishophill Rd.,
Ballymore Eustace,
County Kildare.

1 SCOPE, INTRODUCTION & REFERENCE DOCUMENTATION

The scope of this report is the potential hydrogeological impact of proposed quarrying at Skahanagh South, Watergrasshill. This report must be regarded as provisional and of an interim nature due to the limited time and data available to the author. Apologies are made for any possible inaccuracies contained herein which are completely unintentional on the part of the author.

Planning permission is sought for the continued operation and extension of an existing sand and gravel quarry at Skahanagh South, Watergrasshill. The Meenane Spring is the source of water for ca. 300 houses in the Watergrasshill area and is located a short distance from the quarry.

An inspection was undertaken by the author on Friday, 9th March, 2007. Following the inspection a long term local resident was interviewed.

This report draws from the following documentation:

- Aquifer Source Protection Scheme Map, 1998. Cork CC Northern Division;
- T.E.S. Cork Landfill Site Selection, 6/2000: Kearney's Cross Bedrock Groundwater Flow Map;
- Site Map from 1974 Planning Application by Quarry to Cork CC;
- Ordnance Survey Map of Area ca. 1930, Scale 6" to 1 mile;
- Geology of South Cork & Sheet 25, GSI 1994;

2 METHODOLOGY

The potential impact to groundwater and other hydrologically-related issues are assessed in the following manner:

- Identification of anticipated changes in the current hydrogeological/hydrological and related conditions that are likely to arise from the proposed quarry operation;
- Determination of sensitive receivers and associated pathways;
- Determination of depth to bedrock, depth to groundwater, vulnerability, aquifer classification, recharge mechanism, water-bearing properties, groundwater characteristics and other water-related information;
- Assessment of the above in the light of existing standards and guidelines, available documents and the proposed development.

3 SITE DESCRIPTION

The area is one of steeply undulating terrain containing variable thicknesses of partially reworked glacial outwash overlying Old Red Sandstone bedrock. Land use appears to consist of grazing in the lower elevations with silviculture and marginal grazing in the upper reaches.

Five photographs are attached to this report. These are described as follows:

- Photograph 1 is taken in a northerly direction from close to the entrance to the quarry. It shows the water treatment facility;
- Photograph 2 is a close up of the water treatment facility;
- Photograph 3 is taken in a north easterly direction of a surface water channel or lagoon;
- Photograph 4 is taken in a northerly direction from the southern margin of the quarry. It illustrates the volume of overburden that has been removed;
- Photograph 5 is taken of what appears to be a groundwater monitoring well.

3.1 Local Topography

The quarry elevations are between 180mOD and 230mOD. The gradient is moderate to severe and to the southwest. The water supply spring at Meenane Bridge is at 170mOD and directly below the quarry.

3.2 Overburden

As exposed in the quarry, the overburden appears to consist of sands and gravels with variable silt and clay. The permeability of the overburden appears high and the natural land is free-draining. Heathland type vegetation such as heather and furze are present in the unworked of the quarry.

Bedrock was exposed at certain locations on the quarry floor indicating an original undisturbed overburden thickness ranging between 5m and 20m. Further to the southeast and in the area of the supply spring the bedrock outcrops at the surface.

3.3 Geology & Hydrogeology

Bedrock in the area is described in GSI Sheet 25 as being of the Ballytrasna Formation (BS) consisting of purple mudstone with sandstone. This rock is part of the Devonian Old Red Sandstone. In respect of its water-yielding properties, the Ballytrasna Formation would be regarded generally as an aquitard or unproductive rock. However in this specific area the combination of topography and permeable overburden overlying impermeable bedrock has created a series of bedrock springs that act as a source to the stream that rises ca. 400m north of Meenane Bridge and flows to the Southwest. Further north a second spring-fed stream rises and flows in the opposing direction towards Skahanagh Bridge.

A series of photographs of the quarry floor taken after sustained winter rainfall illustrate the impermeable properties of the exposed bedrock. Water is seen as ponding and flowing over the bedrock surface toward the site entrance located to the southwest.

The historical ca. 1930 map reproduced in Figure 1 identifies springs (rises) at the quarry entrance. These are shown as flowing in a stream to the point where the Meenane Water Scheme spring is located. The stream's surface manifestation has reportedly dried up since the advent of quarrying but it is clear that a shallow underground flow continues to drain the quarry area directly to the Meenane spring.

3.4 Meenane Water Scheme

The source of the Meenane Water Scheme is from one such spring located approximately 100m north of Meenane Bridge. The spring water is directed to a concrete caisson from which a gravity supply is piped to a pumping station and thence to an elevated reservoir. The water supply provides an ample year-round good quality supply.

The quarry lies centrally within the catchment serving the Meenane Spring. Under natural conditions rainfall percolates though the permeable overburden to the bedrock surface. It then generally flows under gravity along such a surface to the southwest. Where the bedrock is exposed at lower elevations groundwater emerges as springs.

Groundwater flow therefore mimics the steep local overburden and bedrock topography creating a hydraulic gradient which is to the southwest.

3.5 Groundwater Vulnerability

The specific area can be classified as Extreme to High Vulnerability (**HE**). Prior to quarrying there was a substantial permeable overburden thickness that provided a protective filtering layer in respect of percolating rainwater. Due to the complete removal of the overburden over the base of the quarry, the vulnerability classification in this area is now extreme (E). It was noted by the author on 9/3/07 that reinstatement of an estimated two metres of material is being undertaken over part of the quarry floor. This is considered an improvement but does not change the vulnerability classification.

3.6 Water Management at the Quarry

Below ground concrete chambers offering silt attenuation and acting as an oil interceptor have been installed close to the low point on the quarry and near the entrance. The discharge from these chambers appears to be to soakaway and to the southwest.

4 POTENTIAL HYDROGEOLOGICAL IMPACTS

The potential impact of most concern in respect of the Meenane Water Scheme is a reduction in water quality in the spring source. The removal of the protective overburden over the quarry base combined with the continued operation of the quarry itself constitutes potential impacts.

A second potential impact is the diminution of the spring flow arising from the significant reduction groundwater storage inherent in the quarried overburden.

4.1 Potential Contaminant Sources

The operation of the quarry gives rise to the following potential contaminant sources:

- The generation of fine sediment-laden percolating water giving rise to turbid spring water in the absence of sufficient natural filtration/attenuation;
- Bulk fuel and lubricant storage for machinery, heating, generators, screening equipment and other operational uses within the quarry;
- Handling of fuels and lubricants including delivery and dispensing;
- Hydraulic fluid losses from excavating machinery. Crude statistics show that preventative maintenance is impractical and that hydraulic hoses catastrophically fail typically every 300 hours for each excavator. Oil losses of the order of 10 litres (2 gallons) for each failure have been reported;
- Routine and emergency machinery maintenance. Insitu maintenance is undertaken for operating machinery. Routine maintenance includes engine and transmission oil changes with associated spillage and takes place over uncontained areas;

- Truck fluid leakage. The cumulative effect pf substantive truck parking and movements in the quarry is recognised as generating significant petroleum oil leakage to ground. All modern road and motorway drainage is directed to oil interceptors;
- Truck and machinery wash banks. Washing of trucks and machinery is typically undertaken on site. This is considered a significant potential contaminant source;
- Foul and grey water discharges. Foul and grey water is generated in offices, toilets, showers, and canteens. Where there is an absence of filtering media, this discharge is considered a potential contaminant source.

Land use including agriculture within the spring catchment and particularly in the area upgradient and immediately adjoining the spring to the northeast is also seen as a potential source of contaminants. Although no associated water quality problems have been reported, a recommendation relating to land use is made later in this report.

4.2 Spring Diminution

The removal of the permeable overburden effectively eliminates groundwater storage. It also increases evaporation by exposing overland flow. These combined effects appear to have resulted in the disappearance of the stream that was spring fed at the quarry entrance. Furthermore it is reported that works have been necessary at the spring source in the past year in an effort to improve flow.

5 FINDINGS & CONCLUSIONS

In the interests of groundwater protection and specifically the protection of the water quality and yield of the spring from which the Meenane Water Supply is drawn, the extension and continued operation of the quarry, is not recommended. This conclusion is based on the following:

- The quarry is located centrally within the catchment area for the Meenane Water Scheme spring;
- Recharge to the spring is directly and predominantly from the quarry footprint;
- Recharge to the spring has been reduced due to the exposure of overland flow and the associated increased evaporation. Additional quarrying is expected to further reduce the volume of available recharge and is likely to result in a significant seasonal reduction in spring flow;
- The quarry lies within the designated Source Protection for the spring. It is located at distances of between 300m and ca. 1,100m directly upgradient from the spring;
- The upper limit of the catchment divide appears to be coincident with the upper limit of the quarry. This implies that there is no significant dilution of recharge generated over the quarry footprint by groundwater originating from further afield;
- The protective media (overburden) has been effectively removed from the floor of the quarry giving rise to a condition extreme vulnerability (**E**) in respect of groundwater;
- In consideration of the distance and pathway, the travel time of recharge between the quarry and the spring is estimated to be of the order of days and certainly not more than one or two weeks.
- The operation of the quarry creates a number of serious potential contaminant sources any one of which could pollute the spring to a condition to where it would be unusable for domestic purposes;

- The reinstatement of ca. two metres of permeable material over the quarry base would not change the extreme vulnerability classification. Over such a large area the non-natural emplacement of such material is expected to leave rapid percolation conduits and regardless 2m is grossly insufficient to provide attenuation of potential contaminants;
- The majority of recharge is not expected to be directed to the surface water treatment facility. Furthermore such a facility is rendered ineffective by severe storm events and even under normal conditions cannot deal with dissolved petroleum hydrocarbons. The apparent discharge of outflow from the facility to a soakaway located close to the quarry entrance appears inappropriate. However the design specification for the facility was not available to the author at the time of writing.

Regardless of these conclusions, the author wishes to point out that the instalment of a water treatment facility and the reinstatement of ca. 1.5 metres of soil over part of the quarry floor are seen as commendable improvements over the previous condition of the quarry. It is also fair to state that there did not appear to be any significant groundwater contaminant sources evident in the quarry on the day of inspection.

6 RECOMMENDATIONS/MITIGATION

The following recommendations pertain to the protection of the Meenane spring. These apply to the quarry and catchment in its current condition and not to any proposed extension or further development:

- The discharge from the treatment facility should be subject to polishing to remove potential contaminants such as dissolved oil and turbidity;
- The soakaway and percolation area for the treatment facility should at a location and level so as to maximise filtration and attenuation;
- The thickness of soil reinstatement should be not less than 3 metres and should extend so as to cover all previous rock exposure. A significant increase in the reinstatement thickness of 3 metres will be necessary in those areas of the site where water currently accumulates. The use of low-permeability soil is not recommended;
- Regular monitoring for drinking water quality parameters and measurement of flow rates at the Meenane spring are recommended.
- Notwithstanding that there have been no reported problems to date; land use in the area between the spring and the quarry entrance should be reviewed. The land owner should be engaged in discussions so as to eliminate or minimise any potential contaminant sources that may exist.
- The creation of new potential contaminant sources within the spring catchment must be avoided.

This concludes this report. □□

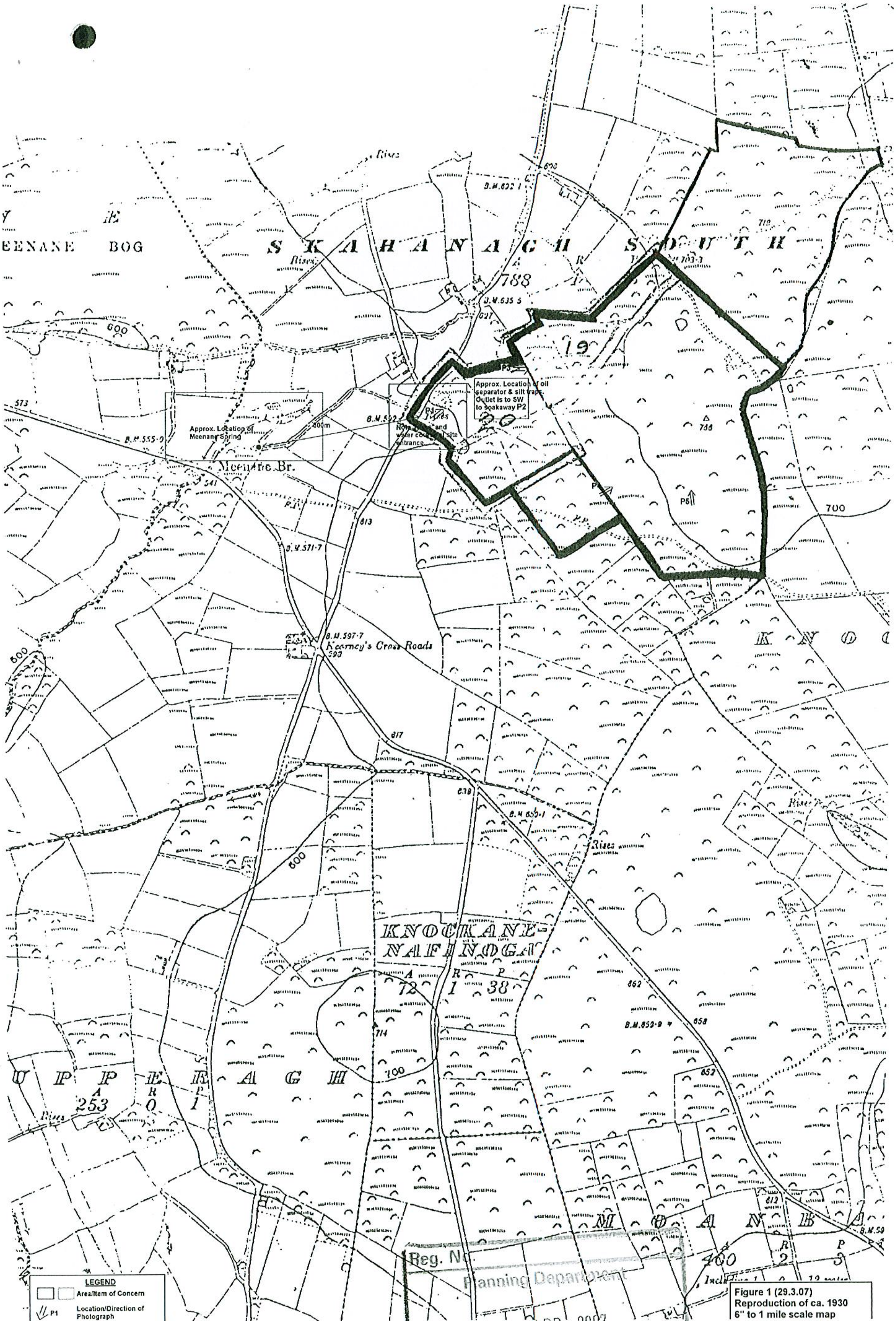
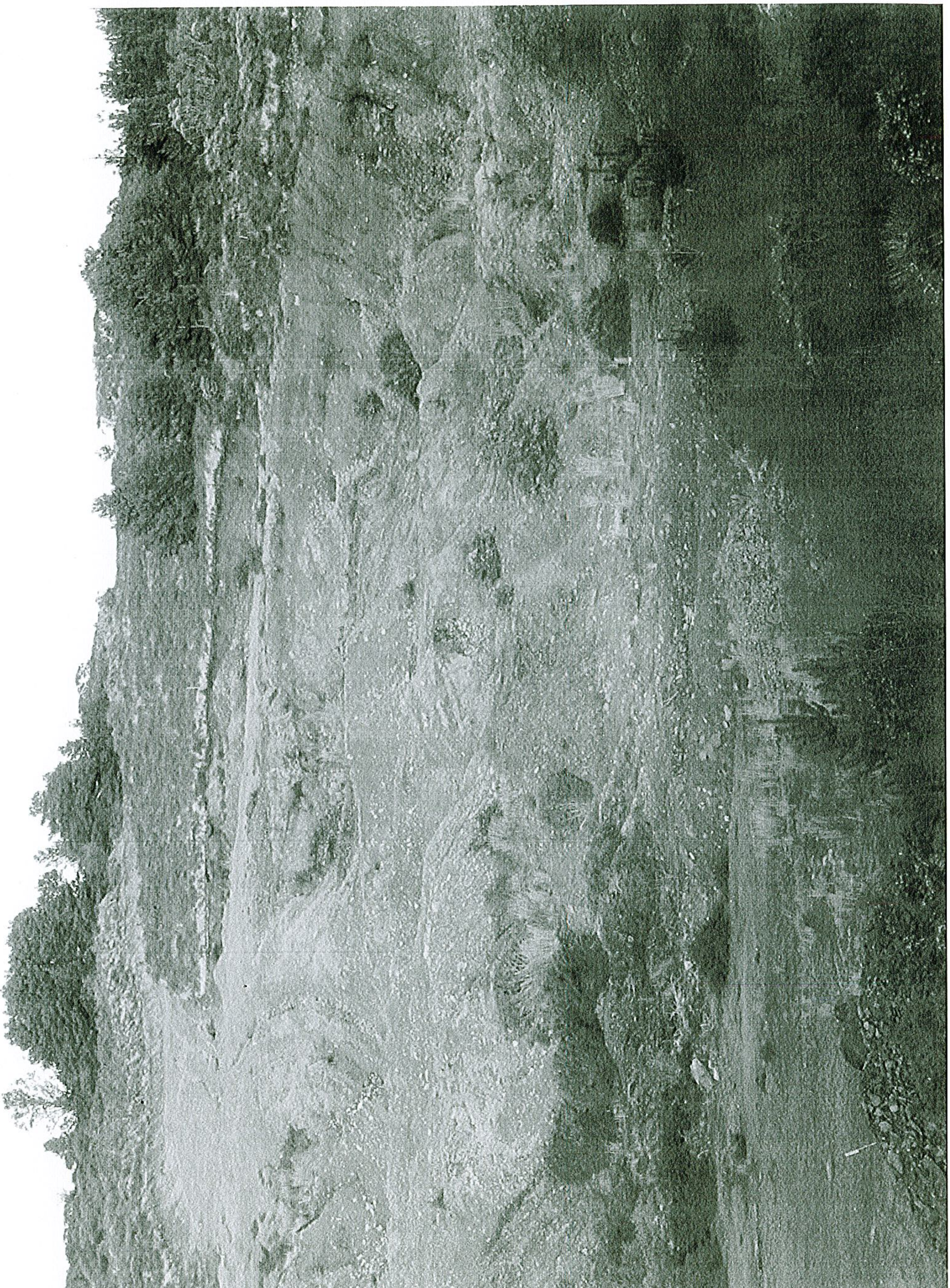
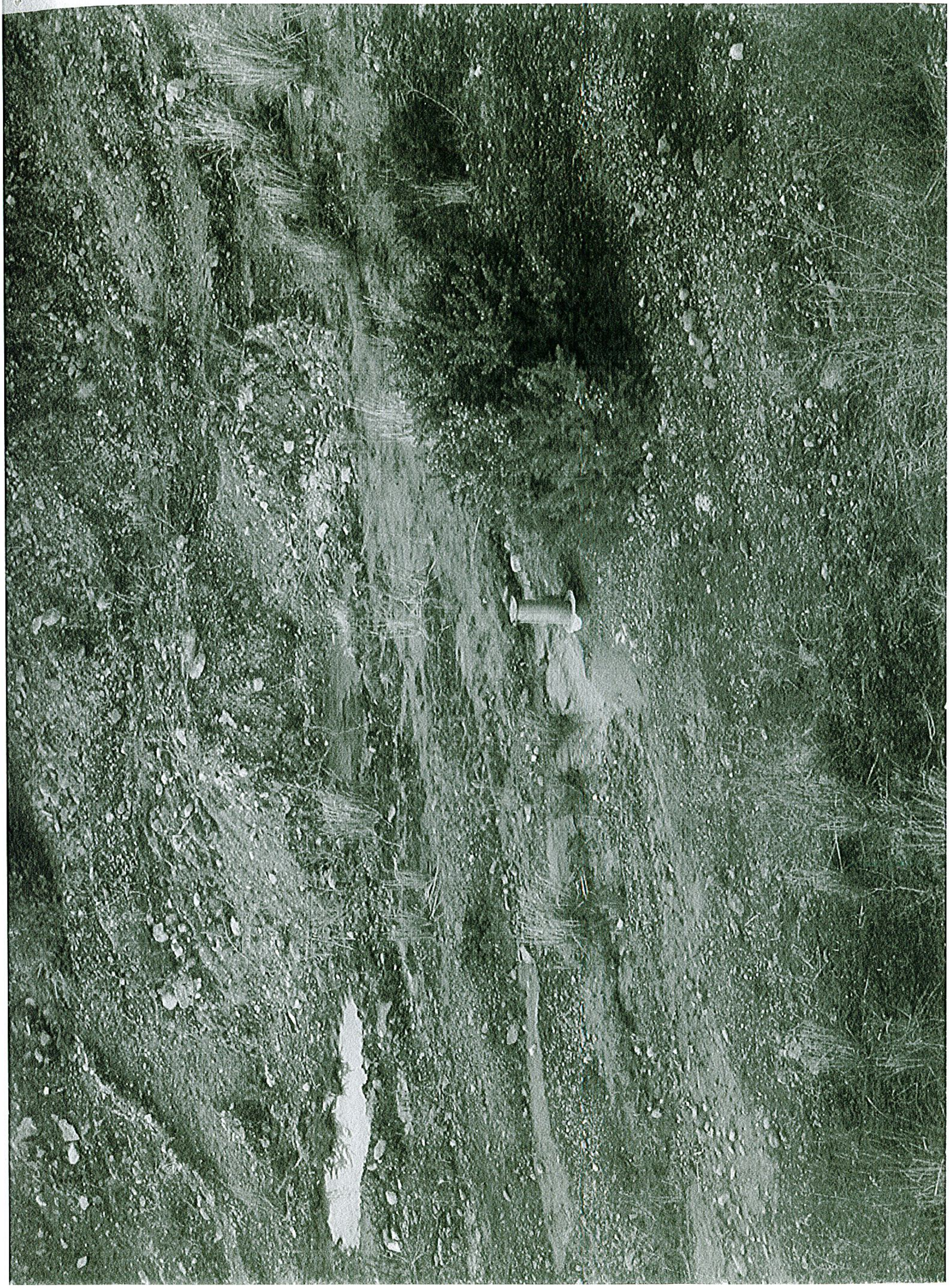


Figure 1 (29.3.07)
Reproduction of ca. 1930
6" to 1 mile scale map





APPENDIX 2

Geological Survey of Ireland (2004) 1st Draft Ballinhassig GWB Description.

Ballinhassig GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
19 Cork Co. Co.	**Rivers:** Awboy, Blarney, Butterstown, Dissour, Dripsey, Dungourney, Foherish, Glashaboy, Glasheen, Kiltha, Leamlara, Owenboy, Owennacurra, Owennagearagh, Bride, Laney, Lee, Martin, Shournagh, Sullane, Toon, Tramore, Womanagh, Aughnaboy, Butlerstown, Caha, Cummer, Cusloura, Douglas, Finnow, Garrane, Keel, Templebodan. **Lakes:** Blarney, Cleanrath, Gouganebarra, Kilbanna, Allua, Beg, Carrignafurark, Carrignamork, Gal, Nambrackderg, Ovens, Quarry, River Lee Reservoirs	Mullaghanish Bog (001890), Blarney Bog (001857), Glashgarriff River (001055), Blarney Lake (001798), Douglas River Estuary (001046), Lough Allua (001065), Owenboy River (001990), Gouganebarra Lake (001057) *To be re-checked*	1762

Topography		This GWB occupies the uplands of the Lee catchment and its tributaries in County Cork. The GWB is bounded to the north by the Glenville GWB, and to the south by the Bandon GWB. The Ballincollig and Midleton karstic GWBs intrude deep into this GWB. The topography is very rugged in the west, encompassing the Sheehy, Derrynasaggart and Boggeragh mountains. Ground elevations range from sea level to over 500 m OD.
Geology and Aquifers	**Aquifer categories**	**Ll:** Locally important aquifer which is moderately productive only in local zones (86%). **Pl:** Poor aquifer which is generally unproductive except for local zones (14%). *There are also some very small areas with an aquifer category of:* ***Rk^d*/Pending Classification:*** **Where these rocks occur in other areas they are classified as Rk^d. In this GWB they may be karstified but are unlikely to be regionally important due to their small size (<10km^2) – a new classification code to represent these areas is pending (<1%)*
	Main aquifer lithologies	Devonian Old Red Sandstones (92%); Dinantian Mudstones and Sandstones (Cork Group) (6%); Namurian Sandstones (1%); Dinantian Pure Unbedded Limestones (0.5%); Dinantian Lower Impure Limestones (0.1%).
	Key structures	The rocks have been folded into anticlines and synclines, with approximately East-West axes, by the Variscan Orogeny. The rocks are also broken by a strong system of steeply-dipping cross faults running approximately NNW-SSE, roughly at right angles to the fold axes. There are also other faults roughly parallel to the fold axes. The widespread faulting and folding has given rise to zones of enhanced permeability in the mudstones and sandstones. These can occur close to faults and fold axes, but such zones are generally local.
	Key properties	Permeability generally decreases rapidly with depth in all aquifers. In general, transmissivities will be in the range 2-20 m^2/d, with median values towards the lower end of the range. However, 'Excellent' yielding wells (>400 m^3/d) are known in some of the ORS units – these yields are usually associated with boreholes being situated on fault zones. Summer yields are sometimes unsustainable. Aquifer storativity will be low in all rock units. Groundwater gradients are likely to be in the range 0.01 to 0.04. Storativity is low, but may be enhanced by overlying sand and gravel deposits which are in continuity.
	Thickness	The Dinantian Mudstones and Sandstones (Cork Group) and Devonian Old Red Sandstone units form sequences which can be several kilometres thick (Sleeman & Pracht, 1994). However, in all aquifers within this GWB, most groundwater flow occurs within the top 15-20 m of the aquifer, in the layer that comprises a weathered zone of a few metres and a connected fractured zone below this. Deeper flows occur along generally isolated faults or significant fractures.
Overlying Strata	**Lithologies**	*Subsoil Types identified in Ballinhassig GWB by Teagasc Parent Material Mapping (Draft): Alluvium (A); Blanket Peat (BktPt); Cutover Peat (Cut); Sandstone sands and gravels (Devonian) (GDSs); Lake Sediments (Undifferentiated); Made Ground (Made); Rock outcrop and rock close to surface (Rck); Till – Devonian Sandstone Till (TDSs).* Till is the most widespread subsoil in Cork. Tills found close to bedrock and where the deposits are relatively thin, comprise a coarse matrix with angular clasts and can be described as broken up bedrock or immature till. Sands and gravels occur in isolated areas along the Sullane River in western areas of South Cork at Ballyvourney and Carrigaphooca as well as at Dunisky on the River Lee.

	Thickness	In general the subsoils are relatively shallow with about 50% of the total area estimated to have less than 3m of subsoil cover. The thinnest subsoils and areas of 'rock close to surface' occur in the smaller valleys where there are rock outcrops along the stream beds; along the east - west trending ridges, particularly in centre and east of the region; and in the mountains in West Cork (Derrynasaggart, Boggeragh). Depth to bedrock is also seen to be very shallow in a lot of coastal areas around the cliffs of South Cork. The thickest deposits are generally encountered in the major river valleys of the Lee, Bride and Bandon. The most frequent occurrences of outcrop and shallow rock are found in the west of the region near Macroom and the Derrynasaggart and Boggeragh Mountains. Subsoil depths of 10-15m are occasionally recorded in this region. In the south of the region there are also frequent occurrences of outcrop and shallow rock particularly in coastal areas and along river valleys. Outside areas of outcrop and shallow rock, subsoils are generally <10m deep, although depths of >10m are occasionally recorded. In general sand and gravel deposits are usually more than 10 m thick, in particular where they have been laid down with tills as morainic deposits. Thicknesses of lake, alluvial and estuarine deposits are usually unknown but it is unlikely that they are more than 10 m thick. Peat on higher ground is typically 3 m thick or less.
	% area aquifer near surface	High
	Vulnerability	A large proportion of the county is classed as having either extreme or high vulnerability while areas of moderate and low vulnerability are much less common. The 3 m contour, which influences the extreme and high vulnerability categories, is based on outcrop information, Quaternary mapping and borehole data. There may be more areas of moderate and low vulnerability than currently depicted.
Recharge	**Main recharge mechanisms**	Diffuse recharge will occur via rainfall percolating through the subsoil or areas of outcropping rock. The generally 'moderate' permeability subsoils will generally not restrict percolation of recharge. However, due to the generally low permeability of the aquifers within this GWB, and the high slopes, a high proportion of the recharge will discharge rapidly to surface watercourses via the upper layers of the aquifer, effectively reducing further the available groundwater resource in the aquifer.
	Est. recharge rates	*To be assessed.*
Discharge	**Large springs and high yielding wells (m^3/d)**	*Note: The following data need to be checked and updated by RBD Project Consultants.* Data from GSI Well Database: Additional data from EPA Groundwater Sources List: Excellent BH – Knockmonalea (436 m^3 /d), Courtbrack (873 m^3 /d), Gurteen (>400 m^3 /d) Good BHs (general)– No. of BHs > 300 m^3/d = 1 > 200 m^3/d = 12 > 100 m^3/d = 44 Water Schemes – Coachford WS (122 m^3 /d), Grenagh WS (147 m^3 /d), Macroom U.D. WS, infil Gallery (1700 m^3 /d), Rylane WS (150 m^3 /d). (*All WS listed above are BHs > 100m3/d unless stated otherwise)*
	Main discharge mechanisms	The main discharges are to the gaining rivers and streams crossing the sandstones, mudstones, shales and impure limestone rock units and to generally small springs and seeps. Groundwater will also discharge at the coast. Localised seepages may develop on the cliff faces. Cross-flow may occur from the aquifers in this GWB to the adjacent karstic GWBs.
	Hydrochemical Signature	This GWB is underlain by non-carbonate rock units, which include Old Red Sandstone rocks and the sandstones and mudstones of the Cork Group. Alkalinity ranges about 10-300 mg/l (as $CaCO_3$) and hardness ranges about 40-220 mg/l (moderately soft to moderately hard). The Old Red Sandstone formations largely contain calcium bicarbonate type water. Conductivities in these units are relatively low, ranging 125-600 µS/cm, with an average of about 300 µS/cm. Conductivities in the Cork Group rocks are quite similar with an average of 380 µS/cm and a range from 160 to 430 µS/cm. In general, high iron (Fe) and manganese (Mn) concentrations can occur in groundwater derived from ORS, due to the dissolution of Fe and Mn from the sandstone/shale where reducing conditions occur. Background chloride concentrations in all aquifers will be higher than in the Midlands, due to the proximity to the sea.
Groundwater Flow Paths		The Devonian ORS and Dinantian Mudstones & Sandstones of this GWB have no intergranular permeability; groundwater flow occurs in fractures and faults; in-filling of fractures is to be expected. The permeability of individual fractures and the degree of interconnection will be generally low, with fracturing confined to local zones. Permeability is highest in the upper few metres but generally decreases rapidly with depth. In general, groundwater flow is concentrated in the upper 15 m of the aquifer, although deeper inflows from along fault zones or connected fractures can be encountered. Significant yields can be obtained where boreholes are drilled into known fault zones. In these rocks groundwater flow paths are expected to be relatively short, typically from 30-300 m, with groundwater discharging to small springs, or to the streams that traverse the aquifer. Flow directions are expected to approximately follow the local surface water catchments. Groundwater is generally unconfined.

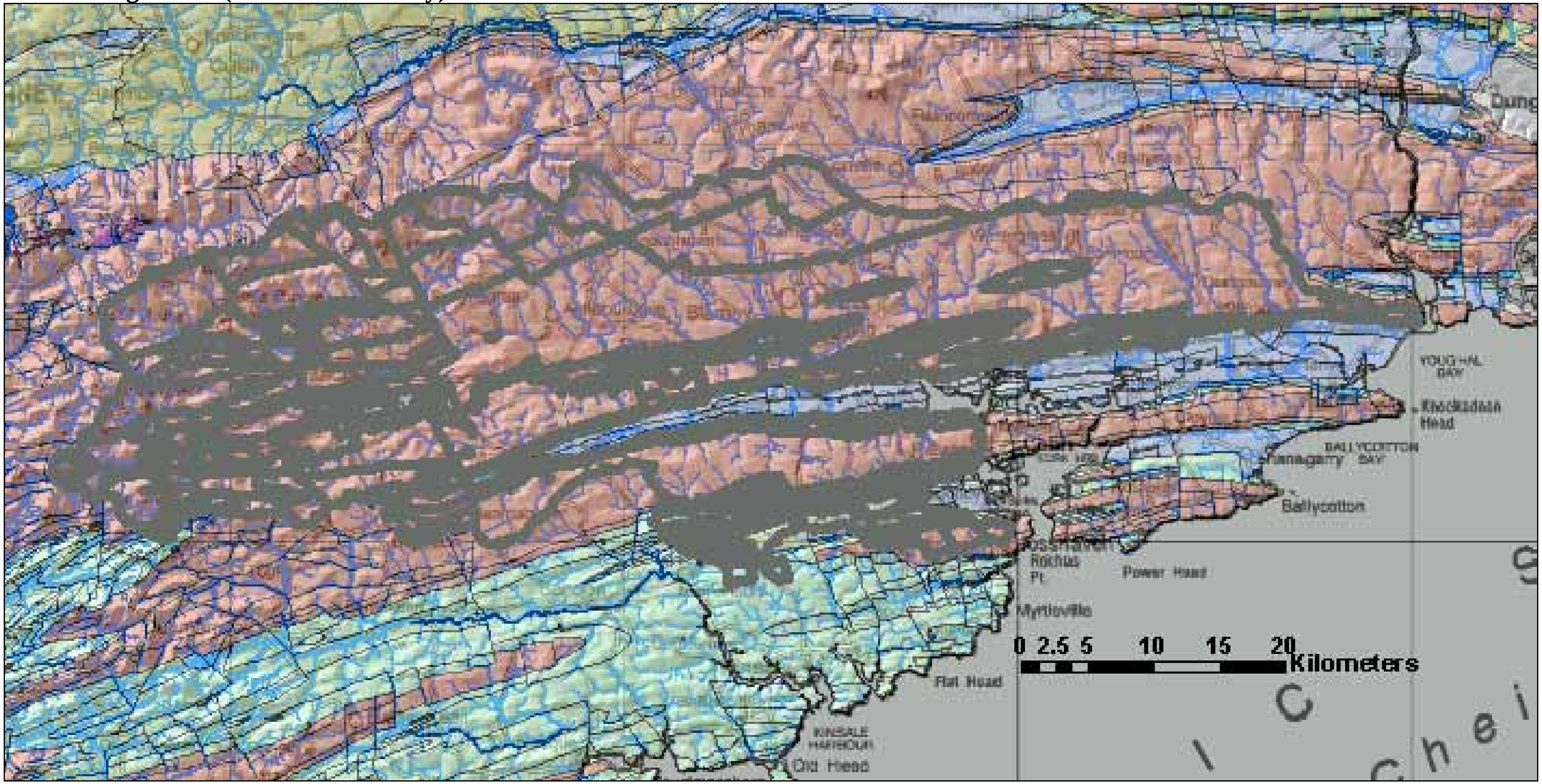
Groundwater & Surface water interactions	Groundwater in the Devonian ORS and Dinantian Mudstones & Sandstones (Cork Groups) will discharge locally to streams and rivers crossing the aquifer and also to small springs and seeps. Owing to the poor productivity of the aquifers in this body it is unlikely that any major groundwater - surface water interactions occur. Baseflow to rivers and streams is likely to be relatively low.

Conceptual model	• The groundwater body is bounded to the south by the Bandon GWB, and to the north by the Glenville GWB • The topography of this body is rugged, especially in the west, and elevations range from sea level to over 500 metres. • The groundwater body primarily comprises Devonian ORS and Dinantian Mudstones & Sandstones (Cork Group) which have low transmissivity and storativity, although localised zones of enhanced permeability occur along fault zones. Flow occurs along fractures, joints and faults. Flows in the aquifer are generally concentrated in a thin zone at the top of the rock, although deeper groundwater flows along faults and major fractures. • Diffuse recharge occurs across the GWB through the subsoils and rock outcrops. • The water table can vary from a few metres up to more than 10 m below ground surface, depending upon topography. Groundwater is generally unconfined. Flow path lengths are generally short, ranging from 30-300 m. Local groundwater flow directions are controlled by local topography. Groundwater discharges to the numerous streams and rivers crossing the aquifer and to small springs and seeps.
Attachments	
Instrumentation	**Stream gauges:** 19001*, 19004, 19006*, 19007, 19008, 19009, 19010, 19011, 19013, 19015*, 19017*, 19018, 19020, 19021, 19023, 19024, 19027, 19028, 19030, 19031*, 19032, 19033, 19034, 19036, 19037, 19038, 19039, 19040, 19041, 19042, 19043, 19044, 19045, 19046, 19047, 19048, 19060, 19066, 19090, 19091. * Dry water Flow available **EPA Water Level Monitoring boreholes:** Kilnamatra (COS 34) **EPA Representative Monitoring points:** Ballincurrig (COS 4), Dungourney WS (COS 25), Rylane WS-south BH (COS 48), White Cross WS (COS 52), Rylane WS-north BH (COS 162)
Information Sources	Kelly D, Leader U, Wright G (2002) *South Cork Groundwater Protection Scheme*. Main Report. Final Report to South Cork County Council. Geological Survey of Ireland. Sleeman AG, Pracht M (1994) *Geology of South Cork. A geological description of South Cork to accompany the Bedrock Geology 1:100,000 Map Series, Sheet 25*. Geological Survey of Ireland, 59pp
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae

List of Rock units in Ballinhassig GWB

Rock unit name and code	**Description**	**Rock unit group**	**Aquifer Classification**
White Strand Formation	Sandstone & interbedded pyritic mudstone	Namurian Sandstones	Ll
Lispatrick Formation (LP)	Pyritic cherty mudstone with dolomite	Dinantian Mudstones and Sandstones (Cork Group)	Ll
Courtmacsherry Formation (CY)	Calcareous mudstone with limestone	Dinantian Mudstones and Sandstones (Cork Group)	Ll
Ardaturrish Member (KNat)	Black mudstone & silt-lensed mudstone	Dinantian Mudstones and Sandstones (Cork Group)	Ll
Pigs Cove Member ((KNpc)	Sand-lensed mudstone	Dinantian Mudstones and Sandstones (Cork Group)	Ll
Narrow Cove Member (KNnc)	Flaser-bedded sandstone & mudstone	Dinantian Mudstones and Sandstones (Cork Group)	Ll
Cuskinny Member (Kncu)	Flaser-bedded sandstone & mudstone	Dinantian Mudstones and Sandstones (Cork Group)	Ll
Old Head Sandstone Formation (OH)	Flaser-bedded sandstone & minor mudstone	Dinantian Mudstones and Sandstones (Cork Group)	Ll
Old Red Sandstone (undifferentiated) ORS	Red conglomerate, sandstone & mudstone	Devonian Old Red Sandstones	Ll
Little Island Formation (LI)	Massive and crinoidal fine limestone	Dinantian Pure Unbedded Limestones	*Rk^d*/Pending Classification*
Waulsortian Limestones (WA)	Massive unbedded lime-mudstone	Dinantian Pure Unbedded Limestones	*Rk^d*/Pending Classification*
Ballysteen Formation (BA)	Fossiliferous dark-grey muddy limestone	Dinantian Lower Impure Limestones	Ll
Ringmoylan Formation (RM)	Calcareous shale & crinoidal limestone	Dinantian (early) Sandstones, Shales and Limestones	Pl
Gyleen Formation (GY)	Sandstone with mudstone & siltstone	Devonian Old Red Sandstones	Ll
Ballyknock Member (Gybn)	Green sandstone, siltstone & mudstone	Devonian Old Red Sandstones	Ll
Ballytrasna Formation (BS)	Purple mudstone and sandstone	Devonian Old Red Sandstones	Ll
Toe Head Formation (TH)	Cross-bedded sandstone & minor mudstone	Devonian Old Red Sandstones	Ll
Castlehaven Formation (CE)	Purple mudstone and siltstone	Devonian Old Red Sandstones	Pl
Gun Point Formation (GP)	Green-grey sandstone & purple siltstone	Devonian Old Red Sandstones	Ll
Caha Mountain Formation (CH)	Purple & green sandstone & siltstone	Devonian Old Red Sandstones	Pl
Gortanimill Formation (GM)	Sandstone and siltstone	Devonian Old Red Sandstones	Ll
Slaheny Sandstone Formation (SL)	Cross-bedded sandstone & siltstone	Devonian Old Red Sandstones	Ll
Bird Hill Formation	Purple siltstone & fine sandstone	Devonian Old Red Sandstones	Pl
Glenflesk Chloritic Sandstone Formation	Green sandstone & purple siltstone	Devonian Old Red Sandstones	Ll

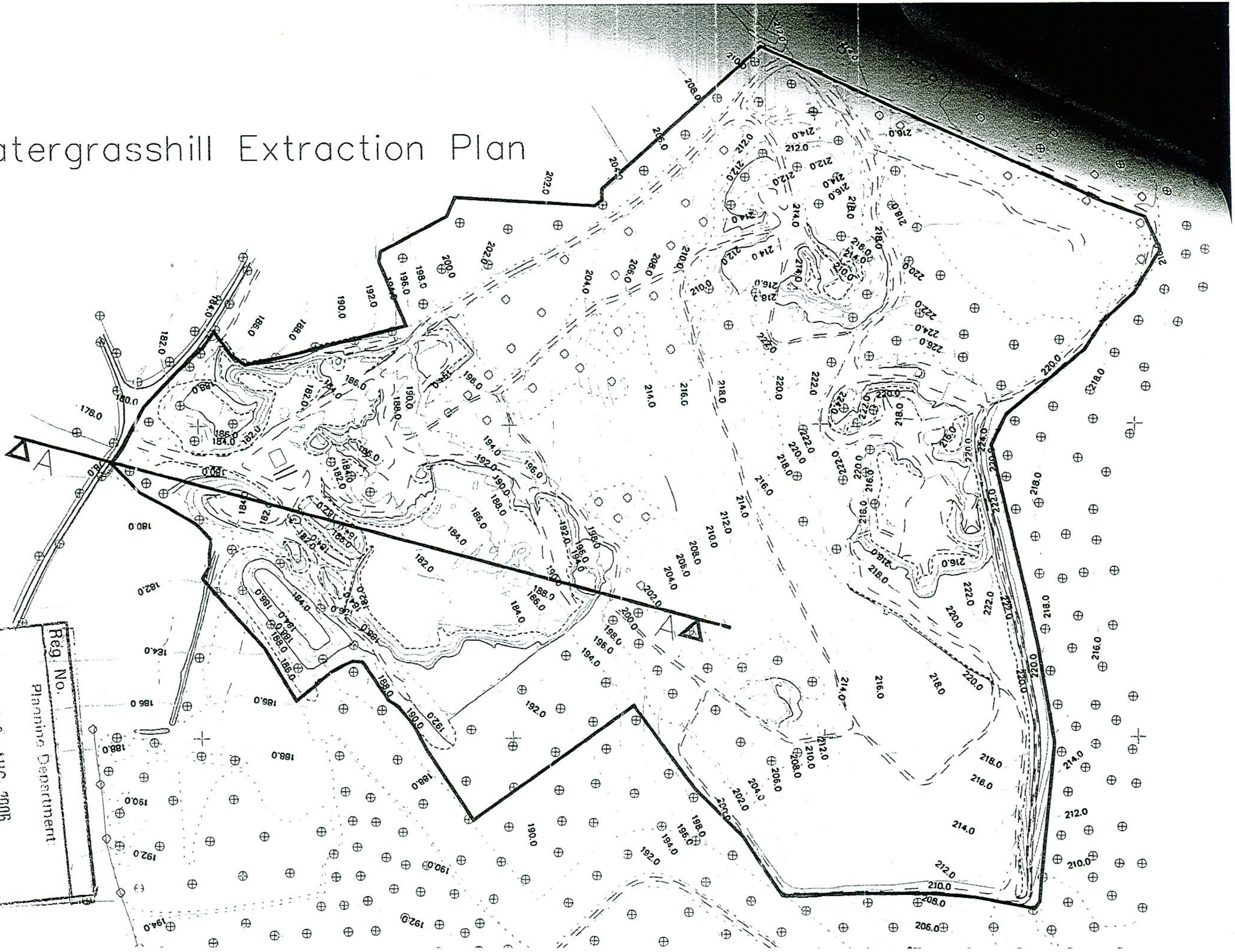
Ballinhassig GWB (For reference only)



APPENDIX 3

Contoured Map of Quarry

Watergrasshill Extraction Plan



APPENDIX 4

Recharge Calculations

Recharge Balance Calculations

Discharge (Q) = Recharge x Area

Table 1 Recharge and Water Balance Figures from Sections 6 and 10 of Main Report

Estimated Annual Rainfall	1230 mm/yr
Estimated Actual Evapotranspiration (A.E.)	400 mm
Estimated Annual Effective Rainfall (ER)	830 mm/yr
Bulk Recharge Co-efficient (RC)	80%
Assumed Recharge	64 mm/yr
Present Abstraction	100 m^3/d
Area of Delineated ZOC	0.527 km^2

Table 2: Areas for ZOC providing 200m^3/day using annual recharge figures

Q (m^3/yr)	ER (m/yr)	RC	Recharge (m/yr)	Area (km^2)	Comments
73000	0.83	0.8	0.664	0.11	
73000	0.83	0.6	0.498	0.15	
73000	0.83	-	0.2	0.37	Recharge cap applied

Table 3: Areas for ZOC for abstraction of 200m^3/d and overflow of 100m^3/d using annual recharge figures

Q (m^3/yr)	ER (m/yr)	RC	Recharge (m/yr)	Area (km^2)	Comments
109500	0.83	0.8	0.664	0.16	
109500	0.83	0.6	0.498	0.22	
109500	0.83	-	0.2	0.55	Recharge cap applied. Area is larger than that delineated. The source is under pressure

Table 4 Summer Rainfall and Evaporation Figures

Watergrasshill Rain	
Month	Rainfall (mm)
Apr	78
May	88
Jun	69
Jul	69
Aug	92
TOTAL	**396**
Total figure applied to whole year	950.4
Effective Rainfall	550.4
Summer Effective Rainfall	61.125

Cork Evaporation	
Month	Evaporation (mm)
Apr	59.1
May	79.7
Jun	88.9
Jul	87.3
Aug	69.9
TOTAL	**384.9**
Total over the year	513
Summer as % Total	75

Table 5: Areas for ZOC providing 200m^3/day using summer recharge figures

Q (m^3/summer)*	**ER (m/summer)***	**RC**	**Recharge (m/yr)**	**Area (km^2)**	**Comments**
30417	0.061	1	0.061	0.50	Area just less than ZOC area delineated. Source almost under pressure.
30417	0.061	0.8	0.0488	0.62	Area greater than ZOC area delineated. Source under pressure
30417	0.061	N/A	0.2	n/a	Recharge not relevant if not enough rainfall

* Summer equals the five months in Table 4

Table 6: Areas for ZOC for abstraction of 200m^3/d and overflow of 100m^3/d using summer recharge figures

Q (m^3/summer)*	**ER (m/summer)***	**RC**	**Recharge (m/yr)**	**Area (km^2)**	**Comments**
45625	0.061	1	0.061	0.75	Definitely no overflow in summer
45625	0.061	0.8	0.0488	0.93	Definitely no overflow in summer
45625	0.061	N/A	0.2	n/a	Recharge not relevant if not enough rainfall

* Summer equals the five months in Table 4