Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Crookstown Water Supply Scheme (Pound Cross – BH1)

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Revision: B

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PROJECT DESCRIPTION

Article 7 of the Water Framework Directive (WFD) requires member states to establish "safeguard zones" for those bodies of water, including groundwater, utilised in the production of drinking water. Since the 1980's, the Geological Survey of Ireland (GSI) have undertaken a considerable amount of work developing Groundwater Protection Schemes across the country, which partly fulfil (and in some cases exceed) the requirements of the WFD. The project "Establishment of Groundwater Source Protection Zones", led by the Environmental Protection Agency (EPA), represents a continuation of this work. The definition and delineation of the source protection zones is a priority for the EPA. A CDM/TOBIN/OCM project team have retained by the Environmental Protection Agency (EPA) to establish of Groundwater Source Protection Zones. This report forms part of a suite of maps and reports for the EPA and the Geological Survey of Ireland. The reports are hosted on the EPA and GSI websites (www.epa.ie ; www.gsi.ie).

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1 INTRODUCTION

Groundwater Source Protection Zones (SPZ) are delineated for the 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 BH1 (Pound Cross) is one of two sources for Crookstown Public Water Supply (Group Water Scheme). BH-1 is located 1.4km to the east of BH-2. There is a separate source report for Bellmount (BH-2). A third borehole was installed approximately 1km to the north northeast of BH-2 and 500m to the northwest of BH-1 but has not been incorporated into the scheme. BH-2 is the older well on the scheme and was for a time decommissioned because of localised contamination and BH-1 was installed as an emergency backup supply for the scheme in 1980.

The objectives of the report are as follows:

- To delineate source protection zones for the Borehole.
- To outline the principal hydrogeological characteristics of the Crookstown area.
- 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 the 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

The borehole BH1 is located approximately 1 km east of Crookstown village in west Cork. The water source is a borehole approximately 27 metres deep. It was drilled in June 1980 in the front garden of a private dwelling about 100 m north of Pound Cross Roads (Photo 1). The house is adjacent to the Road R585. The borehole is protected by a manhole cover although the well casing beneath the manhole cover is not capped (Photo 2). The pump house is located 80m south of the house (Photo 3). A chlorine dosing treatment system is located in the pump house (Photo 4).

The location is illustrated on Figure 1.

Photo1: Manhole Cover

Photo 2: Well Head

Photo3: Pump House

Photo 4: Chlorine system in the pump house

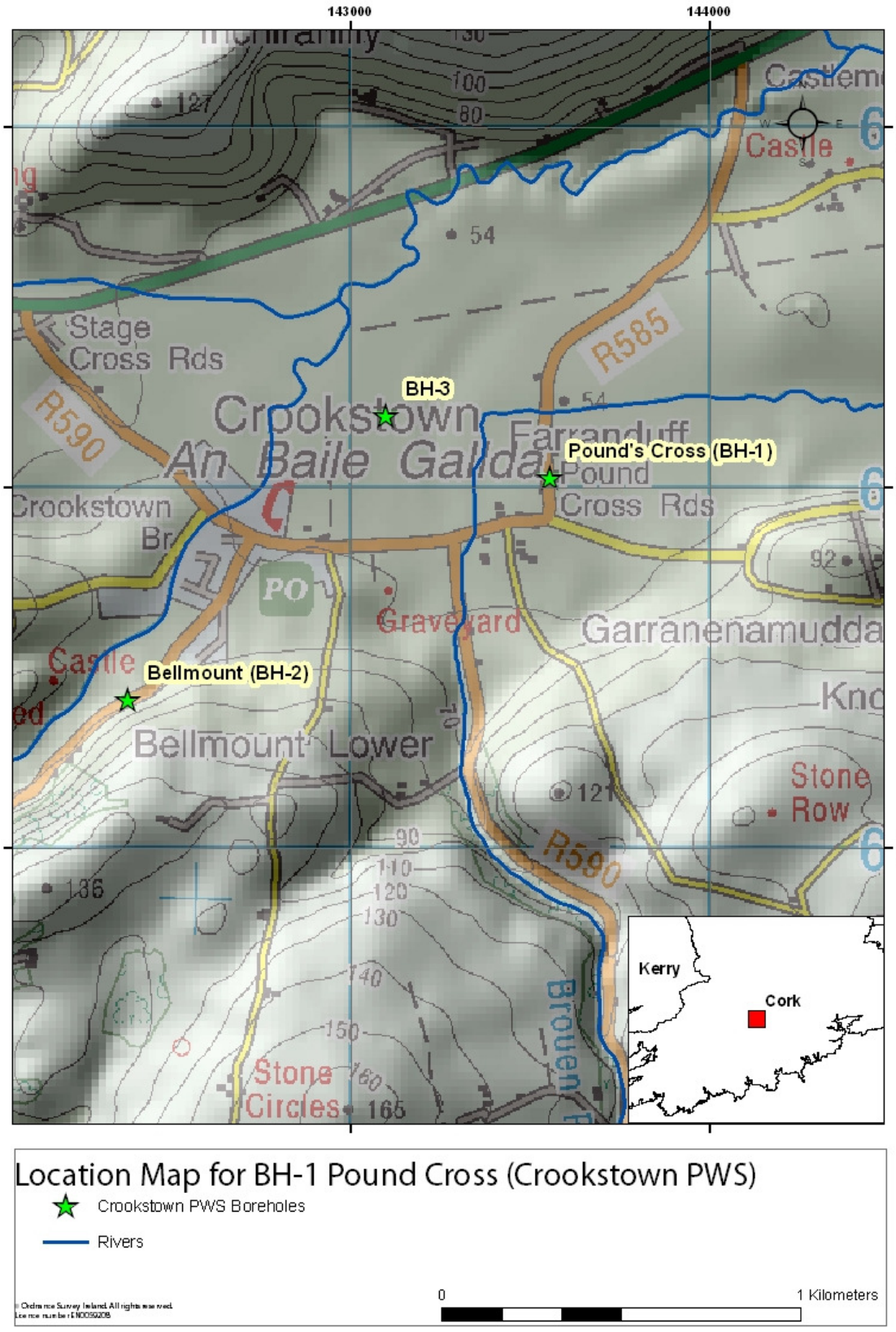

Figure 1: Location Map

3 SUMMARY OF WELL DETAILS

The average abstraction is 145 m3/d operating around 15 hours per day. The abstraction rate automatically responds to demand. The water is pumped simultaneously from BH-1 and BH-2 to a reservoir located on a hill 2 km to the northeast above the N22 (Photo 5), in the Townland of Farnanes.

Photo 6: Reservoir Tank

Table 3.1 below provides a summary of the details as currently known.

Table 3-1 Well Details

EU Reporting Code	
Grid ref. (GPS)	143557 66035
Townland	Crookstown - Pound Cross
Source type	One Borehole
Drilled	1980
Owner	Cork Co. Co.
Elevation (Ground Level)	54.91 m OD
Depth	27 m
Depth of casing	Screen between 18-27 m
Diameter	380 mm
Depth to rock	No reach
Static water level	1.80 mbgl (10/09/2009)
Pumping water level	1.30 mbgl (10/09/2009)
Consumption (Council records)	145 m3/day
Pumping test summary: (i) abstraction rate m3/d	Not Available
(ii) specific capacity m3/d/m	Between 96.25 and 976.78 (from OCM Report)
(iii) transmissivity	500 m2/d (GSI Report, 2002)

4 METHODOLOGY

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

The site visit and interview with the caretaker took place on 09/09/2009 and 22/09/09. Field mapping of the study area (including measuring the electrical conductivity and temperature of the source and streams in the area) and a short term recovery test were carried out.

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 OD. The lands to the south rise steeply to an elevation of 120 mOD.

Drainage density in the river valley is low. At the local scale, the nearest stream to BH1 is the Brouen River, a tributary of the Bride River, which flows eastwards about 150 metres north of the borehole and joins the River Bride approximately 450 m north of BH-1. The flow path of the River Brouen was altered in the past possibly as a flood alleviation measure for the River Bride into which it flows. The river takes a 90 degree turn approximately 200m north of BH1 changing course from north to east. The river is known to dry up to the north of the site during low rainfall periods as a result of quarry dewatering activities at Castlemore Quarries located approximately 1.2km northeast of BH-1. This water is pumped back into the River Brouen downstream of the quarry.

The land in the vicinity of the borehole is primarily agricultural. The land is used primarily as grazing lands for cattle though a portion of the land in the west part is used for tillage (Photo 7). There are 4 No. private dwellings located in the immediate vicinity of BH-1. Castlemore Quarries, a large hard rock limestone quarry operation is located approximately 1.2km to the northeast of BH-1. The existing Quarry operation spans approximately 40 hectares but there are plans to expand the quarry to more than twice the existing size in the future.

Photo7: Landuse upgradient of the well

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 Geological succession is summarised in Table 6-1 and the bedrock geology is illustrated on Figure 2.

Table 6-1: Geological succession

Formation	Code	Description
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
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 Groundwater Source Protection Zones Report 2002).

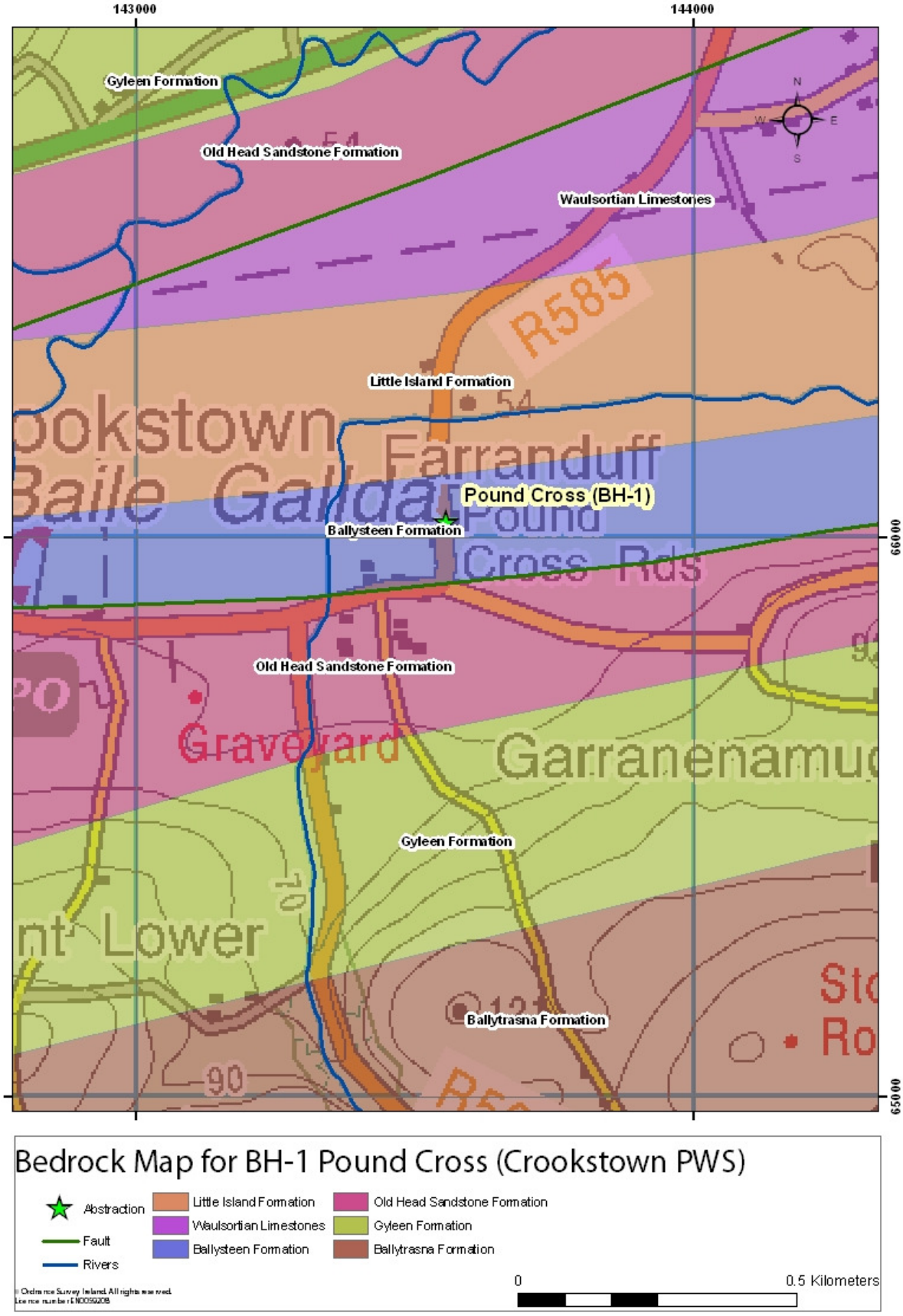

Figure 2 Bedrock Map

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 occur along the valley floor (GSI 2002). The Teagasc map shows the extent of these gravel deposit (which Teagasc has termed 'Alluvium') which mainly runs along both the River Bride and the Brouen River

Particle size analyses from the GSI observation borehole (drilled in 1999) about 30 metres away from the Pound Cross borehole, BH1, (at depths of 20 m, 21.6 m, 23.2 m, 25m and 28 m) show a mixture of sandy gravel and gravelly sand, with percentage fines less than 10% (mostly less than 5%) and gravel percentages from 24% to 73%. Samples of the subsoil were also taken from an auger hole (grid ref. 14364, 06591) in the field next to the borehole, down to a depth of 6.3 m. These samples were analysed using BS 5930 methods. This hole penetrated about 3 m of silty SAND, followed by one metre of sandy CLAY with silt, followed by 1.2 m of Gravel with a clayey sand matrix, followed by just over one metre of sandy CLAY with silt.

Gravels are more prevelant at depth based on the log of the production well. Another auger hole installed by the GSI 500 m north of the first (grid ref. 14377, 06648) met clayey silty SAND down to 3.5 m.

The OCM investigations further to the north in the Bride valley identified gravel subsoils with occasional clay zones to a depth of up to 24m.

The Subsoil map is shown in Figure3

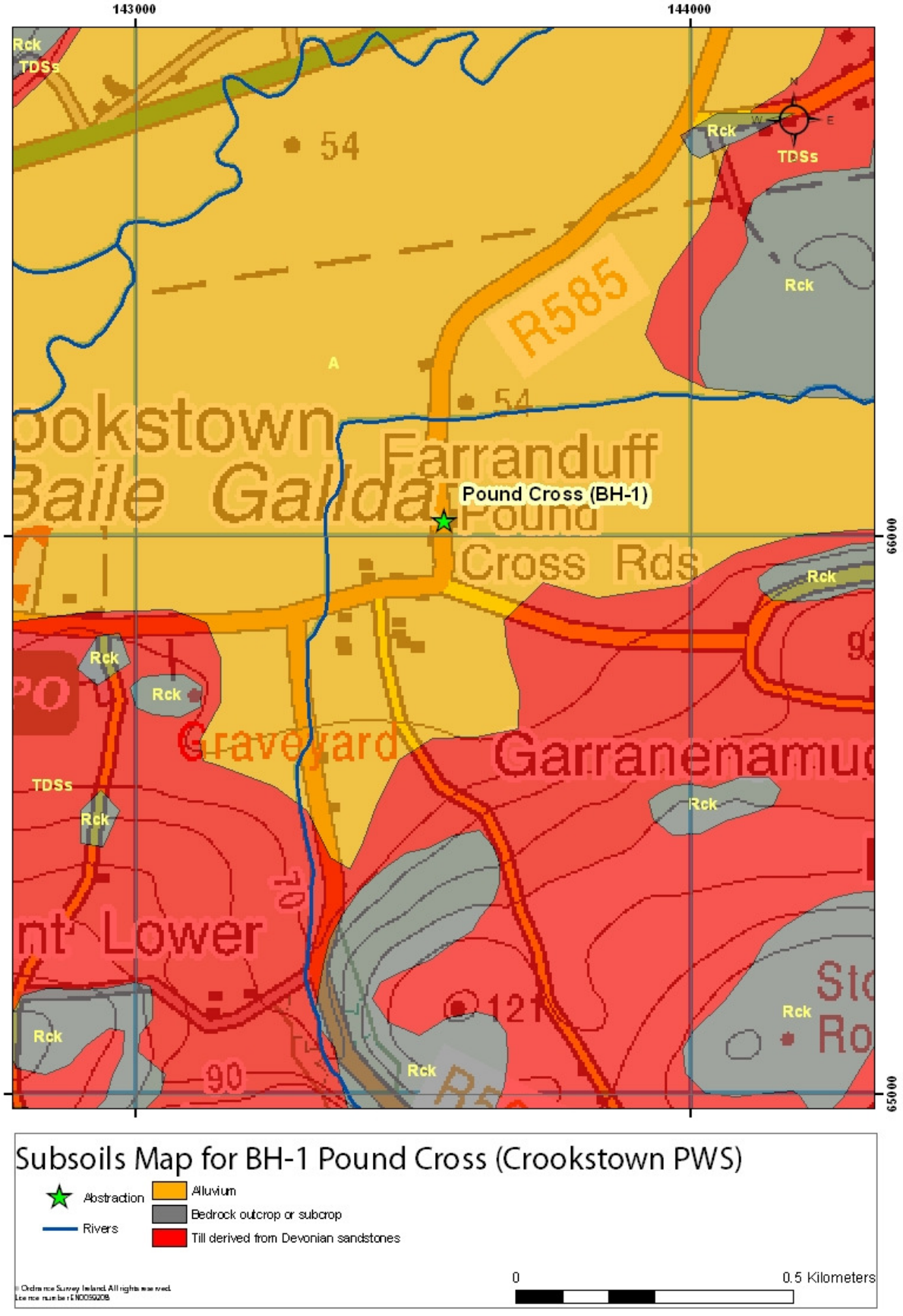

Figure 3: Subsoil Map

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 greater than 24 m close to the River Bride (north of BH-1) where OCM proved a depth of 24 m without encountering bedrock during exploratory drilling in 2003 (Table6-2 and Appendix1).

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

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 mOD	~60 mOD	~60 mOD	~60 mOD	~60 mOD
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).

Based on field observation and review of the additional data gathered during the 2003/4 OCM site investigations as described in the 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 metres 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 Figure4

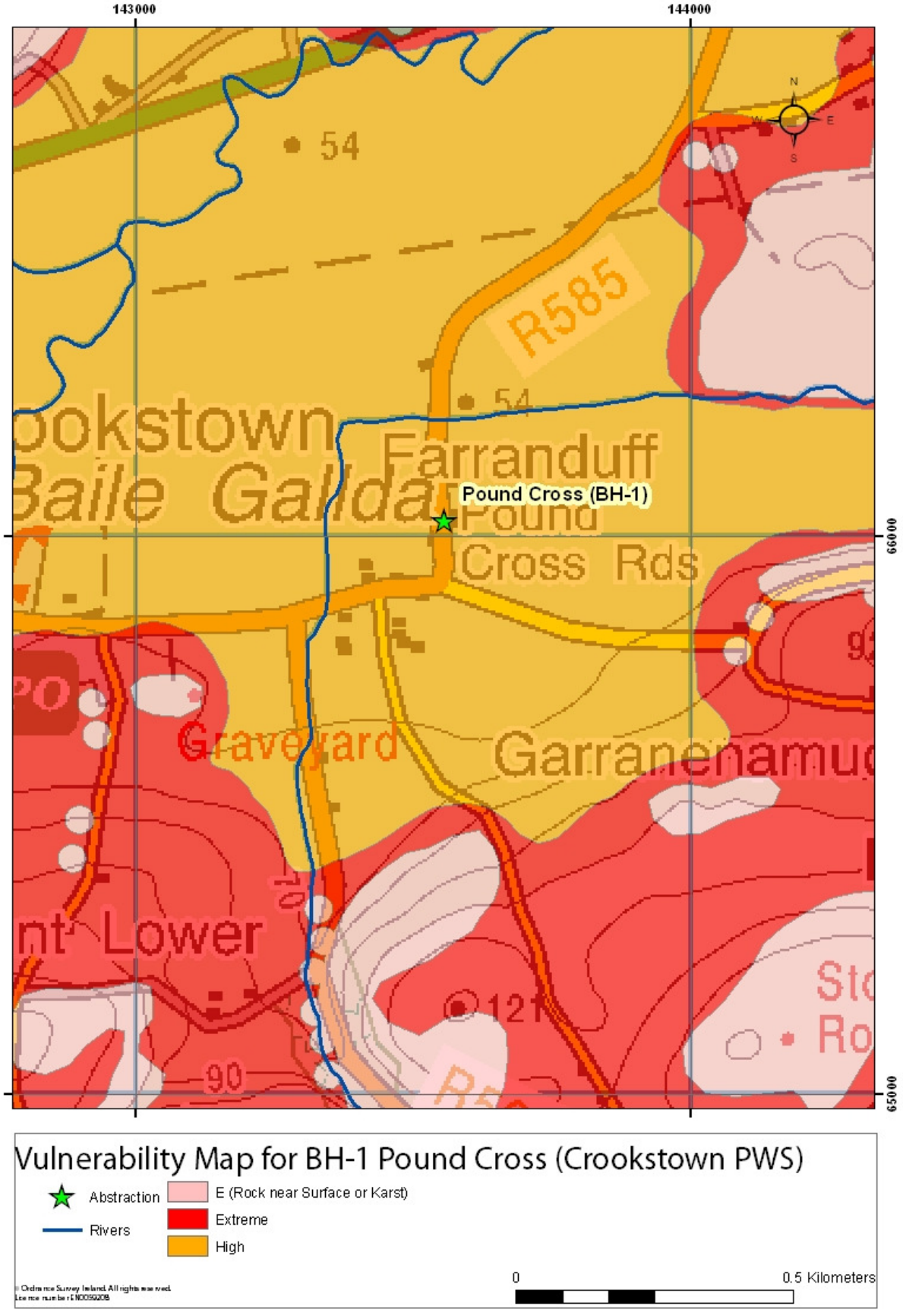

Figure 4 Vulnerability Map

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:

- 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).GSI Source Report 2002
- County Council Staff
- EPA website and Groundwater Monitoring database
- Local Authority Drinking Water returns

8.1 GROUNDWATER BODY AND STATUS

The Crookstown water supply well (BH-1, Pound Cross) is located within the Ballincollig Groundwater Body which has been classified as being of Good Status. The groundwater body descriptions are available from the GSI website: www.gsi.ie and the 'status' is obtained from the Water Framework Directive website: www.wfdireland.ie/maps.html.

This GWB is overlain by alluvium, sand and gravel deposits and some glacial till. There are large areas of alluvium in the west of the body, north of Crookstown and west of Kilcrea Abbey.

The borehole is located in the alluvium which comprises significant portions of sand and gravel at depth. This formation has been proven to be more than 24m thick, averaging 10 m thick and is highly transmissive in the vicinity of the boreholes. While the sand and gravel deposits have not been classified by the GSI as an aquifer, locally they provide significant additional storage to the underlying bedrock aquifer and may well constitute an aquifer given the high sustainable yields from the formation.

8.2 METEOROLOGY AND RECHARGE

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 Met Eireann.

Annual rainfall: 1330 mm. Long term annual average rainfall (P) is estimated at 1330mm (1961 – 1990).

Annual evapotranspiration losses: 486 mm. Long term annual average actual evapotranspiration (Ae) is estimated at 486 mm (EPA, estimated from rainfall minus runoff at Ovens, hydrometric gauging station 19016). The potential evapotranspiration is therefore 512 mm.

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

Un-pumped water levels recorded in BH-1 at Pound Cross and BH-2 located in the same formation 1.4 km to the north indicate that the water table is close to the surface, less than 2 metres below the ground and that the Gravels aquifer is unconfined.

The groundwater flow is estimated to be toward the northeast in the direction of the River Brouen.

The lands in the vicinity of the borehole are located in the river floodplain and are consequently very flat. The slope of the water table which is very shallow is expected to mirror the topography and is estimated to be approximately 10^{-3}.

8.4 HYDROCHEMISTRY AND WATER QUALITY

There is currently no pre-treatment monitoring of water quality being undertaken at BH-1. Hydrochemical data have been obtained by EPA from the BH2 well located in the same formation to assess general hydrochemistry.

Analysis of hardness indicates a medium hard calcium bicarbonate hydrochemical signature (average 100 mg/l CaCo3). The average electrical 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).

Nitrate levels over the past ten years in BH-2 have remained fairly consistently at around 20-25 mg/l as NO3, which is above 'background' levels but does not give rise to significant concern. It is likely that similar nitrate levels are present at BH-1.

Electrical conductivity and pH values are similar for the River Brouen and BH2 and indicates that the gravels are in full hydraulic connection with the River Brouen. The results are outlined in the Table 8-1:

Table 8-1: Groundwater and surface water Field Chemistry

	BH1	**Brouen River**
Date	**1995-2009**	**22/09/2009**
Location	**(data from BH2)**	**Bridge on R590**
Conductivty (µS/cm)	Ave: 238 Max: 274 Min: 174	209
pH	Ave: 7 Max: 8.6 Min: 6.1	8.03

8.5 AQUIFER CHARACTERISTICS

The borehole abstracts water from a sand/gravel deposit which overly 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 and is greater than 1 km^2 in extent) which are the criteria set by GSI to define a Locally Important Aquifer (Figure6).

This aquifer is unconfined and the water table is approximately 2 metres below the ground.

In 2002, a GSI planned pumping test in BH1 (Pound Cross) was unable to go ahead for operational reasons. In 2009, during the walkover, OCM undertook a quick recovery test. The pump was turned off for 15 minutes. The recovery stabilized after 2 minutes (from 1.8 m bgl to 1.3 mbgl). This indicates that the sand and gravels formation are very transmissive in this area.

The nature of the aquifer appears to be highly variable (Table8-2). During the OCM investigations one of the test holes showing a very poor yield (BH 3), one showed a good yield (BH 1) and one with an excellent yield (BH 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 test on different wells

Source Name	BH 1 (OCM Investigations)	BH 1a OCM Investigations)	BH 2 OCM Investigations)	BH 3 OCM Investigations)	BH 4 OCM Investigations)	BH1 (Pound Cross)
Grid Reference	143086 066046	143086 066046	143439 066485	143222 066452	143192 066232	142380 65413
Yield (m3/d)	403				547	145
Drawdown (m)	4.19				0.56	
Specific Capacity (m3/d/m)	96.25				976.78	
Comment	High NH4	Intended Standby for BH 1	Collapsed after drilling	Failed pumping test	Successful Supply	

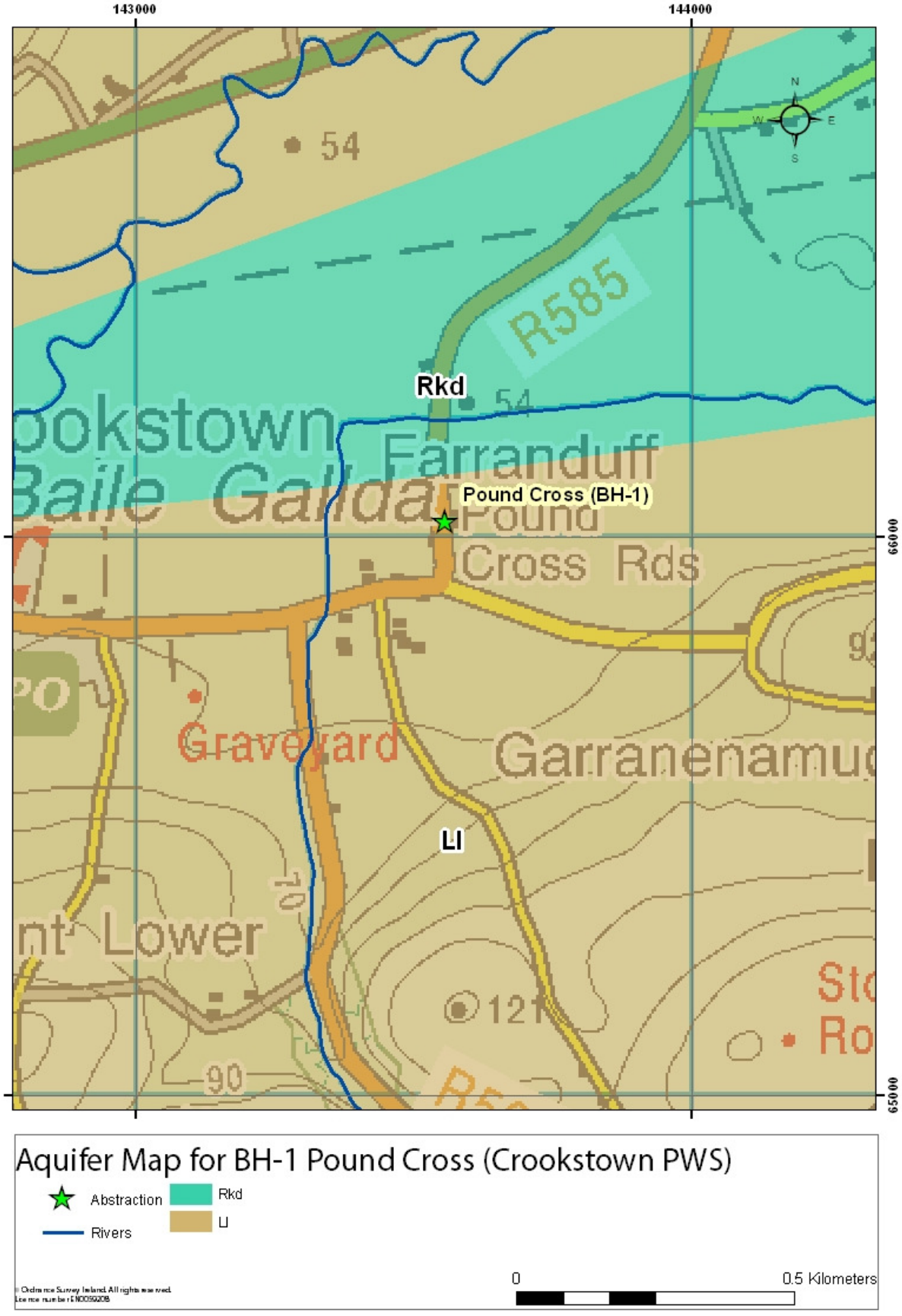

Figure 5: Aquifer Map

It is likely that the permeability and hence the flow of groundwater through the gravely subsoil formation in which the well is located 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. The GSI estimated permeability (from particle size analyses in the borehole observation close to BH1) at approximately 50 m/d. Assuming an aquifer thickness of 10 metres, this gives a Transmissivity of 500 m2/d. Porosity is estimated at 30% (data from GSI report).

The velocity of water moving through this aquifer to the borehole can then be estimated from Darcy's Law:

$$Velocity\ (V) = \frac{K \times groundwatergradient(i)}{porosity}$$

The pumping gradient for BH1 is 0.001. 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 0.17m/d. The aquifer parameters are summarized in the table8-3 below.

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

parameters	Source of Data (from GSI Report)	BH1 Value
Transmissivity (m2/d)	Local	500
Permeability (m/d)	Local	50
Porosity	Assumed	30%
Groundwater gradient	Assumed	0.001
Velocity (m/d)	Local/Assumed	0.17

The extent of the gravels is clearly defined by the local topography. The low and very flat lands to the north of the village in the floodplain of the River Bride contrast with the high ground to the south of the village which is underlain by shallow sandstone and siltstone bedrock. It is likely that there is some water entering the aquifer from surface flow and inter-flow from the higher ground surrounding the aquifer which falls within the catchment of the supply. This will give the aquifer additional resources not identified by simple meteorological calculations.

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 is estimated as follows.

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

Recharge: *506 mm.* In the 2002 GSI Report, the actual recharge is estimated from baseflow separation of hydrographs from Ovens gauging station (19016) as approximately 400 mm per year i.e. or 47% of the annual effective rainfall. The thick sand and gravel formation, and presence of a very shallow water table (less than 2 metres) 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 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 over lain by a well draining soil range from 60 – 100% with an inner range of 80 – 90%.

Because the sand and gravel in this area are not considered to constitute an aquifer in their own right and less permeable clay subsoils have also been identified in the area, applying a recharge coefficient of 80-90% would most likely over estimate the recharge. A recharge coefficient of 60% (506 mm) is therefore proposed which is considered to be conservative.

The bulk ***recharge coefficient*** for the area is therefore estimated to be 60%.

Runoff losses: *338* mm. Runoff losses are assumed to be 40% of potential recharge. This value is based on an assumption the minimum recharge coefficients proposed by the GWG (60%).

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	40%
bulk recharge coefficient	60%
Recharge	**506 mm**

8.7 CONCEPTUAL MODEL

- ✓ The abstraction rate automatically responds to demand and the abstraction is known to fluctuate. The average abstraction is 145 m3/d (around 15 hours per day).
- ✓ The borehole abstracts water from a sand/gravel deposit
- ✓ It has primary porosity and permeability and has intergranular flow. The permeability estimated in the GSI Report is at approximately 50 m/d. Assuming an aquifer thickness of 10 metres, this gives a Transmissivity of 500 m^2/d. The porosity is estimated at 30%.
- ✓ The hydraulic gradient in the gravel is assumed, of the order of 10^{-3}.
- ✓ The direction of local groundwater flow is assumed to be the north or north-west towards the River Brouen.
- ✓ It assumed that the recharge occurs in the Sand and Gravels Formation (Extreme Vulnerability).

The conceptual model is outlined by a schematic cross-section (Figure6).

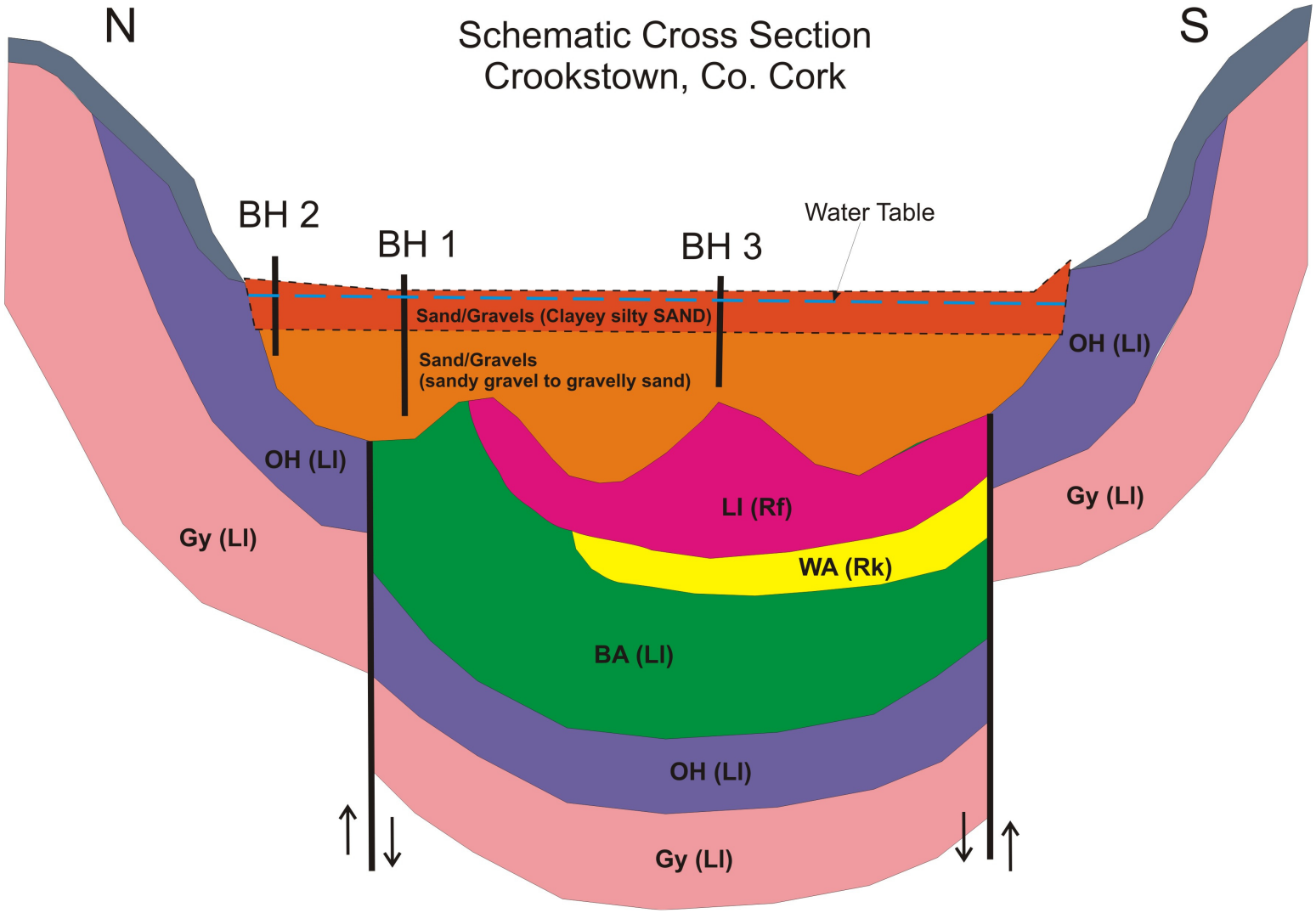

Figure 6 Schematic Cross-section

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.

The Southern boundary is defined by the southern limit of the alluvium (Sand and Gravel) formation.

The Western and Eastern boundaries are conceptualised by groundwater flow-lines within the Sand and Gravels Formation, which are themselves defined by the topography of the area.

The Northern 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).

$xL = Q / (2\pi * T * I)$ 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 145 m^3/d, the transmissivity is 500 m^2/d and the hydraulic gradient is 0.001. This gives an approximate down-gradient extent of 46 metres.

Water balance

The water balance calculations indicate that at a recharge of 506 mm/yr an average discharge of 145 m^3/day would require a recharge area of 0.1055 km^2. The boundaries of the ZOC are shown on Figure 7.

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 outline in section 8.5, the groundwater velocity is estimated as being in the region of 0.17 metres per day therefore the 100-day time of Travel (ToT) is 17 metres.

10 GROUNDWATER PROTECTION ZONES

Groundwater protection zones are shown in Figure 7 and are based on an overlay of the source protection areas on the groundwater vulnerability. Therefore the groundwater protection zones are SI/H and SO/H. The majority of the area is designated SI/E.

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

Source Protection Zone	% of total area (0.1055 km^2)
SI/High	99% (0.1046 km^2)
SO/ High	1% (0.0009 km^2)

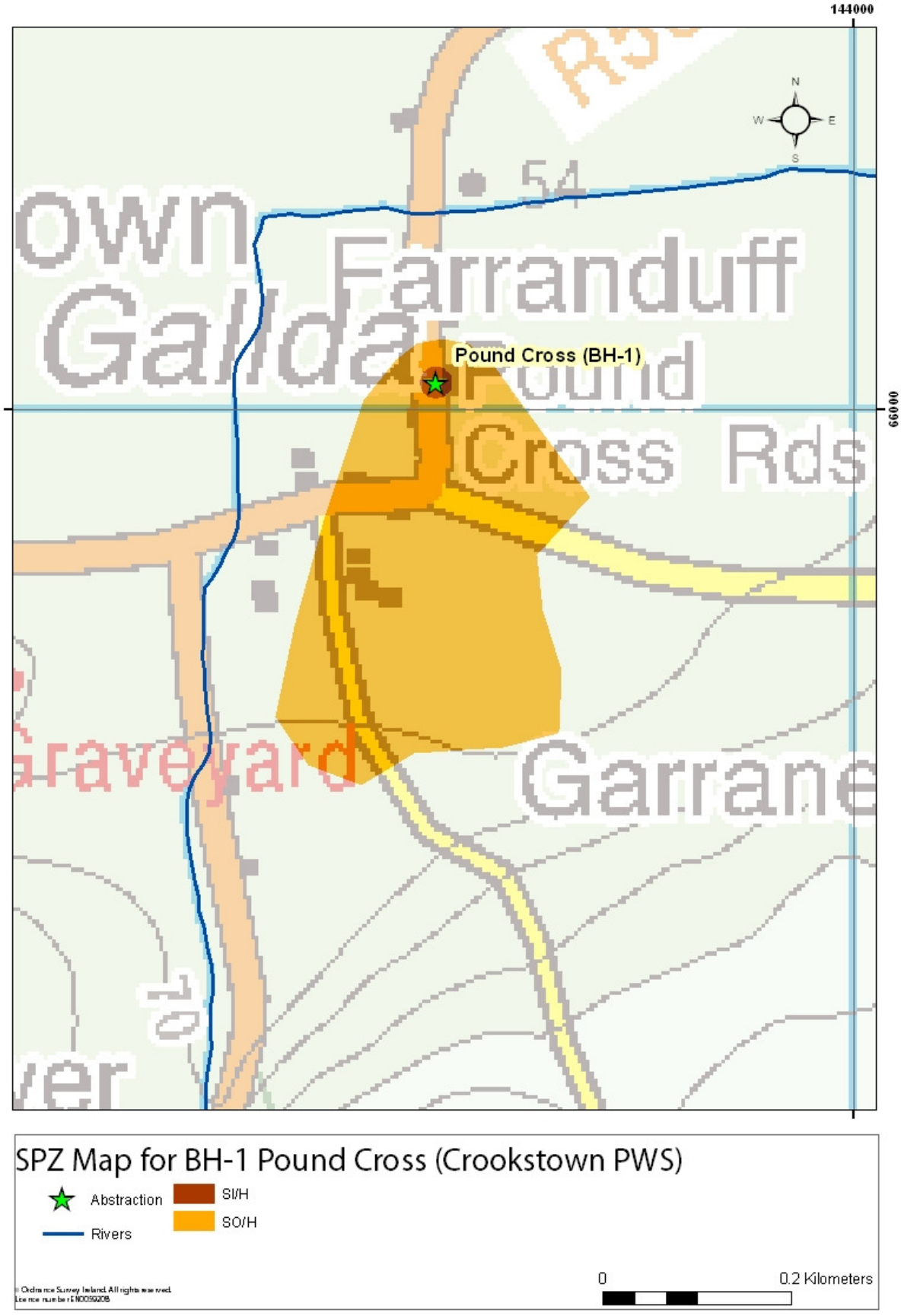

Figure 7: Groundwater Protection Zones

11 POTENTIAL POLLUTION SOURCES

11.1 INNER ZONE:

There are four single houses (4 No.) located within the inner source protection zone. The borehole is located within the garden of one of these houses (Photo 8). OCM understand that the houses are equipped with individual septic tanks which discharge to percolation areas down and up hydraulic gradient of the borehole. Given the high water table and presence of individual septic tanks there is the potential for microbial contamination of the water supply.

The R585 is located adjacent to the borehole (2 metres) and runs from the South to the North (Photo 8). There is the potential that a diesel or petrol spill from the road could discharge into the road and contaminate the well. There is however a slight upward gradient from the public road to the well which might limit the impact of a spill along the road.

Photo8: Borehole Location

11.2 OUTER ZONE

There is a dairy farm located about 180 metres south of the borehole. The farmyard is paved with concrete and the surface water run-off from the concrete area is collected in a drain which discharges to an underground tank. The slurry storage area appears to be well managed and the tanks appear to be in good repair. However there is no information available regarding the structural integrity of the tanks. The storage area is a potential point source of pollution

Approximately 230 metres to the southwest of the borehole there is a vehicle repair garage. The surface water run-off from the paved areas around the garage is collected in a drain which discharges to an oil interceptor. Battery and oil are stored in a bunded container before to be recycled respectively by H-Volt Ireland Limited Recycling Division and Atlas Oil Recycling. The garage is serviced by a septic tank.

12 CONCLUSIONS

The public water supply at Crookstown comprises two boreholes. BH1, which is the subject of this report is located in the garden of a house, beside the R585 and close to Pound Cross Roads (east of Crookstown village). BH2 is located 1.4 km away to the west of Crookstown village.

The borehole, BH1 is currently abstracting an average of 145 m3/day. The well is, 27 m deep and is located in a sand and gravel formation. Testing of wells in the formation nearby indicates that potentially much higher yields are sustainable in this formation.

The formation is not classified by the GSI as a Locally Important Aquifer sand/gravel aquifer though it could potentially be characterised as an Lg aquifer. The alluvium is underlain by the Little Island Formation and Waulsortian Limestone which are classified as Karstified Aquifers (Rk) and Ballysteen Formation and the Old Head Sandstone which are classified as Locally important Aquifers (Ll).

While the aquifer vulnerability indicated by the GSI is Moderate, the depth to water in the borehole of less than 2m indicates that the vulnerability may be extreme.

There is currently no pre-treatment monitoring of water quality being undertaken at BH-1. Hydrochemical data have been obtained from the BH2 well located in the same formation to assess general hydrochemistry. The groundwater is considered to be typical of water from a non-limestone formation with conductivity ranging from 250 – 300 uS/cm. Nitrate levels at BH-2, which are considered indicative of the formation generally, have ranged from 20-25mg/L over the past 10 years. The nitrate levels, while above background are not of concern and reflect the agricultural nature of the catchment.

The Zone of Contribution to BH1 is estimated as 10.5 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.

There is potential for the Pound Cross Water Supply Well to be contaminated because of its location in the drive way of a private dwelling.

13 RECOMMENDATIONS

Given that Pound Cross is the larger of two abstraction wells providing water for the Crookstown Water Supply Scheme it is recommended that this well be incorporated into the EPA groundwater monitoring programme instead of BH-2 at Bellmount Lower.

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

It is recommended that measures be taken to ensure that the well is properly sealed at the surface to minimise the risk of surface based contaminants (eg from an oil spill in the drive way or adjacent public road) from entering the well.

14 REFERENCES

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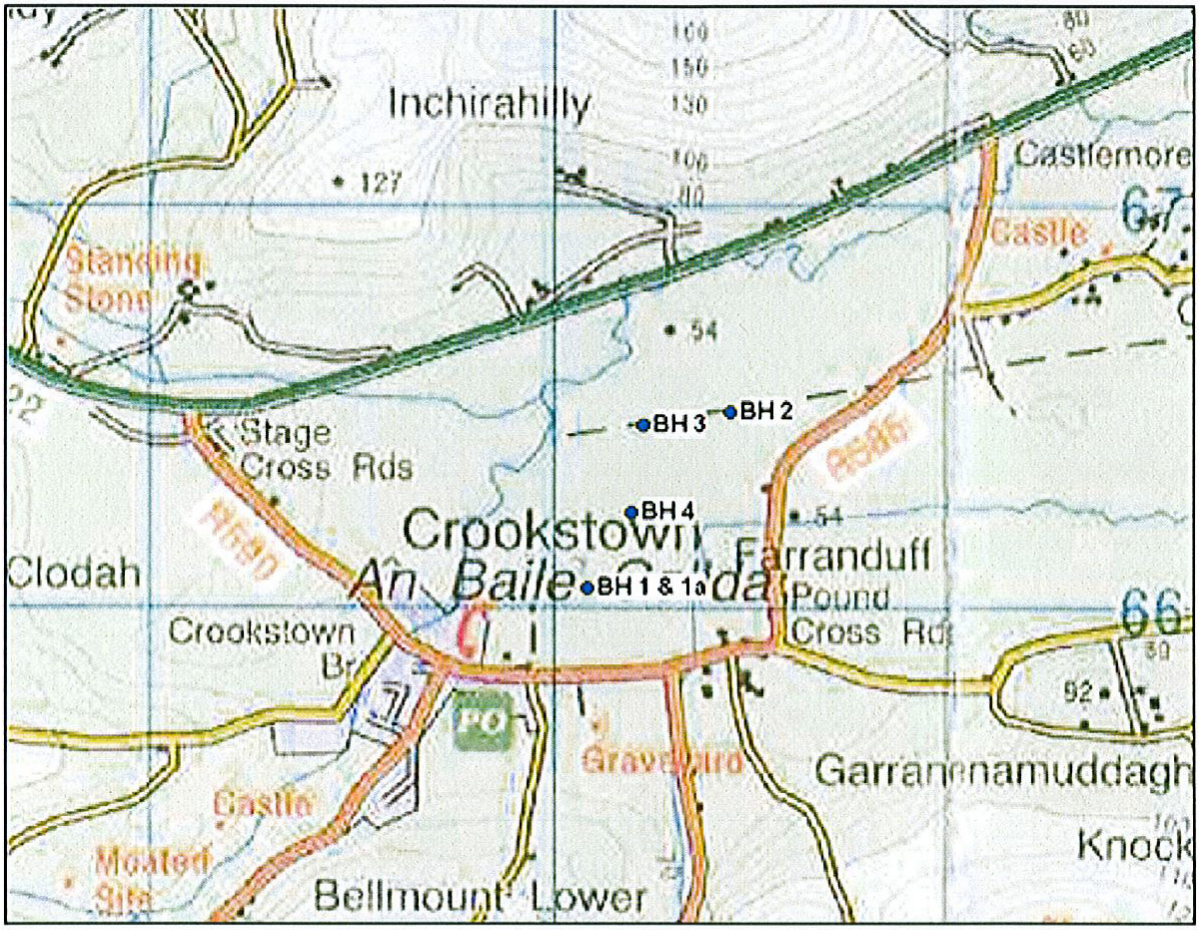
APPENDIX 1

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			