Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Crookstown Water Supply Scheme (Bellmount – BH2)

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GSI
Geological Survey of Ireland
Suirbhéireacht Gheolaíochta Éireann

CORK COUNTY COUNCIL 1899

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 (www.epa.ie ; www.gsi.ie).

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1 INTRODUCTION

Groundwater Source Protection Zones (SPZ) are delineated for the Crookstown 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 SPZ Delineation.

The borehole BH2 (Bellmount) is one of two groundwater source for Crookstown Public Water Supply (Group Water Scheme). BH-2 is situated approximately 1.4 km to the west of BH-1. There is a separate source report for Pound Cross (BH1). A third borehole was installed approximately 1 km to the north-northeast of BH-2 and 500 m to the northwest of BH1 but, for infrastructural reasons has not yet been incorporated into the scheme. BH-2 is the older well on the scheme and was for a time decommissioned because of contamination as a result of a molasses spill in the vicinity of the well. BH-1 was installed as an emergency back up supply for the scheme in 1980 but is currently in continuous use.

The objectives of the report are as follows:

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

The protection zones are delineated to help prioritise certain areas around the source in terms of pollution risk to the source. This prioritisation is intended to provide a guide in the planning and regulation of development and human activities. The implications of these protection zones are further outlined in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

The maps produced are based largely on field work undertaken as part of this study in 2009, previous investigations by GSI and OCM, readily available information in the area 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

BH2 is located approximately 500 metres south-west of Crookstown village, in Bellmount Lower area, beside the R585. The date of installation is unknown but it is known to be prior to BH1 which means earlier than 1980. The well is located in a field adjacent to the public road at an elevation approximately 2 meters below the road (Photo 1). The borehole is protected by a manhole cover although it is not capped beneath this (Photo 2). The pumping house is adjacent to the borehole and the water is treated by a chlorine dosing system. The borehole location is illustrated on Figure 1.

Photo1: Manhole and the Pump House

Photo2: Well Head

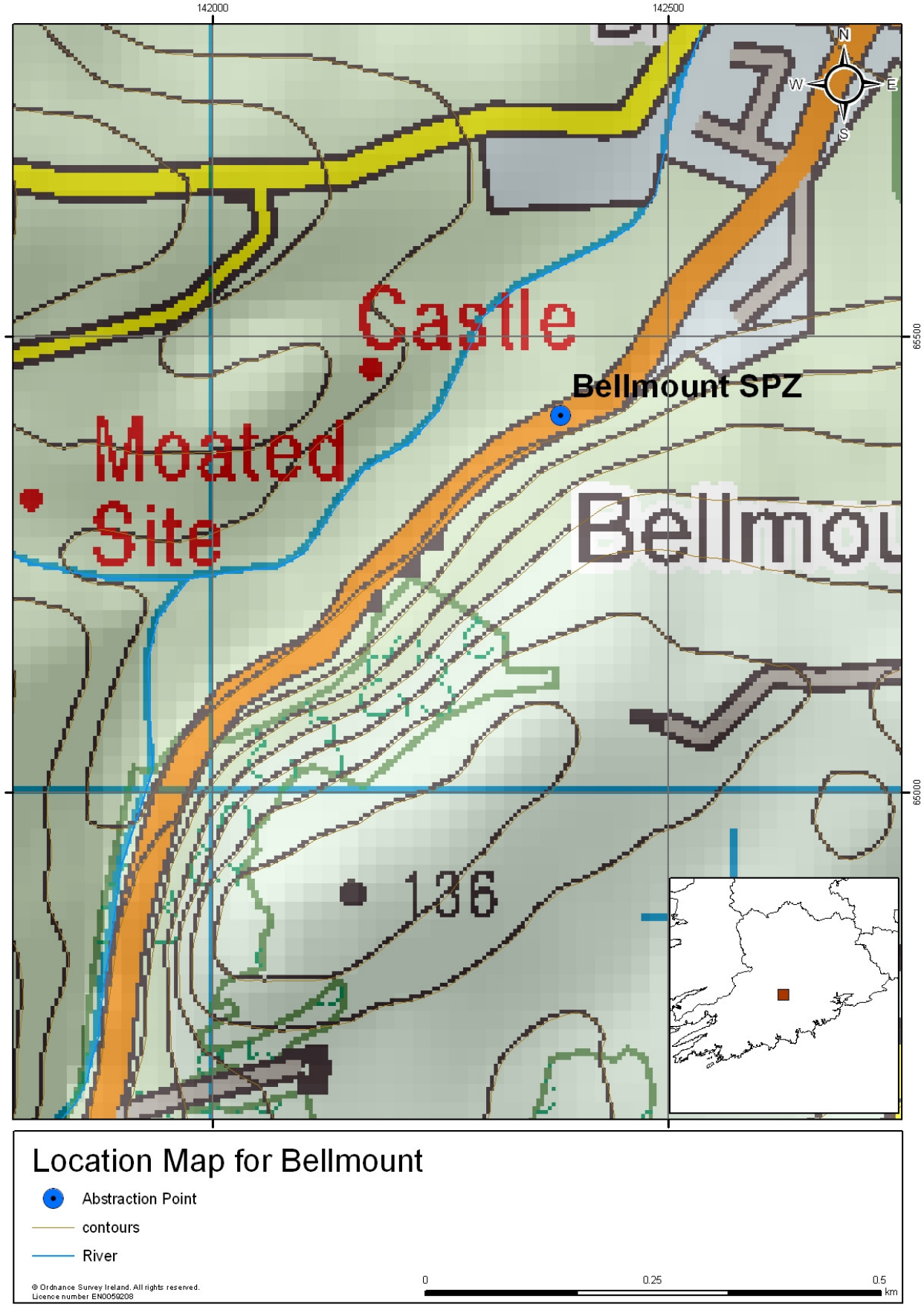


Figure 1: Location Map

3 SUMMARY OF WELL DETAILS

The abstraction is set for BH-2 at 75 m^3/d operating 20 hours per day. The water is pumped simultaneously from BH-1 at Pound Cross and BH-2 to a reservoir located on a hill 2 km to the northeast above the N22 (Photo 6), in Farnanes Townland. The borehole is approximately 14 m deep. There is no borehole log for the well but the well was dipped as part of this study to establish a total depth of 14 m

Photo6: Reservoir Tank

Table 3–1 provides a summary of the details as currently known.

Table 3–1 Well details

EU Reporting Code	IE_SW_G_004_04_012
Grid ref. (GPS)	142380 65413
Townland	Crookstown - Bellmount Lower
Source type	One Borehole
Drilled	Older than BH1, i.e. pre-1980
Owner	Cork Co. Co.
Elevation (Ground Level)	~68 m OD (from DTM)
Depth	14 m
Depth of casing	unknown
Diameter	380 mm
Depth to rock	unknown
Static water level	1.14 m bgl (10/09/2009)
Pumping water level	1.85 m bgl (10/09/2009)
Consumption (Council records)	75 m^3/day
Pumping test summary: (i) abstraction rate m^3/d	74 hours constant rate test in 2000 (Appendix 1) indicates sustainable yield of around 236m^3/d with 7 m drawdown
(ii) specific capacity $m^3/d/m$	106 $m^3/d/m$ for 75 m3/d and 34 $m^2/d/m$ for 236 m^3/d
(iii) transmissivity m^2/d	500 m^2/d based on data from GSI SPZ report for BH-1

4 METHODOLOGY

4.1 DESK STUDY:

Details about the borehole such as depth, date commissioned and abstraction figures were obtained from the County Council information, the GSI (2002) report "Groundwater source protection zones for Crookstown Water Supply" for the Borehole BH-1 located in Pound Cross; and from a report on a further borehole (BH-3) installed approximately 1 km north northeast of BH-2 (OCM, 2005). Bedrock geology information was compiled from the published Geological Survey of Ireland 1:100,000 Bedrock Series (Sheet 25, Sleeman & Pracht, 1994). Additional geological and hydrogeological information was provided by GSI (Pracht 1997) and Teagasc mapping programmes (Meehan, 2002) and from the GSI Vulnerability Mapping and Recharge Map compilation Project. More information on these projects can be obtained from Teagasc and from the Groundwater Section of the GSI.

4.2 SITE VISITS AND FIELDWORK

This part of the work included the following:

- meeting with Cork County Council staff in September 2009,
- Site walkovers in September 2009 to further investigate the abstraction well and the catchment subsoil, geology, hydrogeology and vulnerability to contamination including measurements of pH, temperature and electrical conductivity of the abstraction well and the adjacent river.

4.3 ASSESSMENT

Analysis of the desk study data and assessment of the field studies was used to delineate protection zones around the source.

5 TOPOGRAPHY, SURFACE HYDROLOGY AND LANDUSE

Crookstown lies in the valley of the River Bride, a tributary of the River Lee. The valley floor is generally flat, at an elevation of just under 60 m O.D. The lands to the south rise steeply to an elevation of 120 m OD.

Drainage density in the river valley is low with well draining pasture lands dominating the valley floor. The lands in the higher ground to the south are also well drained pasture lands. At the local scale, BH2 is located on the southern margins of the river valley just to the northwest of the high ground in Bellmount Lower. Run-off from the high ground to the south drains to the River Bride which flows to the northeast approximately 200 m to the northwest of the well.

The land in the vicinity of the borehole is agricultural land used primarily for grazing. (Photo 4).

Photo 4: Landuse in the Catchment

6 GEOLOGY

6.1 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 source protection zones that will follow in later sections. Geological information was taken from a desk-based survey of available data, which comprised the following:

- Geology of South of Cork. Bedrock Geology 1 : 100,000 Map series, sheet 25, Geological Survey of Ireland (M. Sleeman & Pracht, 1994).
- Forest Inventory and planning system – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map, Teagasc (Meehan, 2002).
- Report "the groundwater source protection zones for Crookstown Water Supply" (GSI, revised in May 2002).
- Report "Assessment of proposed additional groundwater supply boreholes and source protection area at Crookstown, Co. Cork", (OCM, 2005).

6.2 BEDROCK GEOLOGY

The bedrock geology is illustrated on Figure2. The Geological succession is summarised in the Table 6–1:

Table 6-1: Geological succession

Period	Formation	Code	Description
Dinantian	**Little Island Formation**	LI	Massive and crinoidal fine limestone
	Waulsortian Limestone	WA	Massive unbedded fine-grained limestone
	Ballysteen Formation	BA	Fossiliferous dark-grey muddy limestone
Upper Devonian	**Old Head Sandstone Formation**	OH	Flaser-bedded sandstone & minor mudstone
	Gyleen Formation	GY	Sandstone with mudstone and siltstone
	Ballytrasna Formation	BS	Purple mudstone with some sandstone

Crookstown lies at the western end of a major east-west syncline which continues eastwards down the Bride valley, through Cork City and on through Midleton, finally reaching the sea at Youghal Bay. The limestones occupy the middle of the syncline, while the northern and southern limbs are underlain by the Ballytrasna Formation. The rocks are also broken by a system of faults running approximately NNW-SSE, or roughly at right angles to the fold axes. The faulting has generally resulted in moving the rocks to the east of each fault a little way to the south (i.e. they are dextral wrench faults) (GSI 2002).

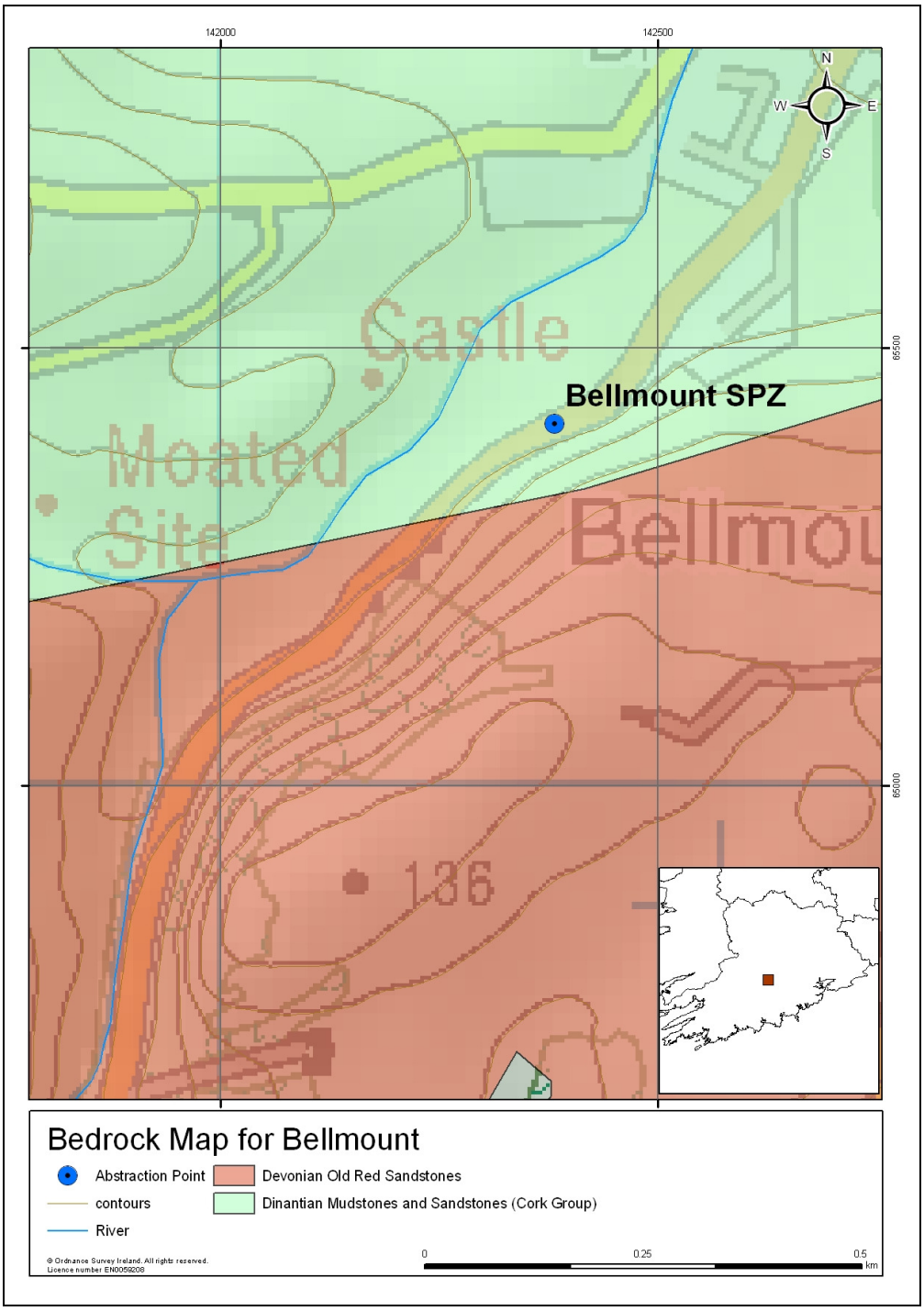


Figure 2: Bedrock/Rock Unit Map

6.3 SUBSOILS GEOLOGY

6.3.1 Till (boulder clay)

Thin till (usually 1–3 m) generally occurs on the slopes and ridges on either side of the valley. The till is largely composed of sandstone and mudstone particles of varying sizes. According to Teagasc's mapping of the soils (Teagasc, 1999) there are two types of till in this area. Limestone till, derived from the underlying limestone rocks, is found towards the Castlemore and Cloughduv areas. Sandstone till, derived from the Devonian sandstones of the hillsides, is found to the north of the River Bride and to the south of Crookstown itself. It is also found around Garranenamuddagh and Knockanroe to the south of BH-1 and around Bellmount Lower to the south and south-east of BH-2,

6.3.2 Gravel

Fluvioglacial gravel usually occurs along the valley floor. The Teagasc map shows the extent of this gravel deposit (which Teagasc has termed 'Alluvium') which mainly runs along the River Bride (GSI 2002). The borehole is drilled into this formation.

There are no borehole data to confirm the nature of the subsoil around BH2. However, based on field observations of the soils and subsoil in the vicinity of BH-2, the characteristics of the subsoils seem comparable to those at BH-1 at Pound Cross. GSI investigations undertaken as part of the 2002 Source Protection Project for BH-1 have therefore been used to gauge the likely subsoil characteristics at this site.

Borehole and auger data from the area around BH1 show that the subsoils comprise a mixture of sediment including SAND, Clay and GRAVEL which are present in layers of up to 3 m thick. The productive gravel zone at that site is located at depth, between 18 and 27 m bgl, where the gravels become less clayey. The shallow depth of the BH2 borehole suggests that the well is likely to be installed into the southern margins of the gravels in the Bride river valley.

The Subsoil map is shown in Figure 3.

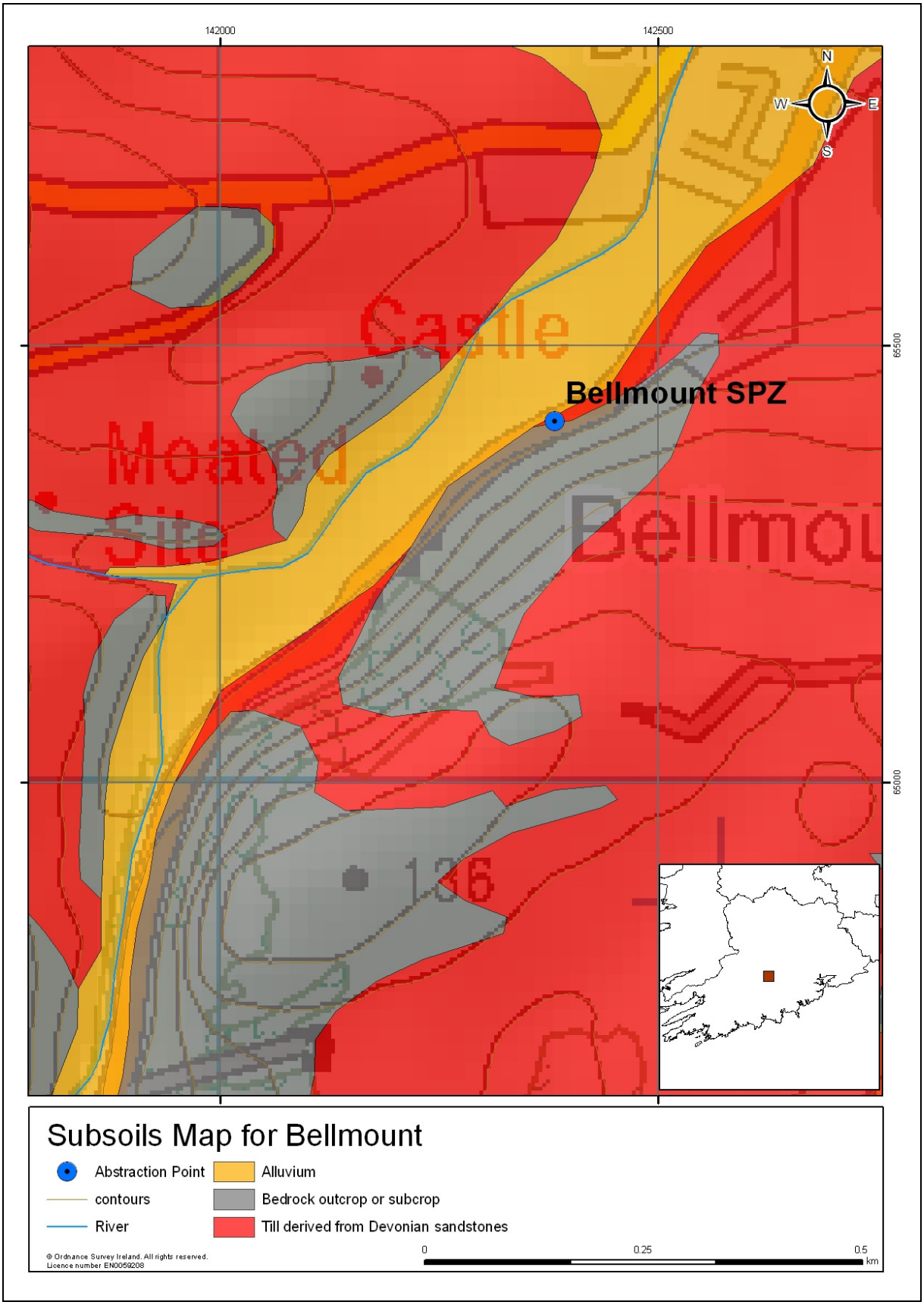


Figure 3 Subsoil Map

6.4 DEPTH TO BEDROCK

The depth of the bedrock increases from the southern margins of the river valley at BH-2 where it is likely to be no more than 14 m, to at least 24 m close to the River Bride (north of BH-1) where a depth of 24 m without encountering bedrock was proven during exploratory drilling in 2003 (OCM 2004) (Table 6–2 and Appendix 2). The well locations are summarized in Figure 4.

Table 6-2: Bedrock Depth (data from OCM 2004)

Source Name (from OCM Study)	BH 1 (OCM Investigations)	BH 1a (OCM Investigations)	BH 2 (OCM Investigations)	BH 3 (OCM Investigations)	BH 4 (OCM Investigations)
GSI No.	N/A	N/A	N/A	N/A	N/A
Grid Reference	143086 066046	143086 066046	143439 066485	143222 066452	143192 066232
Elevation	~60 m OD	~60 m OD	~60 m OD	~60 m OD	~60 m OD
Date Drilled	18/9/03	27/11/03	14/06/04	14/06/04	19/08/04
Depth to Rock	>19 m	>24 m	11.5 m	15.5 m	>18 m
Depth of Hole	19 m	24 m	42 m	15.5 m	18 m

7 GROUNDWATER VULNERABILITY

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. This means that vulnerability relates to the thickness of the unsaturated zone in the sand/gravel aquifer, and the permeability and thickness of the subsoil in areas where the sand/gravel aquifer is absent. 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, 2003).

In terms of subsoil coverage, the area can be divided into two zones:

- The elevated ground to the south (estimated to be approximately 75 % of the ZOC), where the subsoil is very thin or absent and outcrop dominates. Here the vulnerability is classed as Extreme with Rock near the surface.

- In the valley of Bride River (estimated to be 25 % of the ZOC). Based on field observation and review of the additional data gathered during the 2003/4 OCM site investigations as described in section 6.3.2., the subsoil permeability is considered to be Moderate (with Low Confidence) as proposed on the GSI vulnerability map. However, the groundwater table is very shallow with a depth of approximately between 1–2 m below the ground observed during site walkovers. Therefore the vulnerability classification may need to be adjusted from High as indicated in the GSI vulnerability map to Extreme.

The Vulnerability map is shown in Figure 5.

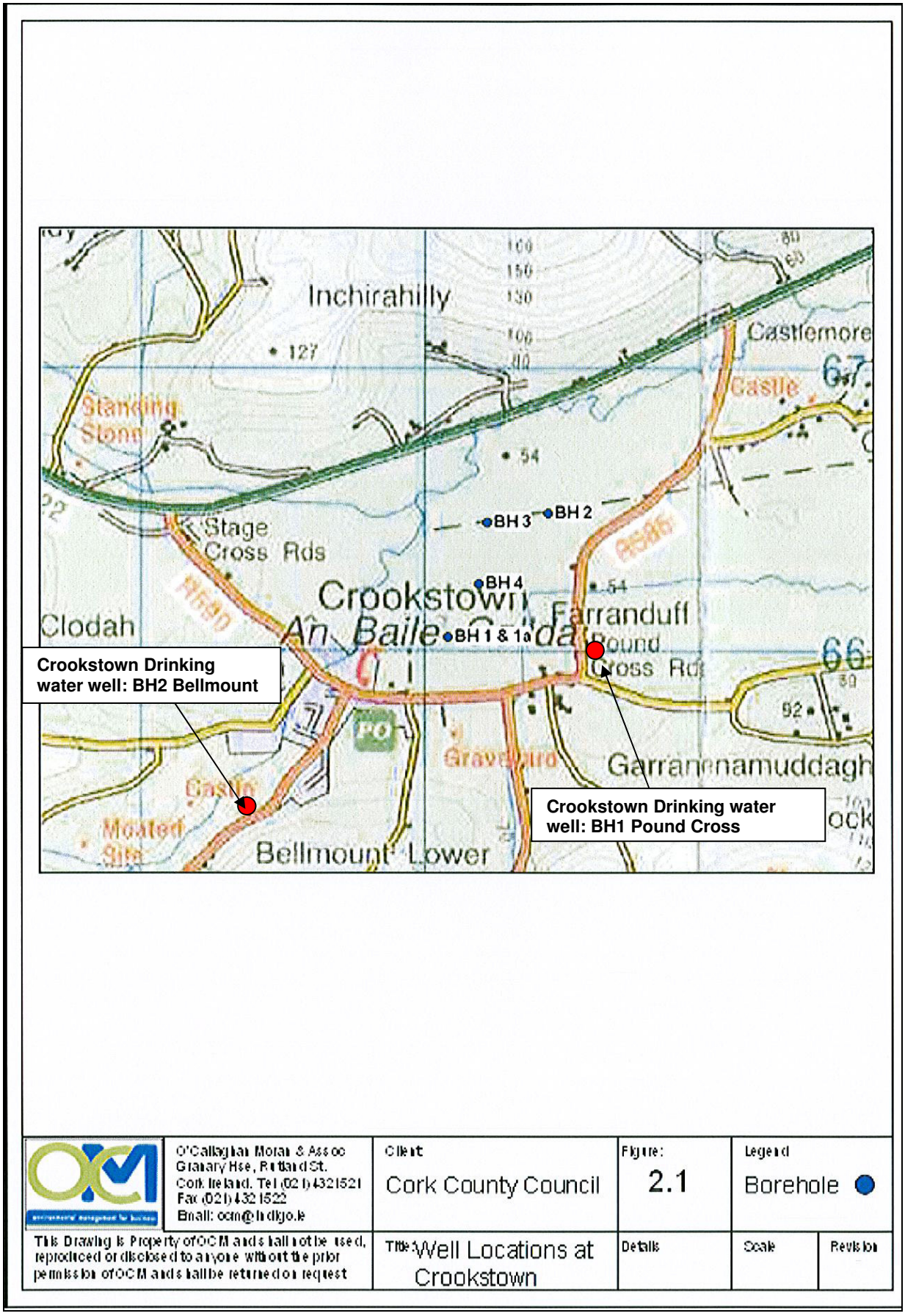


Figure 4: Well locations at Crookstown

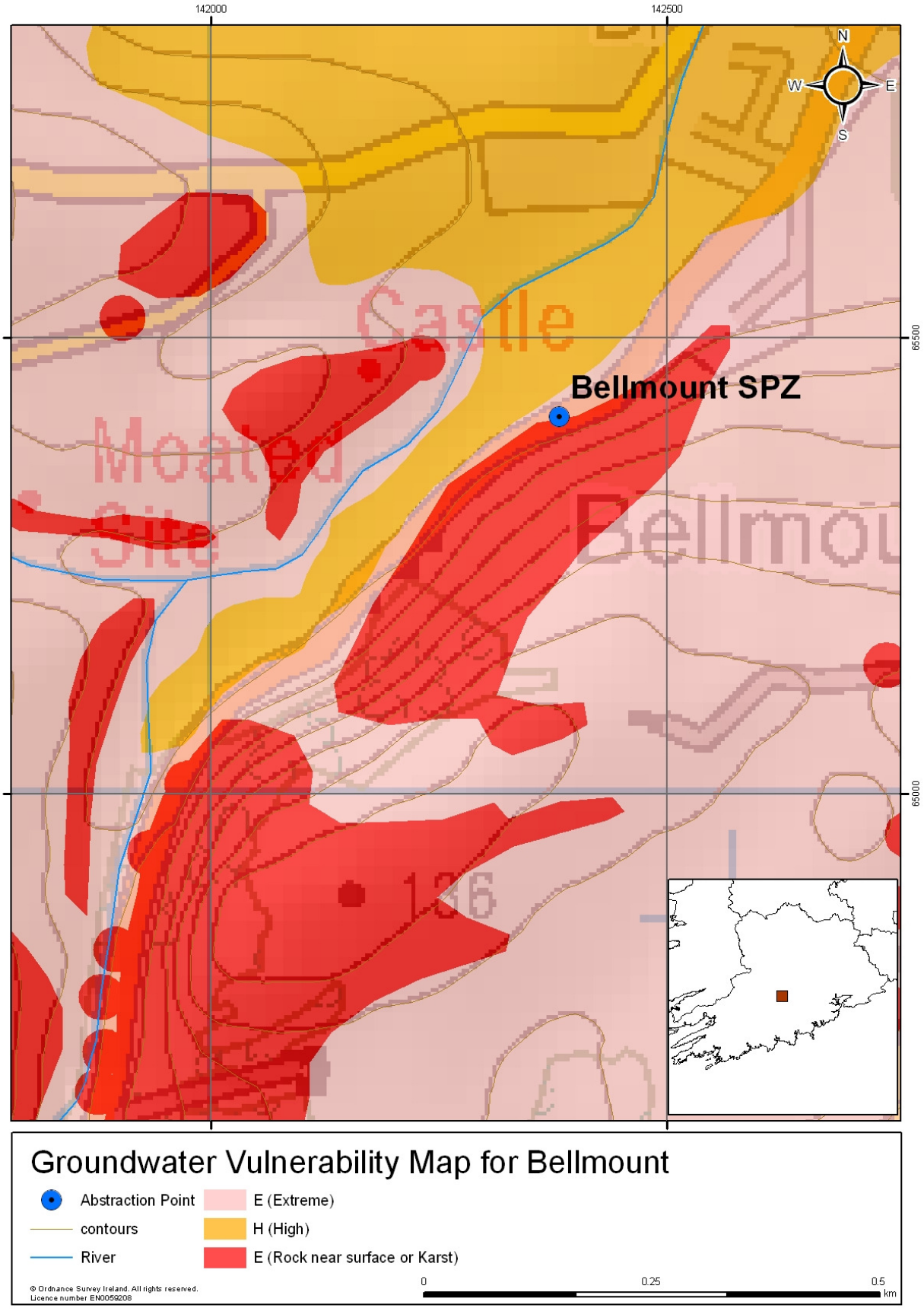


Figure 5 Vulnerability Map

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 Database
- County Council Staff
- EPA website and Groundwater Monitoring database
- Local Authority Drinking Water returns
- Groundwater source protection zones for Crookstown Water 2002
- OCM Groundwater Resource Assessment Crookstown 2003/2004

8.1 GROUNDWATER BODY AND STATUS

The Crookstown water supply well is located in the Groundwater Body (GWB) Ballinhassig_1 (IE_SW_G_004). It occupies the uplands of the Lee catchment and its tributaries in County Cork. Information on groundwater bodies can be obtained from:

Www.gsi.ie/Programmes/Groundwater/Projects/Water+Framework+Directive.htm

The groundwater body is characterised by the EPA as being of good status. More information on groundwater body status can be obtained from

www.epa.ie/whatwedo/monitoring/water/groundwater/programme/

8.2 METEOROLOGY

Establishing groundwater source protection zones requires an understanding of general meteorological patterns across the area of interest. Meteorological information was obtained for this study from the GSI (2002) report "Groundwater source protection zones for Crookstown Water Supply" for the Borehole BH-1 located in Pound Cross, situated approximately 1.4 km to the east of BH-2.

Annual rainfall: 1330 mm. Long term annual average rainfall (P) is estimated at 1330 mm
Annual evapotranspiration losses: 486 mm. Long term annual average actual evapotranspiration (AE) is taken to be 486 mm. (EPA, estimated from rainfall minus runoff at Ovens, hydrometric gauging station 19016).
Annual Effective Rainfall: *844* mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this, or 844 mm/year.

8.3 GROUNDWATER LEVELS, FLOW DIRECTIONS AND GRADIENTS

Water levels at BH-2 when it is not being pumped indicate that the water table is close to the surface, less than 2 meters. The groundwater is likely to be flowing north/ northwest, toward the Bride River. The water table is expected to mirror the topographic gradient. The topographic gradient from the peak of the high ground to the south of the borehole is estimated to be approximately 0.1. However, where the borehole is located, in the flood plain the land is very flat. The gradient is estimated to be much less – in the order of 0.001. An average gradient of 0.01 is therefore assumed which is also likely to represent the typical gradients under pumping conditions.

8.4 HYDROCHEMISTRY AND WATER QUALITY

BH-2 has been included in the EPA operational chemical network since 1995. Hydrochemical data have been obtained from this data set. The data are summarized graphically in Figure 6 to 8 below. The following key points have been identified from these data:

- Analysis of hardness indicates a moderately soft calcium bicarbonate hydrochemical signature (average 100 mg/l CaCo3). The average of the conductivity is 238 µS/cm and pH is around 7. These levels suggest that the gravel aquifer is predominantly composed of non-limestone material (GSI 2002) .

- There are only one reported incidents of Faecal Coliforms in the analysis (3 No/100ml the 05/08/08). Ammonium has not been detected above the threshold level (0.175 mg/l). It is inferred from the available data that the presence Faecal Coliforms only are isolated and do not indicate ongoing contamination or specifically highlight any on-going problems. The values are summarized graphically in Figure 6.

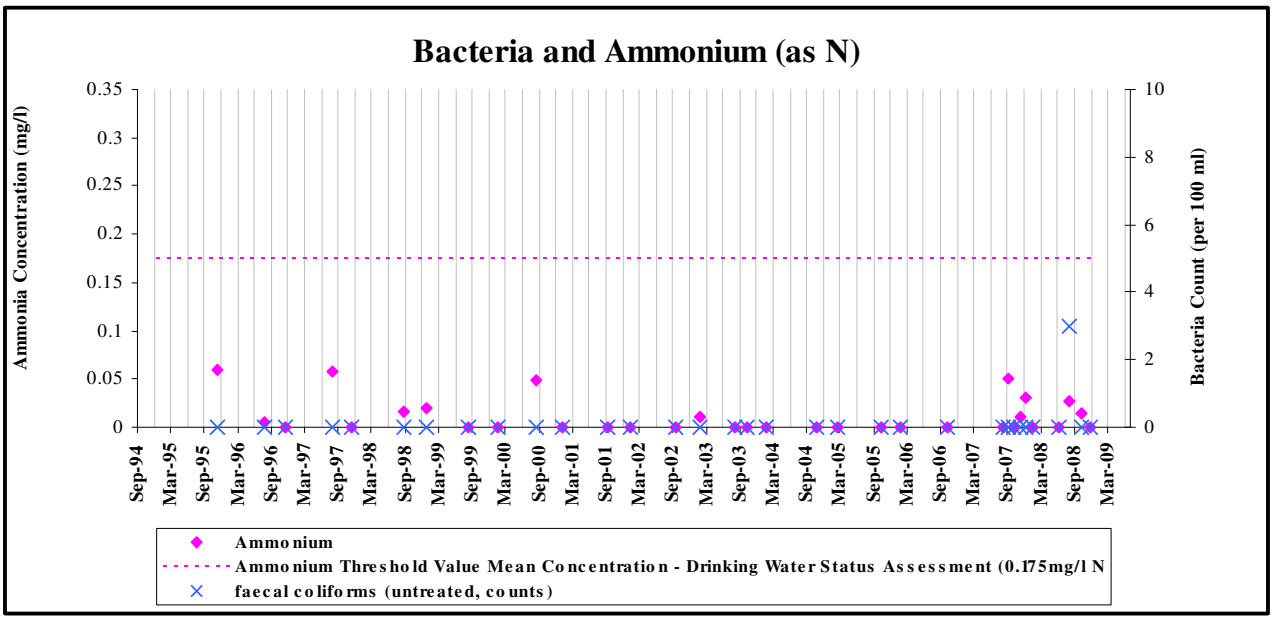


Figure 6: Key Indicators of Agricultural and Domestic Contamination : Bacteria and Ammonium Graph

- The concentration of nitrate ranges from <28.7 mg/l to 11.6 mg/l with a mean of 22.2 mg/l (as NO_3). Though there are no reported exceedances above the EU Drinking Water Directive maximum admissible concentration of nitrate 50 mg/l and the Interim EPA threshold value of 37.5 mg/l. The area around the borehole is relatively sparsely populated. No dwellings were identified in the ZOC. Agricultural activity with the ZOC is low intensity with moat of the lands in use as grassland for grazing animals.

- Chloride is a constituent of organic wastes and levels higher than threshold value 24 mg/l may indicate contamination, with levels higher than the MAC value 250 mg/l usually indicating significant contamination. Chloride concentrations range from 13.6 mg/l to 26 mg/l, with a mean of 19 mg/l. Levels of chloride above the threshold value were recorded on 2 no. out of 33 no. occasions but theses occasions has occurred only at the start of the monitoring (1995 and 1996) and since this period, the chloride value has declined slightly but steadily. The values are summarized graphically in Figure 7.

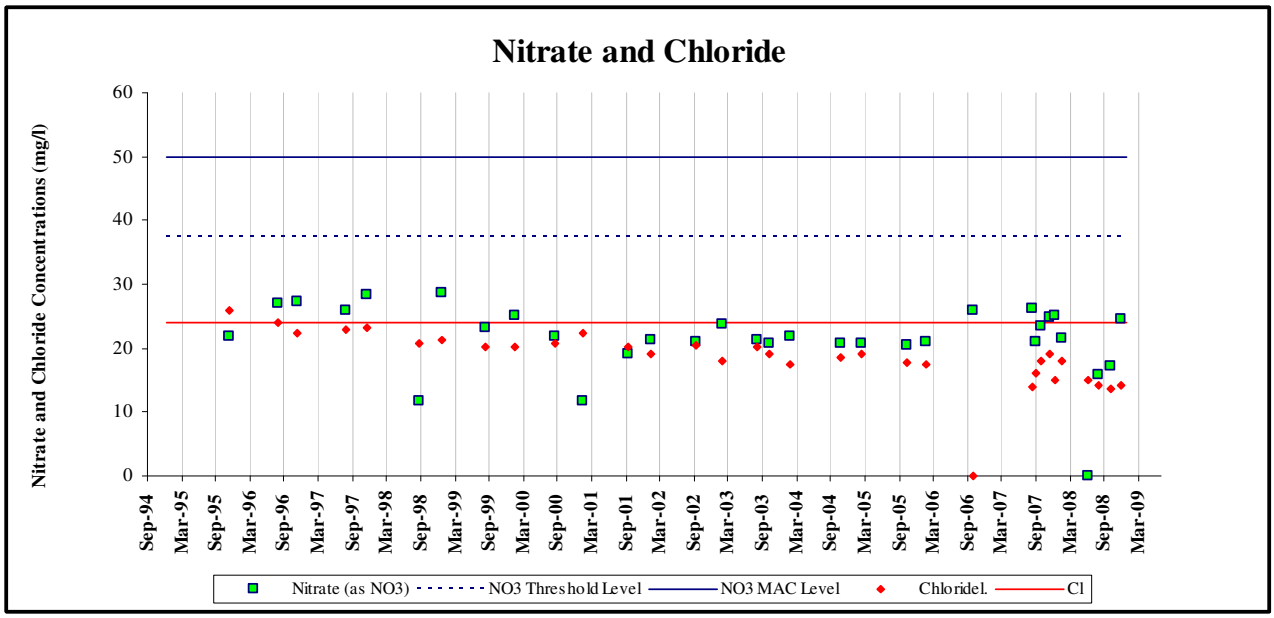


Figure 7: Key Indicators of Agricultural and Domestic Contamination : Nitrate and Chloride Graph

- Turbidity exceeded the MAC twice, on the 10/06/08 (4.1 NTU) and 05/08/08 (3.7 NTU). Values have otherwise been <0.1 NTU.

- The concentration of sulphate, potassium, sodium, magnesium and calcium are within normal ranges. The potassium sodium ratio has slightly exceeded the threshold of 0.35 twice, on the 28/02/02 (0.38) and 21/02/05 (0.36). It is inferred from the available data that the presence of Coliforms and slightly elevated K/Na ratios are isolated incidents and do not indicate ongoing contamination or specifically highlight on-going problems. The values are summarized graphically in Figure 8.

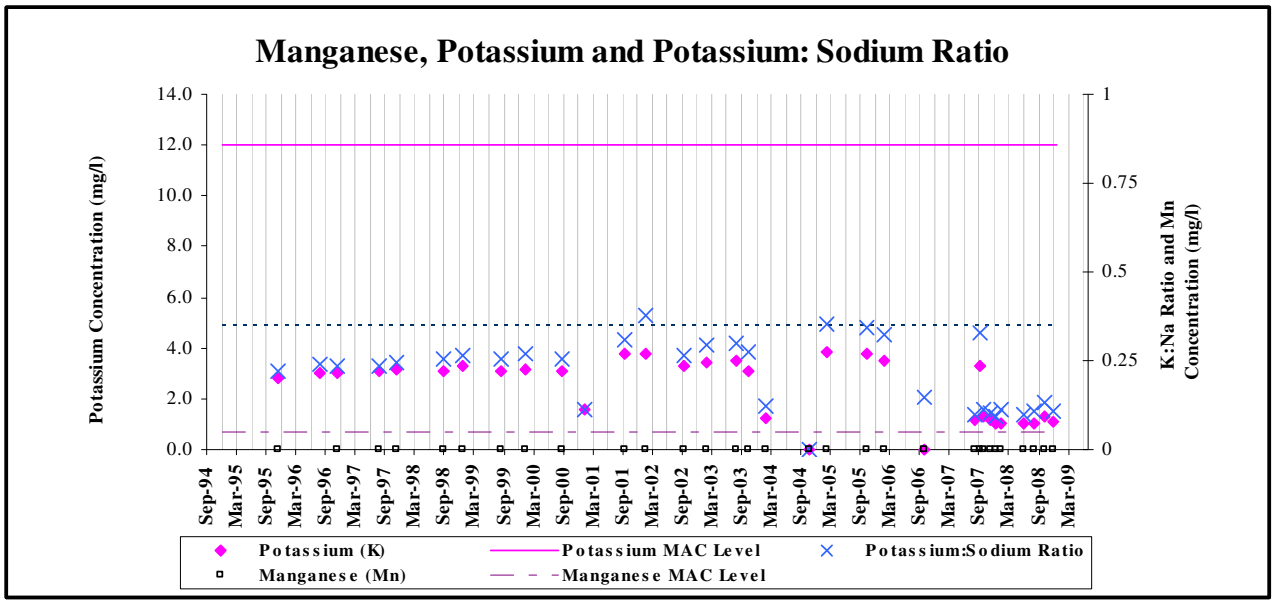


Figure 8: Key Indicators of Agricultural and Domestic Contamination : Manganese, Potassium and Potassium: Sodium Ratio Graph

- Nitrite and Ammonium levels are under their respective threshold limits.
- The concentration of iron and manganese is also within normal ranges, which also suggests an absence of any influence of effluent from organic wastes.
- Normal levels of trace metals were identified or levels are below the detection limit of the laboratory, and the water is safe for drinking. The concentration of all organic compounds and herbicides is below the detection limit of the laboratory.

In summary, nitrate levels are within the expected ranges for drinking water quality

The similar electrical conductivity and pH values in the River Bride and BH2, suggest that the Gravels are hydraulically connected to the River Bride. The results are outlined in the Table 8-1.

Table 8-1: Groundwater and surface water Field Chemistry

	BH2	Bride River
Date	1995-2008	22/09/2009
Location	Bellmount	Bridge on R590
Conductivty (µS/cm)	Ave: 238 Max: 274 Min: 174	198
pH	Ave: 7 Max: 8.6 Min: 6.1	8.15

8.5 AQUIFER CHARACTERISTICS

The borehole abstracts water from a sand/gravel deposit which overlies a Locally Important (Ll) Sandstone bedrock aquifer. The sand and gravel formation may potentially be classified as an aquifer (because the deposit is more than 10 m thick and is greater than 1 km^2 in extent) which are the criteria set by GSI to define a Locally Important Aquifer (Figure 7).

While the borehole logs for pound Cross and the OCM study indicate the presence of locally less permeable zones in the subsoil and the gravels appear to be represent at Pound Cross at depth the aquifer is considered to be unconfined with a the water table is around 2 m below the ground surface.

The County Council completed a 74 hours constant rate test in BH2 (Bellmount) in 2000 (data in appendix 1). The test indicates that the well had a sustainable yield of around 236m^3/d with 7 m drawdown, which gave a specific capacity of 34 m^3/d/m.

The hydrogeological characteristics of the aquifer appear to be highly variable (Table 8–2). During the 2004 OCM investigations (approximately 1 km to the north of BH2), one of the test holes showed a very poor yield (test hole 3), one had a good yield (test hole 1) and another had an excellent yield (test hole 4.). Analysis of the pumping test data for BH 1 indicates a specific capacity in the region of 100 m^3/d/m whereas data from the pumping test on BH 4 indicates a figure an order of magnitude greater.

Table 8-2: Results of pumping tests in wells in the vicinity

Source Name	BH1 (Pound Cross)	BH2 (Bellmount)
Grid Reference	142380 65413	143192 66232
Yield (m^3/d)	145	75
Drawdown (m)		0.71
Specific Capacity ($m^3/d/m$)		106 $m^3/d/m$ for 75 m3/d and 34 $m^2/d/m$ for 236 m^3/d
Comment	No pumping test data	Provided 170 m^3/d before reduced the pump size in 2008

Source Name	BH 1 (OCM Investigations)	BH 1a (OCM Investigations	BH 2 (OCM Investigations	BH 3 (OCM Investigations)	BH 4 (OCM Investigations)
Grid Reference	143086 066046	143086 066046	143439 066485	143222 066452	143192 066232
Yield (m^3/d)	403	Not tested	Test not applicable	Failed pumping test	547
Drawdown (m)	4.19				0.56
Specific Capacity ($m^3/d/m$)	96.25				976.78
Comment	High NH4	Intended Standby for BH 1	Collapsed after drilling	unproductive and persistent presence of fine silt in the gravels	Successful Supply

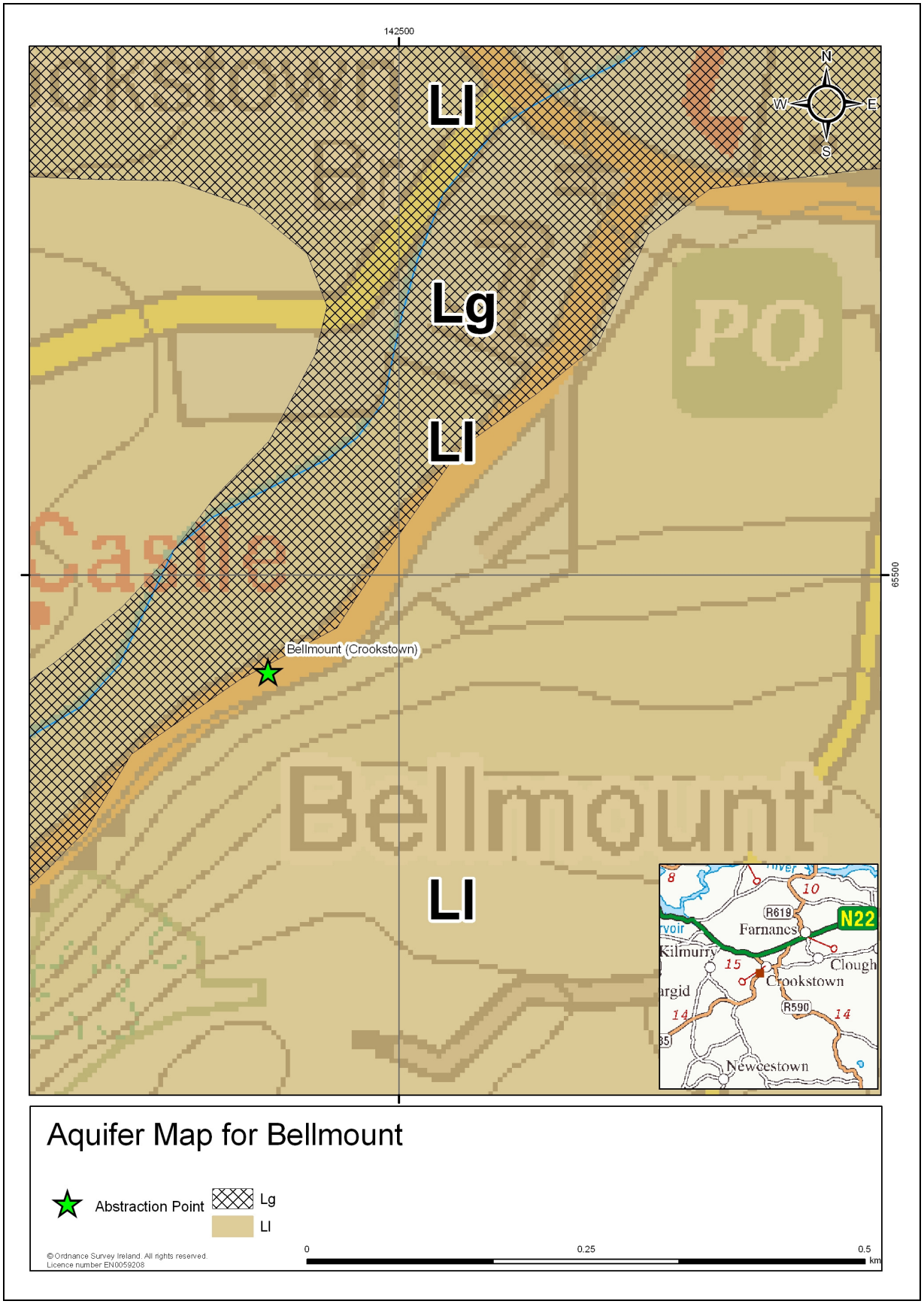


Figure 9: Aquifer Map

It is likely that the permeability and hence the flow of groundwater through the aquifer is defined by the proportion of fine grained sediment present. In an alluvial environment it is common for the river to meander and, as this happens, the nature of the sediment in any one location changes according to its position relative to the river at that time. Zones of low flow will be dominated by the deposition of finer grained materials such as silt or fine sands while zones of faster flow will be dominated by coarser grained deposits of gravels or cobbles. This gives rise to a mixture of coarse grained and fine grained units within the aquifer, and consequently variations in permeabilities and transmissivities.

Transmissivity was estimated in the GSI Crookstown (Pound Cross) report (2002) to be of the order of 500 m^3/d based on a saturated thickness of 10 m and a permeability value of 50 m/d derived from particle size analyses in test boreholes. The porosity was estimated at 30%. The same values are considered appropriate at this source based on field observations of the low drainage density and landform characteristics observed during site walkover with Robbie Meehan in September 2009.

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

$$Velocity\ (V) = \frac{\text{Permeability (K)} \times \text{Groundwater gradient(i)}}{\text{Porosity}}$$

The pumping gradient for BH2 is estimated to be 0.01 based on the assumptions outlined in Section 8.3 A typical effective porosity for permeable sand and gravel aquifer is 0.30 (30 %). Thus the velocity is estimated to be in the order of 1.70 m/d for BH2. The aquifer parameters are summarized in the Table 8–3 below.

Table 8-3: Indicative Parameters for Crookstown Sand and Gravel Aquifer

parameters	Source of Data (from GSI Report)	BH2 Value
Transmissivity (m2/d)	Local	500
Permeability (m/d)	Local	50
Porosity	Assumed	30%
Groundwater gradient	Assumed	0.01
Velocity (m/d)	Local/Assumed	1.70

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 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 Crookstown therefore, the main parameters involved in recharge rate estimation are: annual rainfall; annual evapotranspiration; and a recharge coefficient. The recharge estimate is based on the GSI report for the Crookstown (Pound Cross) source which is located in similar subsoils 1.4 km to the northeast.

Potential recharge is equivalent to 844 mm/year i.e. (Annual Effective Rainfall as outlined in Section 8.2).

Recharge: *506 mm.* The ZOC is divided into two zones: the valley of Bride River composed of the sand and gravel formation (25% of the ZOC) and the hill slopes composed of a thin sandstone till derived from the sandstone rocks of the Old Head and Gyleen formations (75% of the ZOC).

In the 2002 GSI Report, the actual recharge in the Bride Valley is estimated from baseflow separation of hydrographs from the Ovens gauging station (19016) as approximately 400 mm per year i.e. 47 % of the annual effective rainfall. The thickness of the sand and gravel formation, and presence of a very shallow water table (less than 2 m bgl) overlain by a well drained soil, indicates that the recharge may be greater than 47 % of effective rainfall. Applying the recharge coefficients proposed by the Groundwater Working Group (GWG) in 2008, the percentage of effective recharge proposed in 2002 is more indicative of till overlain by well drained soil.

The recharge coefficient proposed for a sand and gravel aquifer overlain by a well draining soil ranges from 60–100% with an inner range of 80–90%. As the productive sands and gravels in this area are at depth and are overlain by moderate permeability subsoils with some thin clay layers, applying a recharge coefficient of 80–90 % would most likely over estimate the recharge. A recharge coefficient of 60% (506 mm) is therefore proposed.

The elevated ground to the south (estimated to be approximately 75 % of the ZOC), where the subsoil is very thin or absent and outcrop dominates. Here the vulnerability is classed as Extreme with Rock near the surface. Applying the aquifer cap to Locally Important aquifers (GWG 2008), the recharge is estimated to be 200 mm/yr. This is assumed to be the case in this area.

The bulk ***recharge coefficient*** for the area is therefore estimated to be 33% which amounts to an estimated recharge of 278 mm

Runoff losses: *561* mm. Runoff losses are assumed to be 67% of potential recharge.

These calculations are summarised as follows:

Average annual rainfall (R)	1330 mm
estimated P.E.	512 mm
estimated A.E. (95% of P.E.)	486 mm
effective rainfall	844 mm
potential recharge	844 mm
runoff losses	67%
bulk recharge coefficient	33%
Recharge	**278 mm**

8.7 CONCEPTUAL MODEL

- The borehole abstracts water from a sand/gravel alluvial deposit in the bottom of the Bride Valley. The aquifer is at least 10 m thick and is highly transmissive at depth where the gravels are relatively clean.

- The sediments towards the top of the sequence become more clayey and are considered to be of moderate permeability. This results in less recharge than would normally be expected in a sand and gravel aquifer.

- While the sand and gravel deposits have not been classified by the GSI as an aquifer, locally it is likely that they provide significant additional storage to the underlying bedrock aquifer and may well constitute an aquifer in their own right given the high sustainable yields from the formation.

- Based on work carried out at the nearby Crookstown (Pound Cross, BH1) borehole, the permeability is estimated at approximately 50 m/d, the transmissivity at 500 m^2/d and the porosity at 30%.

- The hydraulic gradient in the gravel is assumed to be low, of the order of 0.001. However the gradient in the steeper areas to the south is more likely to reflect the topography and be closer to 0.1. An average gradient of 0.01 is therefore assumed which is also likely to represent the typical gradients under pumping conditions. The direction of local groundwater flow is assumed to be the north or north-west towards the River Bride.

- It is assumed that much of the recharge occurs from runoff and shallow groundwater flow from the high ground to the south with a approximately 25% of the recharge originating from the alluvium.

- The alluvial aquifer is considered to be 'extremely vulnerable' because the depth to the water table is less than 3 m. The steep slopes immediately south of the well where the subsoil is very thin or absent and outcrop dominates are also characterised by Extreme Vulnerability.

The conceptual model is outlined by a schematic cross-section (Figure8).

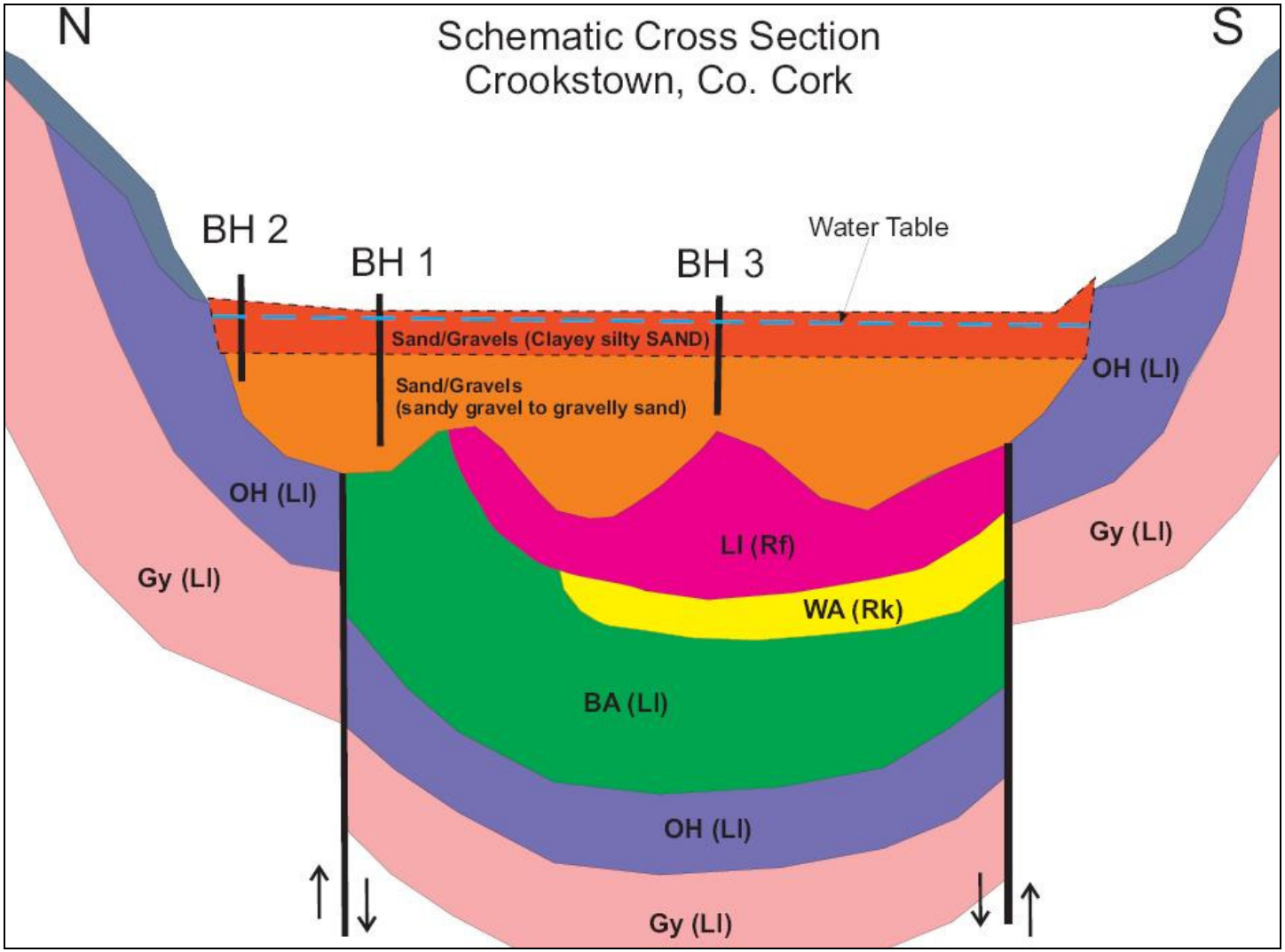


Figure 10: Schematic cross-section

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 conceptualisation of the groundwater pattern, as described in Section 8.7 Conceptual Model and presented in Figure 7.

Two source areas are 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.

To allow for daily variations in abstraction and to allow for expansion of ZOC during dry weather periods the GSI usually increase the abstraction rate for a source by a factor of safety of 50%. However, the well is currently being pumped close to the maximum capacity of the pump and there is another abstraction well, currently not in use, installed in the same formation located approximately 1 km to the north-northeast of the well. In the event that increased abstraction is required, the new abstraction well has much higher sustainable yield than this borehole which the Council can incorporate to cater for increased demand in the future for the Crookstown area. For these reasons the ZOC area has not been increased by 50%.

The Southern and Eastern boundaries are defined by conceptualised groundwater flow-lines, which are themselves defined by the topography of the area.

The Western boundary is located between the Bride River and the well. Even with the river in full hydraulic connection with the aquifer as described in section 8.3, the drawdown in the abstraction well under pumping at the source in the gravels is only 70cm. This indicates that the abstraction rate would not be capable of pulling water from the gravels as far away as the River Lee. The boundary has been delineated between the river and the margins of the steeply sloping bedrock to the south within the alluvium to account for some flow to the well from this formation.

The Northwest boundary – the Downgradient boundary is 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 (taken from aquifer characteristics)

I is background non pumping gradient.

Where the pumping rate is 75 m^3/d, the transmissivity is 500 m^2/d and the hydraulic gradient is 0.001 (i.e. the gradient in the gravels only), the down-gradient extent of the zone of contribution is approximately 24 m.

Water balance

The water balance calculations indicate that at a recharge of 506 mm/y in the sand and gravels formation and 200 mm in the Locally Important aquifer to the south, an average discharge of 75 m^3/day would require a recharge area of 0.10 km^2. The boundaries of the ZOC are shown on Figure 7.

The hydrogeological mapping techniques used in delineating the ZOC have incorporated groundwater flow lines defined by topography and have resulted in a slightly larger area contributing to the source (0.1 km^2) than the water balance suggests. This is considered to be the more conservative approach.

9.2 INNER PROTECTION AREA

According to "Groundwater Protection Schemes" (DELG/EPA/GSI 1999), delineation of the Inner Protection Area is required to protect the source from microbial and viral contamination and it is based on the 100-day time of travel (ToT) to the supply.

Based on the indicative aquifer parameters outlined in section 8.5, the groundwater velocity is estimated as being in the region of 1.7 meters per day and therefore the 100-day time of Travel (ToT) distance is 170 m.

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/X, SI/E, SO/X, SO/X.

Table 10-1 Source Protection Zones (%area, km^2)

Source Protection Zone	% of total area (0.10km^2)
SI/X	23% (0.023 km^2)
SI/Extreme	10% (0.010 km^2)
SO/X	35% (.035 km^2)
SO/Extreme	32% (0.032 km^2)

11 POTENTIAL POLLUTION SOURCES

Within the ZOC the lands are in agricultural use primarily as grazing lands for cattle that may also be used for land spreading.

The R585 is located 2 m above the level of the borehole. The distance between the public road and the borehole is only 3 m. The road has no drainage to divert run off away from the land where the borehole is located. There is the potential for diesel or petrol spill from the road to discharge into the subsoils close to the well.

There are no private houses or farm yards present within the ZOC.

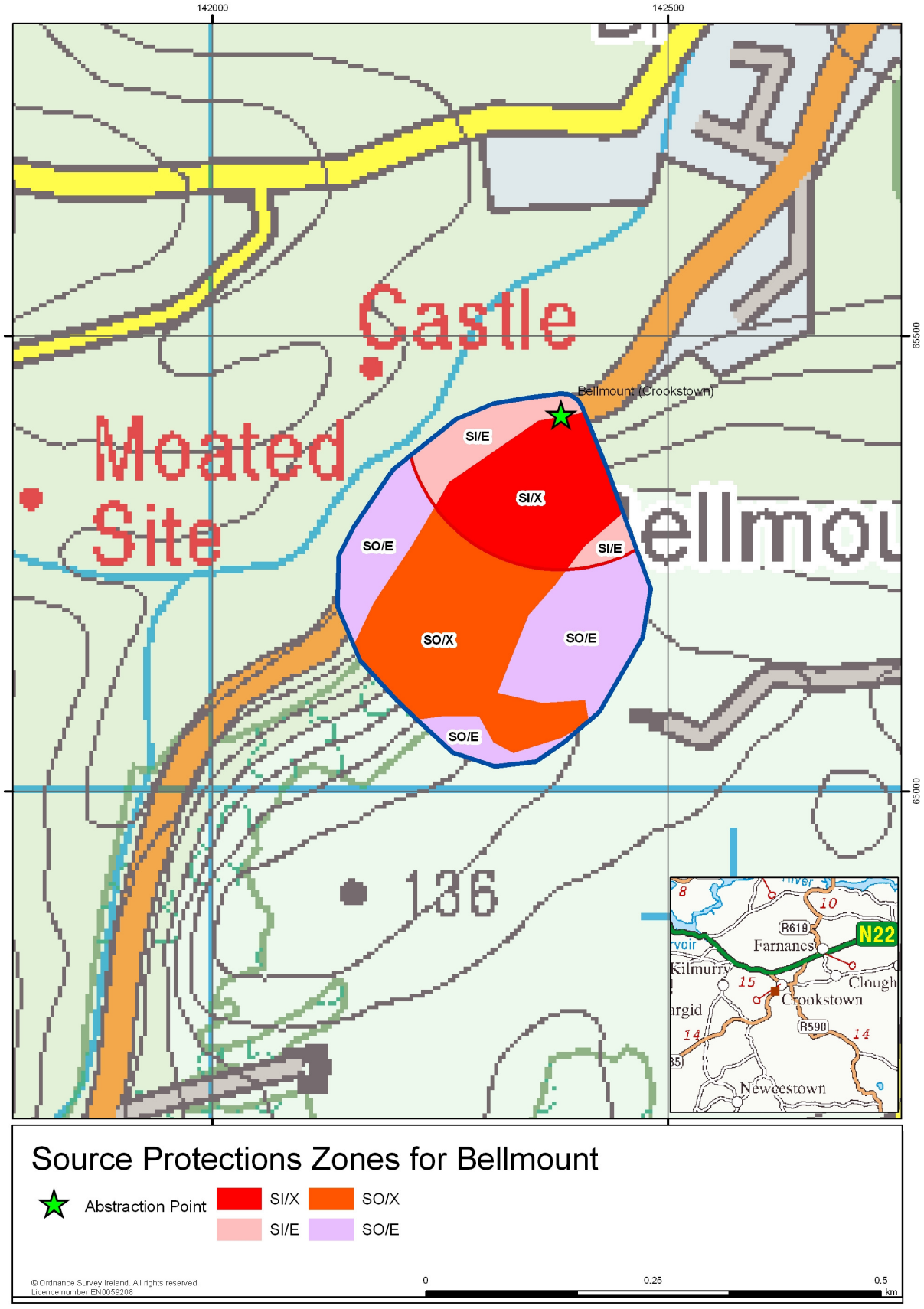


Figure 11: Groundwater Protection Zones

12 CONCLUSIONS

The Crookstown Water Supply Schemes consists of two boreholes located 1.4 km apart, Bellmount and Pounds Cross, which together abstract an average of 220 m^3/d. Bellmount, the subject of this report, abstracts 75 m^3/d (20 hours pumping per day). The water from both wells is pumped simultaneously to a reservoir located on a hill 2 km to the north east above the N22.

The well is shallow (14 m) and is abstracting groundwater from alluvial sands and gravels in the Bride river valley though much of the groundwater inflow appears to originate from the bedrock aquifer immediately to the south. Based on information from the Pounds Cross area, the sediments towards the top of the sequence include clay layers and are considered overall to be of moderate permeability. This results in less recharge than would normally be expected in a sand and gravel aquifer. The productive zone of the gravels is likely to be at depth. The formation is not classified by the GSI as a Locally Important Aquifer sand/gravel aquifer though it could potentially be characterised as such. The alluvium is underlain by the Little Ballysteen Formation and the Old Head Sandstone which are classified as Locally Important Aquifers (Ll).

The depth to water in the borehole is less than 2 m which indicates that the vulnerability is likely to be extreme.

Water quality from this borehole is good. Nitrates levels have ranged between 20-25 mg/l for more than 10 years. While the levels are above typical background levels they do not give rise to significant concern. Nitrate levels are typical of many rural catchments with moderately intensive farming activities. There are no houses or farmyards located within the zone of contribution (ZOC) to the source but animal grazing and potentially landspreading is common.

The Zone of Contribution to the source is estimated to be approximately 10 hectares. The inner and outer source protection zones delineated in the report are based on our current understanding of the groundwater conditions and the available data. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.

The groundwater in BHB-2 could potential be at risk of pollution from road run off, particularly in the event of an oil spill along the road adjacent to the site.

13 RECOMMENDATIONS

Given the proximity to farm land that may be used for land spreading within the ZOC, and the extreme vulnerability over the entire ZOC, it is recommended that the treatment system for the water supply be upgraded to include a Cryptosporidium filtration unit.

It is recommended that measures be taken to prevent the direct discharge of road run off to the lands where the borehole is located. For example a berm and storm drain diverting water away from the site entrance to prevent the direct discharge of run off into the ground adjacent to the well

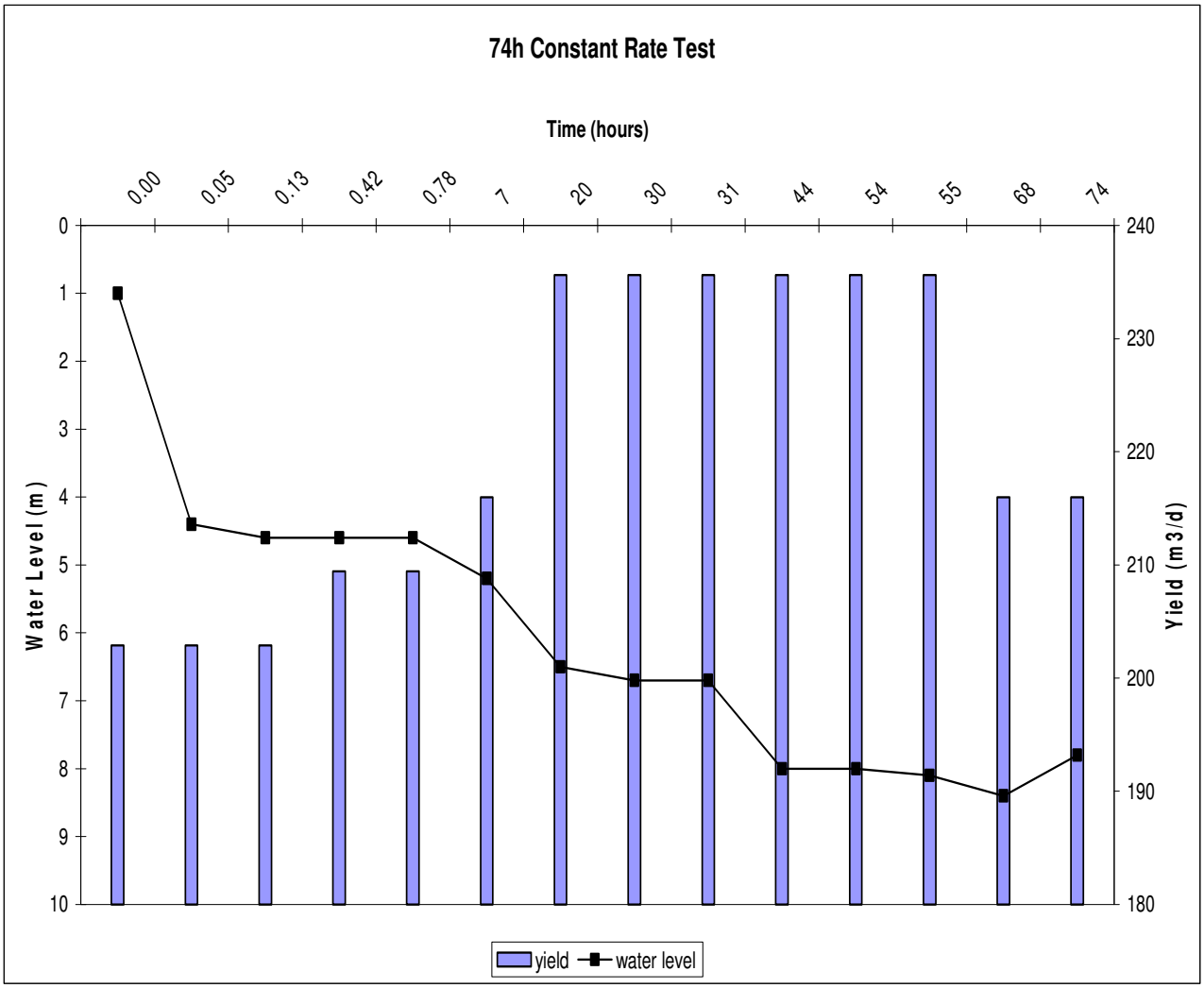
14 REFERENCES

- Environmental Protection Agency (2003) *Towards Setting Guideline Values for the Protection of Groundwater in Ireland*. Environmental Protection Agency.
- European Communities (Drinking Water) Regulations (2000). S.I. No. 439 of 2000.
- Sleeman. A. & Pracht. M. (1994) Geology of South of Cork. Bedrock Geology 1:100,000 Map series, sheet 25, Geological Survey of Ireland ().
- GSI (2002) G*roundwater source protection zones for Crookstown Water Supply* –revised.
- GSI (2004) 1st Draft Ballincolling GWB Description
- Meehan, R. (2002) Forest Inventory and planning system – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map, Teagasc.
- OCM (2005) *Assessment of proposed additional groundwater supply boreholes and source protection area at Crookstown, Co. Cork* on behalf of Cork County Council

APPENDIX 1

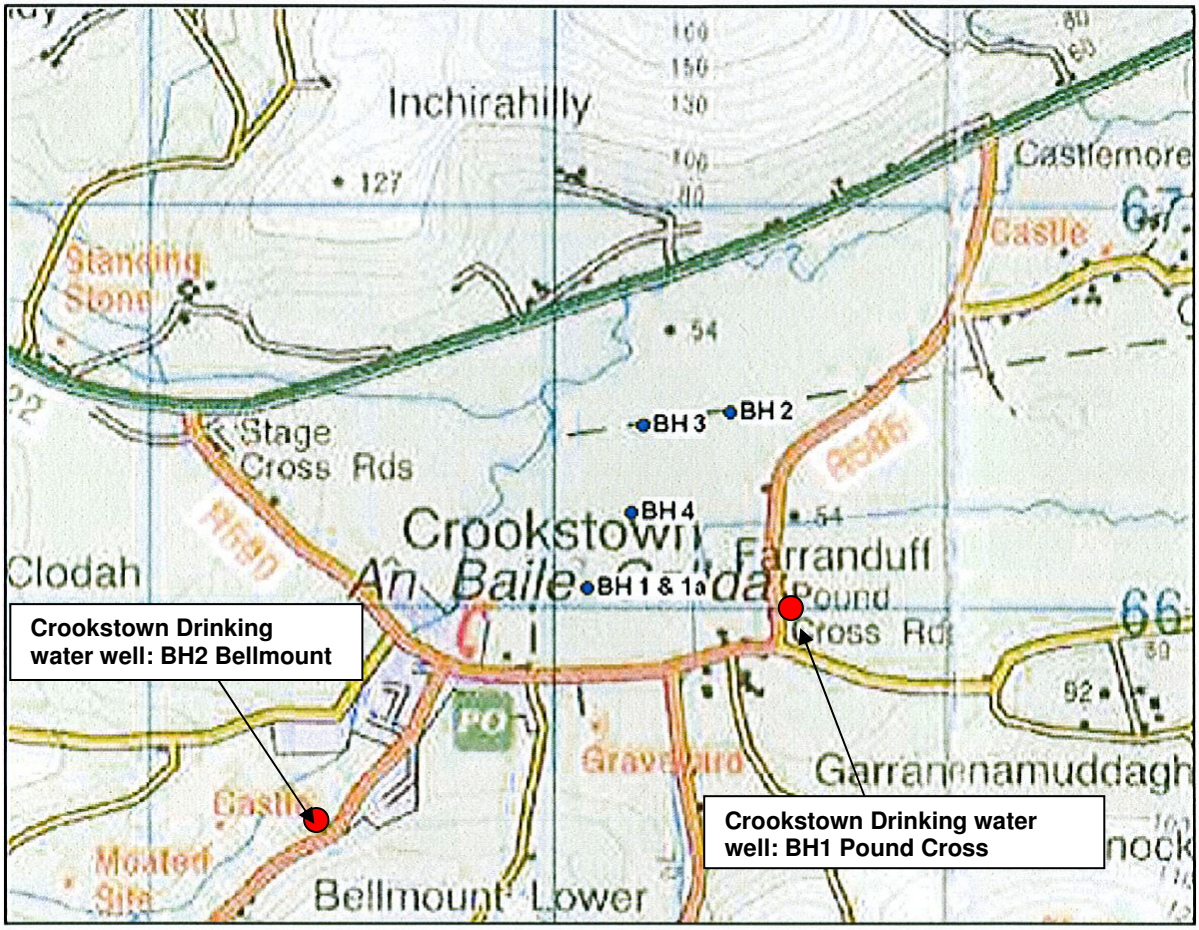
Data of the Pumping test in BH2 (Bellmount) in 2000

day	Time	hours	minutes	water level (m)	pumping rate(gls/min)	pumping rate(l/min)	l/h	m3/h	m3/d
Monday	12:00	0.00	0	1	31	141	8454	8	203
	12:03	0.05	3	4.4	31	141	8454	8	203
	12:08	0.13	8	4.6	31	141	8454	8	203
	12:25	0.42	25	4.6	32	145	8726	9	209
	12:47	0.78	47	4.6	32	145	8726	9	209
	19:00	7	467	5.2	33	150	8999	9	216
Tuesday	08:00	20	1200	6.5	36	164	9817	10	236
	18:00	30	1800	6.7	36	164	9817	10	236
	19:00	31	1860	6.7	36	164	9817	10	236
Wednesday	08:00	44	2640	8	36	164	9817	10	236
	18:00	54	3240	8	36	164	9817	10	236
	19:00	55	3300	8.1	36	164	9817	10	236
Thursday	08:00	68	4080	8.4	33	150	8999	9	216
	14:00	74	4440	7.8	33	150	8999	9	216



APPENDIX 2

Map Location and Borehole logs from OCM Investigations in 2004



O'Callaghan Moran & Assoc Granary Hse, Rutland St. Cork Ireland. Tel (021) 4321521 Fax (021) 4321522 Email: ocm@indigo.ie	Client Cork County Council	Figure: 2.1	Legend Borehole	
This Drawing is Property of OCM and shall not be used, reproduced or disclosed to anyone without the prior permission of OCM and shall be returned on request	Title: Well Locations at Crookstown	Details	Scale	Revision

BOREHOLE RECORD				
CONTRACT: Cork County Council	**BOREHOLE NO:** BH-2			
LOCATION: Crookstown, Co.Cork	**DATE:** 14/06/'04			
METHOD OF EXCAVATION: Rotary Percussion				
DESCRIPTION	**TRIAL PIT DEPTH (m)**	**SYMBOLIC LOG**	**SAMPLE TYPE**	**DEPTH (m)**
	Metres (m)			
Topsoil- Brown pebbly sandy soil				
	1.0m			
Brown Sand & Gravel				
Becoming moist	2.0m			
	3.0m			
	4.0m			
	5.0m			
	6.0m			
	7.0m			
	8.0m			
Water Strike at approximately 8.5m				
Increasing gravel content with depth	9.0m			
	10.0m			

BOREHOLE RECORD				
CONTRACT: Cork County Council	BOREHOLE NO: BH-2 Cont'd			
LOCATION: Crookstown, Co.Cork	DATE: 14/06/04			
METHOD OF EXCAVATION: Rotary Percussion				
DESCRIPTION	TRIAL PIT DEPTH (m)	SYMBOLIC LOG	SAMPLE TYPE	DEPTH (m)
	Metres (m)			
Red/brown SAND & GRAVEL	11.0m			
Limestone Bedrock	12.0m 13.0m 14.0m 15.0m 16.0m 17.0m 18.0m 19.0m 20.0m			

BOREHOLE RECORD				
CONTRACT: Cork County Council	**BOREHOLE NO:** BH-2 Cont'd			
LOCATION: Crookstown, Co.Cork	**DATE:** 14/06/04			
METHOD OF EXCAVATION: Rotary Percussion				
DESCRIPTION	TRIAL PIT DEPTH (m)	SYMBOLIC LOG	SAMPLE TYPE	DEPTH (m)
	Metres (m)			
	21.0m			
	22.0m			
Limestone Bedrock	23.0m			
	24.0m			
	25.0m			
	26.0m			
	27.0m			
	28.0m			
	29.0m			
	30.0m			

BOREHOLE RECORD	
CONTRACT: Cork County Council	**BOREHOLE NO:** BH-2 Cont'd
LOCATION: Crookstown, Co.Cork	**DATE:** 14/06/04
METHOD OF EXCAVATION: Rotary Percussion	

DESCRIPTION	TRIAL PIT DEPTH (m)	SYMBOLIC LOG	SAMPLE TYPE	DEPTH (m)
	Metres (m)			
	31.0m			
	32.0m			
Limestone Bedrock	33.0m			
	34.0m			
	35.0m			
	36.0m			
	37.0m			
	38.0m			
	39.0m			
	40.0m			

BOREHOLE RECORD

CONTRACT: Cork County Council.	**BOREHOLE NO:** BH-2 Cont'd
LOCATION: Crookstown, Co.Cork.	**DATE:** 14/06/04
METHOD OF EXCAVATION: Rotary Percussion	

DESCRIPTION	TRIAL PIT DEPTH (m)	SYMBOLIC LOG	SAMPLE TYPE	DEPTH (m)
	Metres (m)			
	41.0m			
	42.0m			
Borehole terminated at 42m				
	43.0m			
	44.0m			
	45.0m			
	46.0m			
	47.0m			
	48.0m			
	49.0m			
	50.0m			

BOREHOLE RECORD				
CONTRACT: Cork County Council.	BOREHOLE NO: BH-3			
LOCATION: Crookstown, Co.Cork.	DATE: 14/06/04			
METHOD OF EXCAVATION: Rotary Percussion				
DESCRIPTION	TRIAL PIT DEPTH (m)	SYMBOLIC LOG	SAMPLE TYPE	DEPTH (m)
	Metres (m)			
Topsoil- Brown pebbly sandy soil				
	1.0m			
Red/brown Sand & Gravel Occasional cobbles				
Becoming moist	2.0m			
	3.0m			
	4.0m			
	5.0m			
Water Strike at approximately 6.0m	6.0m			
	7.0m			
	8.0m			
Orange/brown SAND & GRAVEL	9.0m			
	10.0m			

BOREHOLE RECORD				
CONTRACT: Cork County Council.	BOREHOLE NO: BH-3 Cont'd			
LOCATION: Crookstown, Co.Cork.	DATE: 14/06/04			
METHOD OF EXCAVATION: Rotary Percussion				
DESCRIPTION	TRIAL PIT DEPTH (m)	SYMBOLIC LOG	SAMPLE TYPE	DEPTH (m)
Metres (m)				
11.0m				
12.0m				
13.0m				
14.0m				
15.0m				
Limestone bedrock- Borehole ended				
16.0m				
17.0m				
18.0m				
19.0m				
20.0m				

BOREHOLE RECORD				
CONTRACT: Cork County Council		BOREHOLE NO: BH-4		
LOCATION: Crookstown, Co.Cork		DATE: 19/08/04		
METHOD OF EXCAVATION: Rotary Percussion				
DESCRIPTION	TRIAL PIT DEPTH (m)	SYMBOLIC LOG	SAMPLE TYPE	DEPTH (m)
Metres (m)				
Topsoil- Brown pebbly sandy soil				
1.0m				
Orange/brown SAND & GRAVEL				
Gravel varying from rounded to angular				
Becoming moist				
2.0m				
3.0m				
4.0m				
Water Strike at approximately 5m				
5.0m				
Red/brown SAND & GRAVEL				
6.0m				
7.0m				
8.0m				
9.0m				
10.0m				

BOREHOLE RECORD				
CONTRACT: Cork County Council		BOREHOLE NO: BH-4 Cont'd		
LOCATION: Crookstown, Co.Cork		DATE: 19/08/04		
METHOD OF EXCAVATION: Rotary Percussion				
DESCRIPTION	TRIAL PIT DEPTH (m)	SYMBOLIC LOG	SAMPLE TYPE	DEPTH (m)
	Metres (m)			
Gravels becoming coarser with depth	11.0m			
	12.0m			
Red/brown SAND & GRAVEL	13.0m			
	14.0m			
	15.0m			
	16.0m			
	17.0m			
	18.0m			
Borehole ended	19.0m			
	20.0m			