Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Cuffesgrange Water Supply Scheme

Cuffesgrange Borehole

May 2010

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PROJECT DESCRIPTION

Since the 1980's, the Geological Survey of Ireland (GSI) has undertaken a considerable amount of work developing Groundwater Protection Schemes throughout the country. Groundwater Source Protection Zones are the surface and subsurface areas surrounding a groundwater source, i.e. a well, wellfield or spring, in which water and contaminants may enter groundwater and move towards the source. Knowledge of where the water is coming from is critical when trying to interpret water quality data at the groundwater source. The Source Protection Zone also provides an area in which to focus further investigation and is an area where protective measures can be introduced to maintain or improve the quality of groundwater.

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

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

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1 INTRODUCTION

Groundwater Source Protection Zones (SPZ) are delineated for the Cuffesgrange 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 Cuffesgrange Borehole is the main source for the village of Cuffesgrange and the surrounding area located adjacent to the N76 Kilkenny to Clonmel national road.

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the Cuffesgrange area.
- To delineate source protection zones for the Cuffesgrange Borehole.
- To assist the EPA, EPS and Kilkenny County Council in protecting the water supply from contamination.

Groundwater protection zones are delineated to help prioritise the area around the source in terms of pollution risk to groundwater. This prioritisation is intended as a guide in evaluating the likely suitability of an area for a proposed activity prior to site investigations. The delineation and use of groundwater protection zones is further outlined in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

The maps produced are based largely on the readily available information in the area, specific field work for this source 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.

The borehole was drilled in 1970 by Flood Drilling Ltd., Borris, Co. Carlow and operated as a group water scheme until 2007. Control of the GWS has since ceded to EPS as part of the South Leinster Design-Build-Operate (DBO) scheme.

Kilkenny County Council, in partnership with Kildare, Carlow, Laois, Wexford and Wicklow County Councils, have grouped together 32 previously individual rural group water schemes, spread across six counties as part of the South Leinster DBO.

T.J. O'Connor & Associates were appointed as the Clients' Representative. EPS Pumping and Treatment Systems (the DBO operators) commenced work on the Cuffesgrange scheme in 2007.

2 LOCATION, SITE DESCRIPTION AND WELL HEAD PROTECTION

The Cuffesgrange source, located within Cuffesgrange Village as shown in Figure 1, supplies approximately 40 houses, Cuffesgrange national school, church, local farms and small businesses. Cuffegrange is located within the Nore River catchment, 6km southwest of Kilkenny City adjacent to the N76. Since taking over the scheme, additional treatment and security measures have been implemented at the Cuffesgrange Borehole.

The borehole is not grouted and no further details are available at the time of writing.

The borehole is securely located within a compound. The water is pumped into the pump house where the untreated water is chlorinated. Water is then pumped directly into the distribution network from the chloride contact tank. The scheme is monitored remotely using an eSCADA system. The eSCADA system remotely monitors flow, water level and chloride levels at the Cuffesgrange scheme and sends updates to EPS staff.

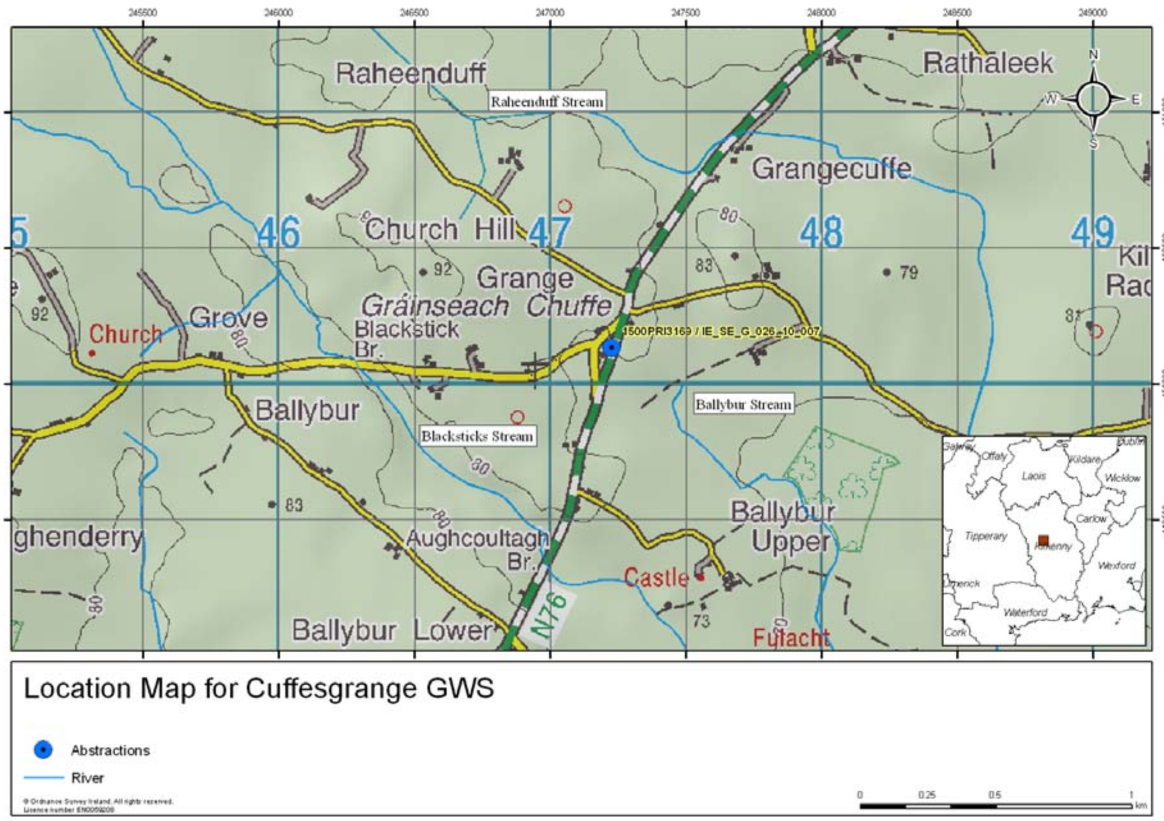


Figure 1 Location Map

3 SUMMARY OF WELL / BOREHOLE DETAILS

The borehole was drilled to 12.4 mbgl, with an 8″ steel casing into bedrock. The borehole casing depth is 7.5m deep (pers comm. Jim Fennelly, former caretaker). Typically the casing is completed in bedrock, therefore the assumed subsoil depth is less than 7m. GSI well database records suggest the depth to bedrock is c. 12 m with some local information suggesting the depth to bedrock is less than 3m. The borehole is not grouted and no further details are available at the time of writing.

Approximately **50 m^3/day** is abstracted from the borehole at present. Previously in excess of 100 m^3/day was pumped at times, with distribution losses accounting for the balance. Improvements in leak detection has reduced abstraction to 50m^3/day. The borehole was dipped on the 23rd November 2009 to establish the groundwater level, following three weeks of heavy rainfall. Water levels within the well were measured during a site visit at 5.5 m bgl with a drawdown of 0.5 m during pumping and 5.96 m bgl (pump on, 290 m^3/day). The borehole, although only 12. 4m deep, has never run dry in its 40 years of operation. Table 3-1 provides a summary of the borehole details as currently known.

Photograph 1 Cuffesgrange GWS

Table 3-1 Summary of borehole details

EU Reporting Code	IE_SE_G_026_10_007
Grid reference	E247227 N150133
Townland	Grangecuffe
Source type	Borehole
Drilled	1970
Owner	Kilkenny County Council
Operator	EPS
Elevation (Ground Level)	~82.5m OD
Depth	12.4 m
Depth of casing	-
Diameter	0.2 m
Depth to rock	Unknown. GSI records suggest c. 12 m
Static water level	5–8 m bgl
Consumption (EPS records)	50 m^3/d
Specific capacity	c. 285 m^3/m/day
Transmissivity	c. 400 m^3/m/day

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 initial site visit and interview with the caretaker took place on 28/11/2009.

Site walk-overs and field mapping of the study area (including measuring the electrical conductivity and temperature of streams in the area) were conducted on 28/11/2009 and 01/12/2009 and 02/12/2009.

5 TOPOGRAPHY, SURFACE HYDROLOGY AND LAND USE

The topography around the source area comprises gently rolling land (70–90 mOD), with a gentle gradient from west to east. Typical topographic gradients in the study area range from between 1:50 to 1:200.

The source is located within the River Nore catchment with three surface water streams evident within 1 km of the source. The main stream (Blacksticks Stream) is located 0.7 km southwest of the source and flows in a southeasterly direction. Another stream (Raheenduff Stream) is located 0.7 km to the north, flowing to the southeast. Ballybur stream rises from an area of springs approximately 0.3 km to the southeast and also flows in a southeasterly direction. These surface water features were identified from existing data sources and site visits in November 2009.

There is a moderate density of drainage ditches located to the west of the source, with a high density of drainage ditches located approximately 300 m to the southeast.

The population of Cuffesgrange and the surrounding area is less than 200. Over the last five years, approximately ten houses have been built in the area surrounding Cuffesgrange, particularly to the west of Cuffesgrange Borehole. Land use in the area is primarily agricultural, with lands set to pasture or used for tillage. A number of farmyards have been noted in the area. The nearest farmyard is located 350 m to the west of the source. Cuffesgrange church, graveyard and school are located 300 m to the west of the borehole. A number of small businesses are located within 1 km of the village, comprising warehouses (approximately three) and a local pub.

A large area (>1 km^2) of managed forestry is located within a wet area, 300 m to the east of Cuffesgrange Borehole.

6 GEOLOGY

6.1 BEDROCK GEOLOGY

This section briefly describes the relevant characteristics of the geological materials that underlie the Cuffesgrange source. The geological information is based the bedrock geological map of Tipperary Sheet 18, 1:100,000 Series (Archer et al, 1996) and the GSI Karst Database. The bedrock map (Figure 2) indicates borehole is underlain principally by dolomitised Waulsortian Limestones, which are also described as the Dinantian Dolomitised Limestones for the purposes of the generalised rock unit map prepared by the GSI for characterising and describing the groundwater bodies for the Water Framework Directive.

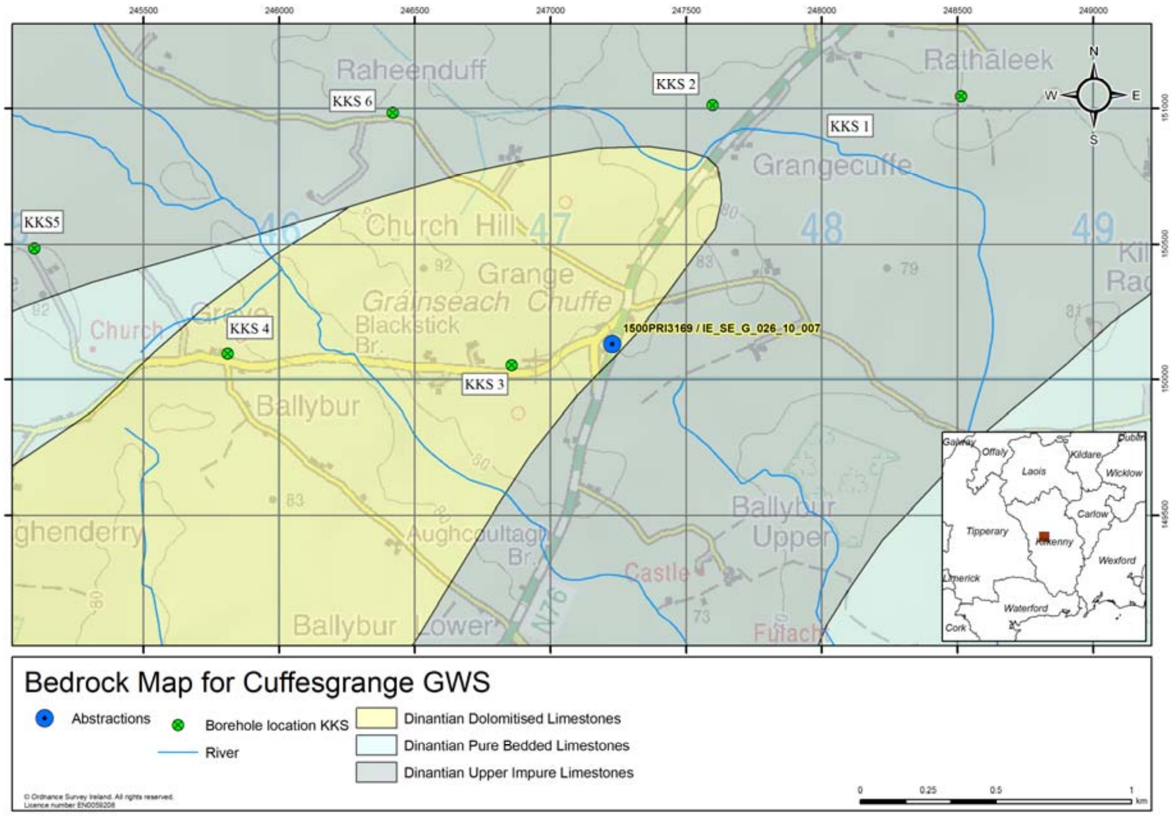


Figure 2 Bedrock Geology

The mapped distribution of the Waulsortian dolomite limestones is bounded by Dinantian Upper Impure Limestones of the Aghmacart Formation to the north, west and east. The GSI maps are primarily based on data from 1980-1994 and do not take into account exploratory drilling conducted by RioFinex (Blaney, D., 1996). Six boreholes were drilled by RioFinex within 2 km of the source, to depths between 23 m bgl and 487 m bgl. Borehole logs are included in Appendix I. All boreholes encountered partially to completely dolomitised bedrock, with the degree of dolomitisation varying from minor veining to complete re-crystallisation A revised geological bedrock map (Blaney, D., 1996) was proposed and is included in Appendix I. Caution should be used in using geological maps for the area as the formation of dolomite alters the original bedding and structure of the limestone. The geology map used within this report reflects the current GSI bedrock map (Archer et al, 1996). Dolomite is a calcium and magnesium bearing carbonate rock (Archer et al, 1996). Dolomite undergoes a significant mineralogical change after it is deposited as calcium carbonate and results in an increase in secondary intergranular porosity.

Dinantian Pure Bedded Limestones are composed of clean-bedded limestone and contain varying amounts of dolomite. The presence of dolomite is significant as it is generally associated with high permeability limestone and therefore has potential for high yielding wells. Based on Riofinex drilling records, the area mapped by the GSI, as Aghmacart Formation and Waulsortian Formation are both dolomitised. Drilling is thought to have encountered 'buff' coloured dolomitised limestone bedrock at the borehole source.

No surface exposures of bedrock were identified or mapped during field studies conducted around the source in November 2009.

6.1.1 Karst Geology

Hydrogeological mapping (November 2009) included searching for karst features in the vicinity of the source. One karst feature as listed in Table 6-1 is recorded in the GSI Karst Feature Database within a 2 km radius of the source.

Table 6-1 Karst features within a 2 km radius of Cuffesgrange source

Number	Feature type	Feature name	Easting	Northing	Distance to source	Townland
K1	Spring	St Dallan's Well	247940	148310	2 km southeast	Burnchurch

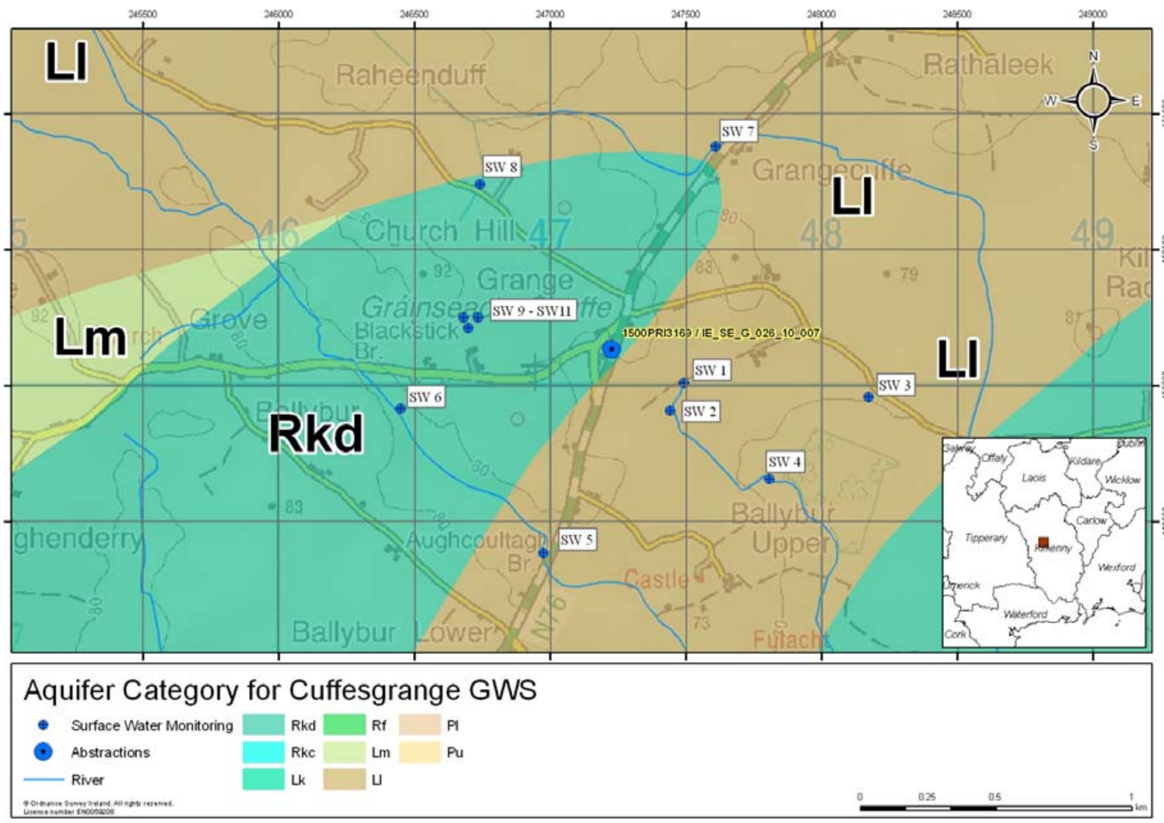


Figure 3 Aquifer, Karst Features and water monitoring locations map

6.2 SUBSOILS GEOLOGY

According to GSI and EPA web mapping, the study area is dominated by till derived from Namurian Shale and Sandstones (TNSSs). However, this map depicts till at and just below the surface only, and from an examination of historical mapping data from the EPA Soil and Subsoil Mapping Project, in areas adjacent to Cuffesgrange two till units occur, stacked on top of each other. These areas host till derived from limestone at depth, capped by the till derived from Namurian rocks just below the surface, which has been carried from the area of Namurian rock-outcrop 6 km to the northwest. The

Cuffesgrange locality seems to have a similar scenario occurring from secondary indicator data gathered in the current project (see below).

A large area of alluvial deposits is also located just over 300 m to the east of the borehole. This flanks a small stream and is likely to be underlain by till.

The soils surrounding the borehole and to the east are dominated by 'dry' soil types: typically well drained deep mineral soils (AminDW). Areas of poorly drained deep soils (AminPW) are mapped surrounding the alluvial area to the east and >1km to the north and northwest (EPA website and An Foras Talúntais, 1981).

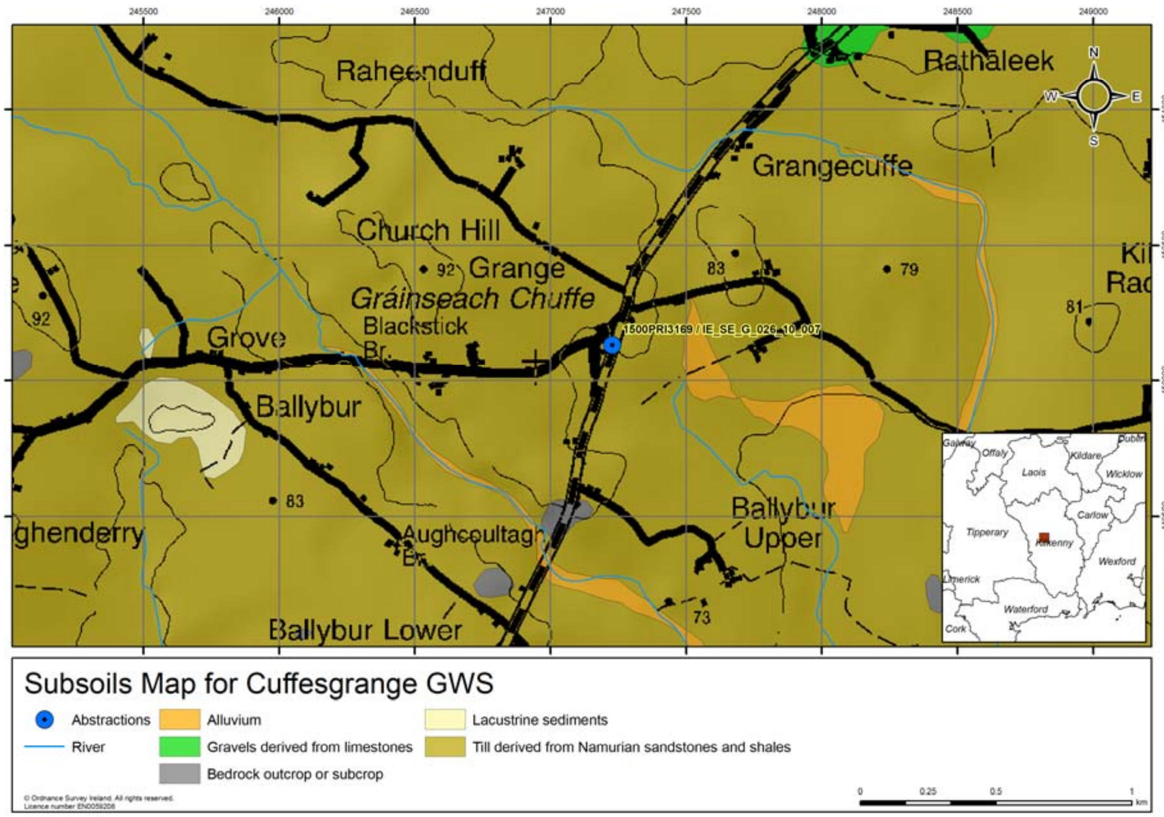


Figure 4 Subsoil Map

The subsoils across County Kilkenny have been classified according to British Standard 5930 in the preparation of the Groundwater Vulnerability map for Kilkenny County Council, by the Geological Survey of Ireland. The data were made available for the preparation of this report. The subsoil permeability of the Namurian till unit has been classed as '***Moderately Permeable***'.

Based on the presence of intensive agriculture/tillage, it is considered that the till is relatively free draining and that the Namurian subsoils are dominated by '*Low Permeability*' while that of the underlying limestone till is classed as 'Moderate Permeability'. Given that the till derived from Namurian rocks forms only a thin layer just below the surface in the locality, the moderate permeability material dominates with respect to bulk permeability characteristics.

Based on the presence of intensive agriculture/tillage, it is considered that the entire till sediment pile is relatively free draining and that the subsoils are dominated by '**moderately permeable**' sediments, in keeping with the overall subsoil permeability categories. However, following field inspections, small areas of 'low' permeability material are thought to occur; these are most likely pockets of land where the surface layer of till derived from Namurian rocks is slightly deeper. In these areas, stagnant surface water ponds were noted on Church Hill (<5 hectares), rushes/sedges/creeping buttercup. Based on field indicators, the general subsoil permeability is likely to occur at the lower end of the 'moderate' spectrum.

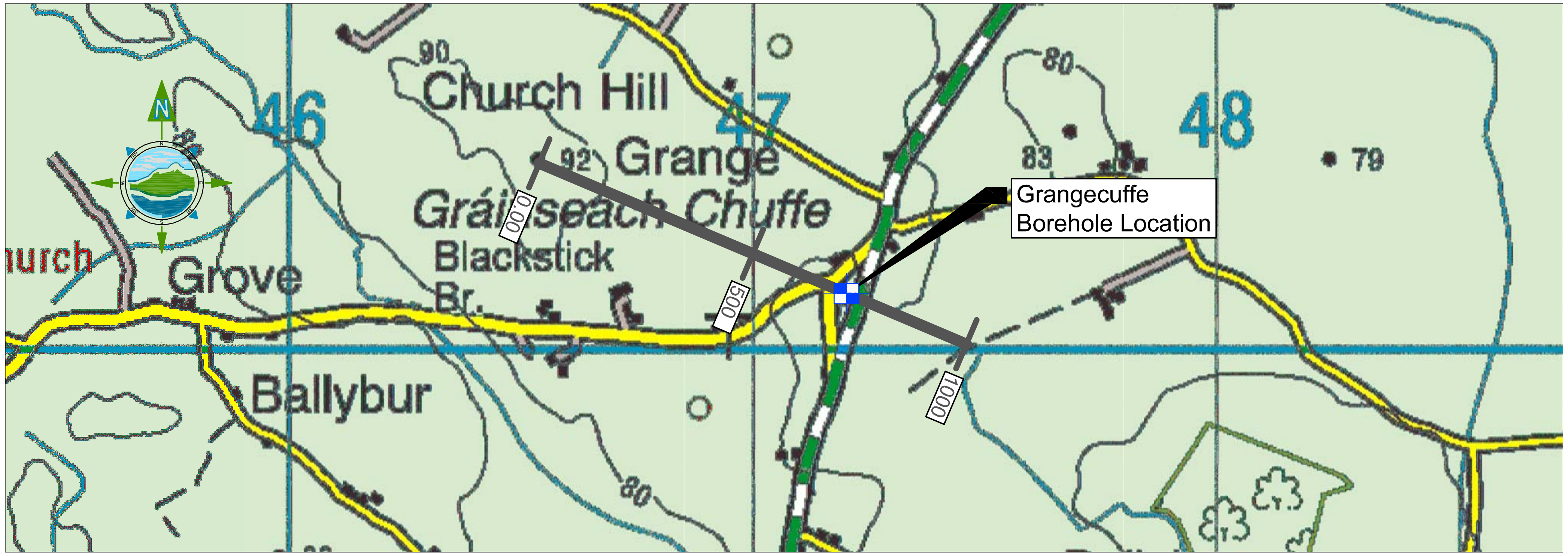
6.3 DEPTH TO BEDROCK

Depth to bedrock varies greatly throughout the study area. The GSI hydrogeological mapping suggests that the depth of subsoil is generally less than 3 m on Church Hill, increasing in depth in all directions. Local information on the graveyard on Church Hill indicates that the depth to bedrock at this location is 2m, with some graves encountering bedrock.

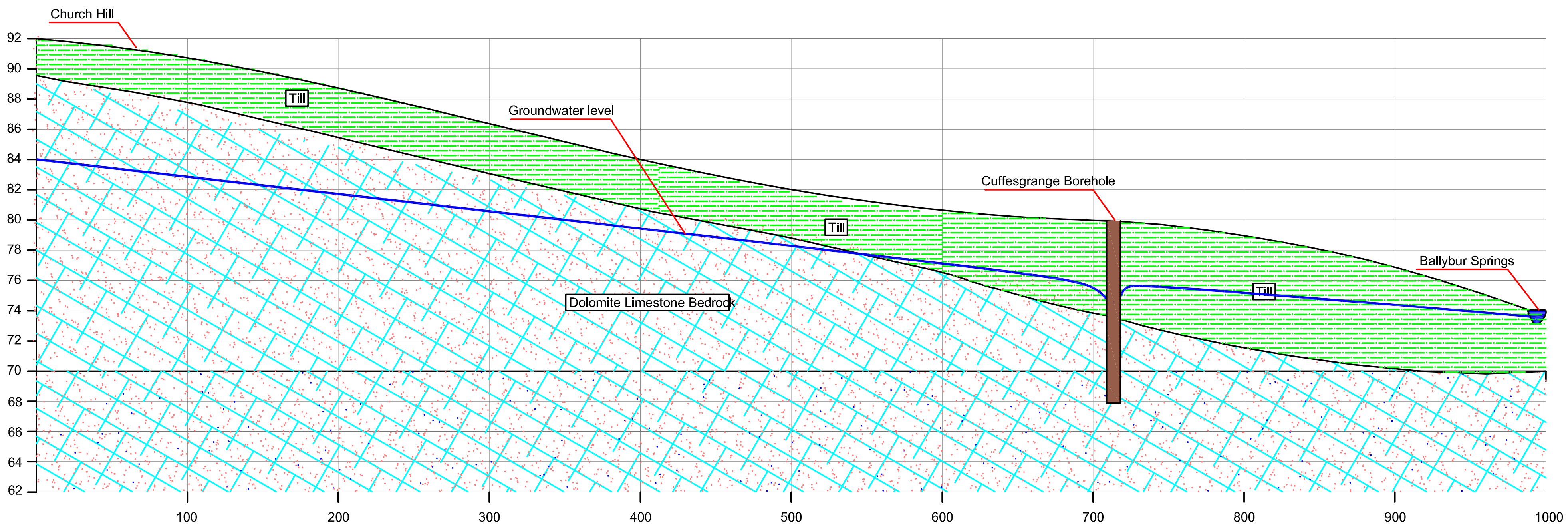
A conceptual cross section through the subsoil/bedrock across the source area is shown in Figure 5. Site investigation data from borehole drilling in the surrounding area (Blaney, 1996) established that the depth of subsoil in the area surrounding the borehole is typically between 6 and 20 m deep. Refer to Table 6.2 and Figure 3.

Table 6-2 Depth to Bedrock

Borehole/Exposure ID	Depth to Bedrock (mbgl)
KKS1	6
KKS2	16.9
KKS3	12
KKS4	20.9
KKS5	6.5
KKS6	6
KKD1	16
KKD2	6.9
KKD3	10



LOCATION MAP SHOWING LOCATION OF LONGITUDINAL SECTION
Scale 1:12,500



LONGITUDINAL SECTION SHOWING GEOLOGY AND GROUNDWATER LEVELS
Scale H: 1:4,000 V: 1:400

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL DRAWINGS TO BE CHECKED BY THE CONTRACTOR ON SITE
3. ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
4. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.
B	11.11.09	DRAFT ISSUE FOR REVIEW	MN	JD

Client: EPA / GSI

Project: CUFFESGRANGE BOREHOLE

Title: CONCEPTUAL LONGITUDINAL SECTION NW - SE

Scale @ A3: As Shown

Prepared by: M. Nolan | Checked: J. Dillon | Date: Jan 2009

Project Director: D. Grehan

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Drawing No.: 5604-2814 | Issue: B

7 GROUNDWATER VULNERABILITY

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. 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 groundwater vulnerability map is shown in Figure 6. It was amended for the study area based on new depth to bedrock from borehole drilling (Blaney, 1996), described in the previous section. The area around the source ranges from Extreme to Moderate Vulnerability.

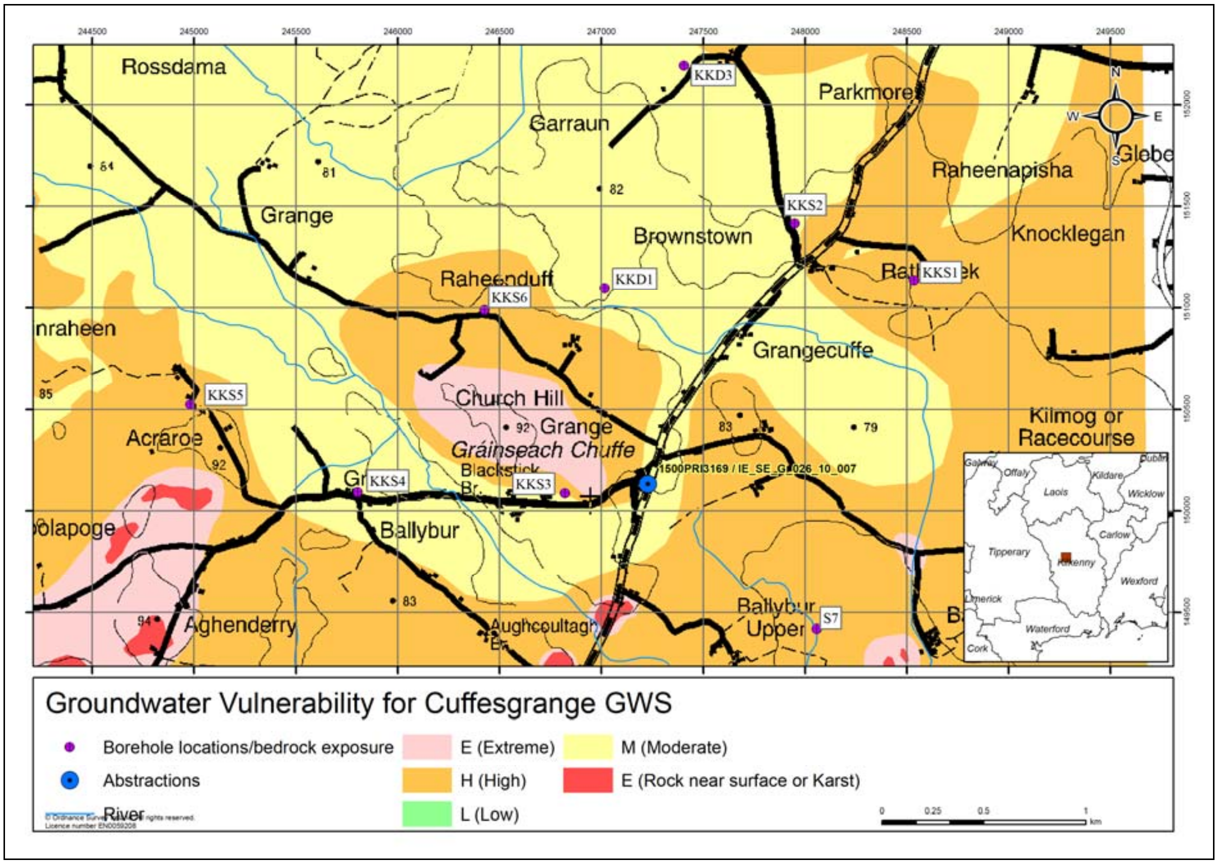


Figure 6 Proposed Groundwater Vulnerability Map

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 Well Database
- ⇨ County Council Staff
- ⇨ EPS Staff
- ⇨ EPA website and Groundwater Monitoring database
- ⇨ Local Authority Drinking Water returns

- ⇨ Hydrogeological mapping by TOBIN Consulting Engineers and Robert Meehan in September and November 2009.
- ⇨ County Kilkenny Groundwater Protection Scheme (GSI, 2004).

8.1 GROUNDWATER BODY AND STATUS

The area around Cuffesgrange, including the townland of Grangecuffe, is included in the Callan Groundwater Body which is of Poor Status www.wfdireland.ie/maps.html. The groundwater body descriptions are available from the GSI website: www.gsi.ie and the 'status' is obtained from the Water Framework Directive website: www.wfdireland.ie.

8.2 METEOROLOGY

Establishing groundwater source protection zones requires an understanding of general meteorological patterns across the area of interest. The data source is Met Eiréann.

Annual rainfall: 858 mm. The closest meteorological stations to the Cuffesgrange Source are at Callan and Kilkenny. The 858 mm figure is based on the long term average annual rainfall data from Met Éireann (Fitzgerald and Forrestal, 1996). The contoured data map of rainfall in Ireland (Met Éireann; 1961-1990 dataset) show that the source is located between the 800 mm and 1000 mm average annual rainfall isohyets.

Annual evapotranspiration losses: 435 mm. Potential evapotranspiration (P.E.) is estimated to be 458 mm/yr (based on data from the Met Éireann Kilkenny synoptic station). Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits.

Annual Effective Rainfall: 423 mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this, or 423 mm/year. See section on recharge which estimates the proportion of effective rainfall that enters the aquifer.

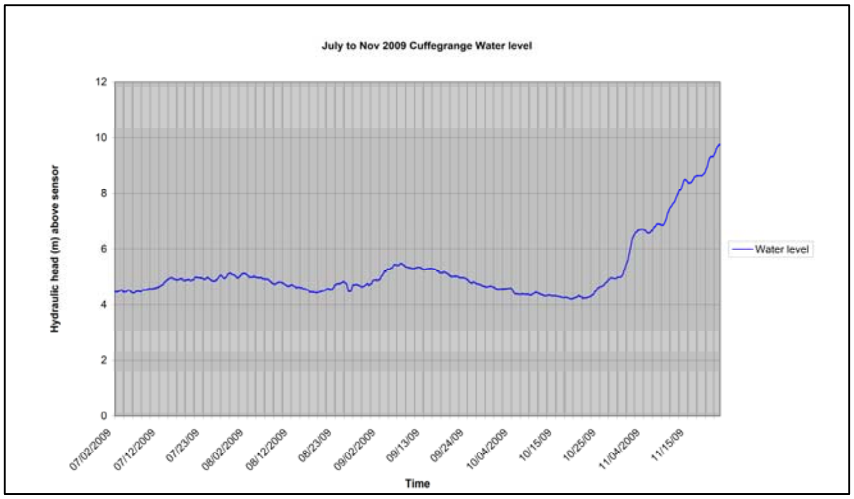
8.3 GROUNDWATER LEVELS, FLOW DIRECTIONS AND GRADIENTS

The borehole was drilled in 1970 and no borehole log or pumping test data were available for this report. A pumping test was completed at the time of drilling but records are not available. GSI records indicate that the well yield was 131 m^3/day. Anecdotal evidence from the former caretaker and EPS staff indicates that the borehole has never run dry. Based on a borehole depth of 12.4 m, 7 m of hydraulic head is present within the borehole in winter and approximately 4m in summer.

Water levels within the well were measured during a site visit at 5.5 m bgl with a drawdown of 0.5 m during pumping and 5.96 m bgl (pump on, 290 m^3/day or 12.1 m^3/hour).

A continuous level monitor is installed at the source with levels detailed below in table 3.1. Caution should be used when using the eSCADA water levels. The eSCADA water levels appeared to vary (by 1m) compared to manual dip meter readings (0.5m variation). The eSCADA water level meter may require recalibration.

Table 8-1 Water levels in Cuffesgrange borehole



Note: All available data from eSCADA system. Values based on 24 hour average.

Groundwater levels in the surrounding area are estimated to be lower than the topographical contours to account for the absence of surface water features on Church Hill. Groundwater gradients are expected to be relatively flat and are calculated to be 0.01. Accurate level data in this area could provide more conclusive information on flow directions. Flow directions are assumed to broadly focus towards the spring discharge areas (Ballybur Stream & Blacksticks Stream), mirroring topography.

8.4 HYDROCHEMISTRY AND WATER QUALITY

The hydrogeological field mapping carried out in November 2009 and December 2009 included obtaining field measurements of electrical conductivity and temperature of surface water features which provides information on potential groundwater discharges to the Ballybur stream. Table 8-2 provides the field results of 2nd December 2009.

Monitoring of the Ballybur stream indicates a moderately high electrical conductivity (approximately 530 µS/cm @ 25°C) and temperature (10.2 °C) compared to areas of standing surface water (<400 µS/cm @ 25°C) and temperature (6.1 - 8.2 °C). The springs feeding the Ballybur stream have high conductivity values indicating the Ballybur stream is primarily groundwater fed. Measurements were taken after three weeks of high rainfall and a component of surface water dilution is expected.

Lower conductivity levels were recorded in Blacksticks stream and Raheenduff stream, indicating that these streams are predominantly surface water runoff fed with minor groundwater discharge (Refer to table 8.1). Small changes of conductivity (481 µS/cm) at SW7 indicated a possible groundwater discharge point to the Blacksticks Stream. This location corresponded with a possible spring on the 25″ map. A number of water features on the crest of Church Hill were recorded on the 6″ and 25″ maps. These were investigated to determine if they were surface water or groundwater fed. Low dissolved oxygen levels, low temperature and conductivity indicated these features are rainfall fed (Refer to table 8.2 below).

Table 8-2 Field measurements of electrical conductivity and temperature

SW stream ID	Conductivity (µS/cm @ 25°C)	pH	Dissolved Oxygen %	Temperature °C	Notes
SW 1	532	7.3	50	10.1	Drainage ditch to Ballybur stream
SW 2	526	7.3	48	10.1	Drainage ditch to Ballybur stream
SW 3	528	7.5	62	10.1	Drainage ditch to Ballybur stream
SW 4	513	7.4	45	10.1	Drainage ditch to Ballybur stream
SW 5	510	7.2	50	10.1	Drainage ditch to Ballybur stream
SW 6	410	7.1	75	7.3	Blacksticks Bridge
SW 7	480	7.4	62	8.6	Possible minor spring discharge to Blacksticks stream.
SW 8	390	7.4	63	8.1	Raheenduff Stream
SW 9	360	7.3	82	8.2	Raheenduff Stream
SW10	420	7.2	80	7.9	Raheenduff Stream
SW11	331.4	6.8	1.1	7.4	Surface water feature (pond)
SW12	331	7.0	1.21	7.4	Surface water feature (pond)
SW13	207	7.1	0.5	6.1	Surface water feature (pond)

Eight samples were available from the EPA Groundwater Monitoring Network. The water quality is very hard, (362 to 464 mg/l $CaCO_3$). Alkalinity ranges from 290 to 444 mg/l $CaCO_3$. The pH ranges between 7.0 and 7.4, which is slightly alkaline. The electrical conductivity ranges from 712 to 783 µS/cm. The hydrochemical signature is calcium/magnesium bicarbonate and compares favorably with the signature and data given in the Callan groundwater body description. The calcium/magnesium bicarbonate is typical of dolomite bedrock in County Kilkenny.

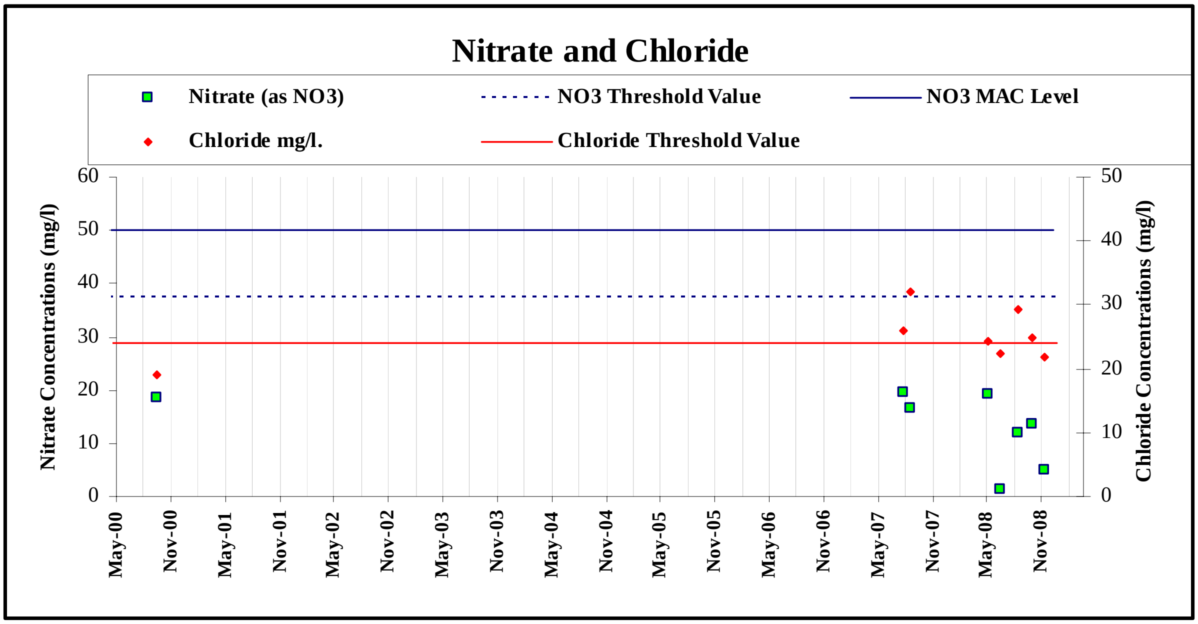
The concentration of nitrate ranges from 1.4 mg/l to 19.6 mg/l with mean of 13.3 mg/l (as NO_3). There are no reported exceedances above the EU Drinking Water Directive maximum admissible concentration of 50 mg/l, or the groundwater threshold value (Groundwater Regulations S.I. No. 9 of 2010) of 37.5 mg/l. Occasional spikes in nitrite and ammonia were noted in the water quality samples but below their respective PVL. The presence of nitrite suggests a potential source of contamination close to source. The area around the borehole is moderately populated and served by septic tank systems. The area around Cuffegrange is under urban influence from Kilkenny City with a number of one off housing developments built within the last five years.

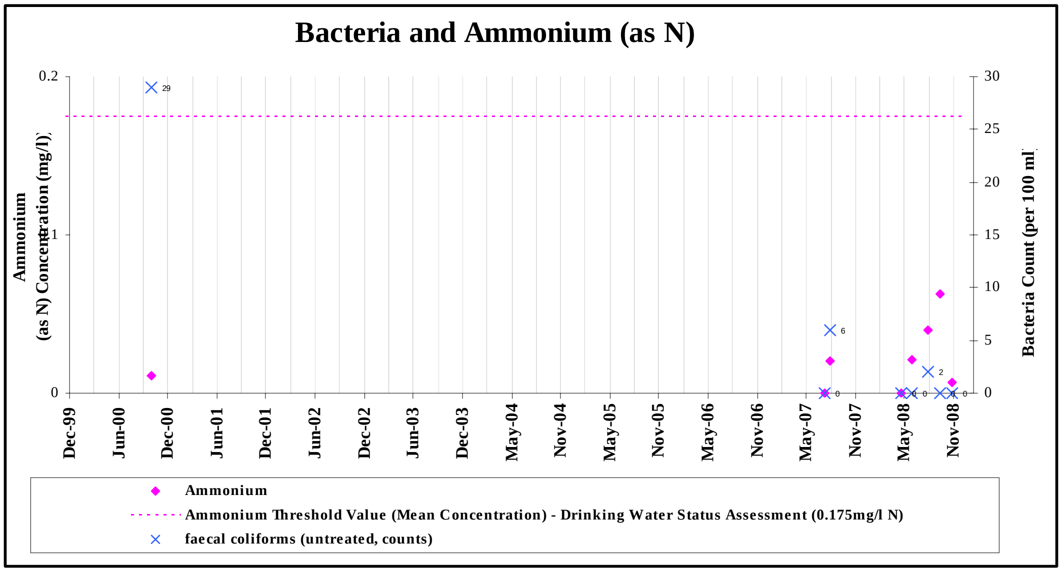
Chloride concentrations range from 19 to 32 mg/l, with a mean of 25 mg/l which is considered to be above the mean natural background level of 18 mg/l (Baker et al, 2007) and above the groundwater threshold value (Groundwater Regulations S.I. No. 9 of 2010) of 24 mg/l for the saline intrusion test. A spike in chloride concentrations in August 2008 may potentially be as a result of contamination from organic sources. The potassium:sodium (K:Na) ratio is high, at 0.32 to 0.49 (see Figure 8). The high K:Na ratio suggests a source of organic contamination (e.g. septic tank systems or farmyards or landspreading of agricultural wastes). Iron and manganese concentrations are low and consistently below their respective Parameter Value Limits (PVL's).

Faecal coliforms were present in the water in 40% of samples, with gross contamination on one occasion (greater than 10 faecal coliforms per 100 ml). Potential sources include agricultural activity and septic tank systems.

The concentrations of sulphate, potassium, sodium, magnesium and calcium are within normal ranges. The concentrations of all other trace metals are low and/or are below the detection limit of the laboratory.

In summary, bacteriological exceedances, a high K:Na ratio, occasional spikes in chloride, nitrite, and ammonia concentrations suggest contamination from an nearby organic source. Nitrate, which would also usually be expected to be present, may be relatively low because the travel times to the well are so short that the nitrogen is still in the form of ammonia and/or nitrite; or the nitrate is being diluted by high groundwater flows in a high transmissivity zone. All dwellings within 200m of the source are served by septic tank systems. Currently no public sewerage scheme exists for Cuffesgrange.





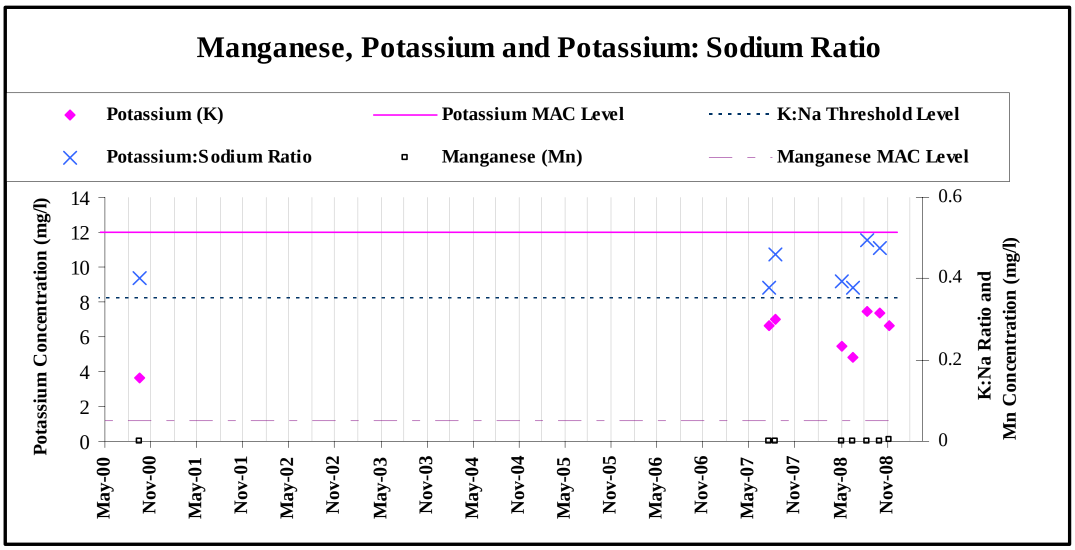


Figure 7 Water quality graphs

8.5 AQUIFER CHARACTERISTICS

The groundwater source is located in the Callan Groundwater Body. The GSI bedrock aquifer map of the area indicates that the Dinantian Dolomite Limestone (Dolomitised Waulsortian Limestones), is classified as a *Regionally Important Diffuse Karstified Aquifer* (RK_d) dominated by diffuse flow.

Flow in the aquifer is assumed to occur through a network of fractures, fissures and joints, which are well connected and widely dispersed, resulting in a relatively even distribution of highly permeable zones. Groundwater velocities through fissures/conduits may be high and aquifer storage and permeability are enhanced by the presence of dolomite. Porosity within the dolomite limestone is relatively high at approximately 5% (Blaney, 1996).

A yield test was commissioned by T.J. O'Connor & Associates in September 2004 but due to supply requirements, the test was limited. The yield test was conducted over a 4 day period with water level and flow monitoring data recorded. A pumping rate of 100 m^3/day resulted in a 0.35 m drawdown. Based on the brief yield test in November 2009, the specific capacity of the well is estimated at 285 m^3/m/day. Groundwater levels as measured in December 2009 indicate that the gradient between the well and the spring area is 0.01.

Using the Logan transformation (Misstear, 1998) and a calculated specific capacity (based on yield tests) of 285 m^3/m/day, the transmissivity in the vicinity of the borehole is estimated to be of the order of 350 m^2/day. Transmissivity values throughout the aquifer are likely to vary depending on the degree of fractures/fissures and the degree of dolomitisation present. These values correspond favourably with the Callan groundwater body data, which indicates high transmissivities (50-500 m^2/day).

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

Due to the highly permeable nature of the dolomitised limestone bedrock, there is no recharge cap applied. The recharge is estimated as follows.

Runoff losses are assumed to be 55% of potential recharge (effective rainfall). This value is based on an assumption of *c*. 50% runoff for 70% of the area (extreme vulnerability, moderate permeability subsoils and soils, moderate-high drainage density), and 65% runoff over 30% of the area due to high vulnerability, moderate permeability subsoil (Irish Working Group on Groundwater, 2005).

The bulk ***recharge coefficient*** for the area is therefore estimated to be 45%.

These calculations are summarised as follows:

Average annual rainfall (R)		858 mm
Estimated P.E.		458 mm
Estimated A.E. (95% of P.E.)		435 mm
Effective rainfall		423 mm
Potential recharge		423 mm
Recharge coefficient for extreme Vul + gleyed soil	50%	211 mm
Recharge coefficient for high Vul	35%	148 mm
Averaged runoff losses	55%	232 mm
Bulk recharge coefficient	45%	
Recharge		**190 mm**

8.7 CONCEPTUAL MODEL

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

- The source under consideration in this report comprises a 12m borehole at Grangecuffe, Cuffesgrange, Co. Kilkenny. The abstraction rate from the source is 50 m^3/day, although 100 m^3/d has been sustained in the past.

- GSI maps and mineral exploration indicate a varying degree of karstified dolomitised limestones. The borehole source is completed within the dolomitised bedrock. These features support the aquifer classification of *Regionally important karstified diffuse aquifer* (Rk_d).

- In general, the depth to bedrock is less than 3m on elevated areas, increasing in depth towards the low-lying parts of the study area. Depth to bedrock away from the hilltop is between 3 and 20 m. The subsoils are classified regionally as being 'moderately' permeable with some 'low' permeability areas.

- Groundwater flow directions are likely to be from the hill to the west towards Cuffesgrange borehole source and Ballybur Stream. The natural hydraulic gradients in the aquifer are likely to be moderate, approximately 0.01 (Dec 2009), reflecting the generally moderate to high transmissivity of the limestones. Groundwater levels vary from c. 77.5 m OD on Church Hill to 73.5 m OD towards the spring area adjacent to the Ballybur stream.

- Recharge is predominantly diffuse on the higher ground. The lower ground adjacent to the streams is a discharge zone with several springs known to occur. Surface water ponding occurs on the crest of Church Hill, thought to correspond to localised low permeability subsoil. Surface water flooding is known in Cuffesgrange Village. Over the region, an average recharge rate of 190 mm/year is estimated, which is 45% of the total potential recharge. The remaining 55% of potential recharge runs off to nearby streams. This estimate is based on the extent of moderate to low permeability tills overlying the high permeability aquifer in the area.

- The groundwater is of calcium/magnesium bicarbonate signature and hard. Concentrations of nitrite, chloride and ammonical nitrogen were on occasion above background levels but below their respective PVL. The nitrate concentration is below it's PVL. Gross faecal contamination was recorded on one occasion. Elevated K:Na ratios are regularly recorded indicating that groundwater is impacted by contamination from organic sources. The lack of a grouted borehole seal may be a contributing factor.

- Limitations to the conceptual model mainly lie with a lack of information on the following:
    - ⇨ Site specific depth to bedrock and localized differences in the subsoil permeability. Further information on the depth to bedrock would provide greater detail and confidence in the level of protection afforded by the subsoils and also a greater understanding on the 3D visualization and interaction of the borehole, till and bedrock.
    - ⇨ Surveyed levels of groundwater levels will give confidence to groundwater contours and flow directions.
    - ⇨ Discharge data. Information on this is required to be confident on the size of the area required to provide the water to the borehole.

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 flow to the source, as described in Section 8.7 Conceptual Model.

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 western boundary is based on the topographic divide along the topographical high in Church Hill townland, that is assumed to coincide with the groundwater divide. It is assumed that there is a groundwater divide based on topography between the Cuffesgrange source and the groundwater discharges to the Blacksticks Stream to the south and the Raheenduff stream to the north.

The **eastern** boundary is based on an estimate of the down-gradient distance from the pumping well using the Uniform Flow Equation.

The uniform flow equation (Todd, 1980) is:

$$x_L = Q / (2\pi * T * I) \text{ where}$$

Q is the daily pumping rate

T is Transmissivity (taken from aquifer characteristics)

I is background non pumping gradient.

Given a natural groundwater gradient of 0.01 and an induced borehole hydraulic gradient of 0.5, the maximum distance flow can be induced into the well is 16 m. A 30 m distance is applied for the downgradient boundary for sanitary purposes.

The northern boundary is estimated based on a water balancing exercise and the regional groundwater flow direction. Based on an abstraction of 50 m^3/day on average (max 100 m^3/day) and the estimated recharge of 190 mm/year, a zone of contribution of 0.1 km^2 in area is calculated. Hydrogeological field mapping and the conceptual model determined an area of 0.2 km^2. The ZOC presented is therefore conservative and allows for the unpredictability of heterogeneous flow in a karstified dolomite aquifer.

The Southern boundary is based on the topographic divide along the topographical high between the source and Blackstick Stream. It is assumed that there is a groundwater divide based on topography between the Cuffesgrange source/Ballybur stream and the Blacksticks Stream.

Water balance: Based on an abstraction of 50 m^3/day on average and the estimated recharge of 190 mm/year, a zone of contribution of 0.1 km^2 in area is calculated. Hydrogeological field mapping and the conceptual model determined an area of 0.2 km^2. Current GSI guidance states that ZOC delineation should conservatively account for 150% of the abstraction volume. The ZOC presented is therefore conservative and allows for some groundwater discharge to local streams. Further refinement of the zone of contribution will require further investigation.

9.2 INNER PROTECTION AREA

The Inner Source Protection Area is the area defined by the horizontal 100 day time of travel from any point below the watertable to the source (DoELG, EPA, GSI, 1999). The 100-day horizontal time of travel to the source is calculated from the velocity of groundwater flow in the bedrock. The velocities are normally based on the results of the hydraulic test programme, however, in this instance, the aquifer category of Rk^c, suggests that very rapid groundwater velocities are likely in this area due to karstification of the limestones. Groundwater flow can be focused and travel very fast. Results from tracing programmes in similar rock types indicate velocities in the order of hundreds of metres/day. On this basis, all of the ZOC is designated as part of the inner protection area to the source.

10 GROUNDWATER PROTECTION ZONES

Groundwater protection zones are shown in Figure 8 and are based on an overlay of the source protection areas on the groundwater vulnerability. Therefore the groundwater protection zones are SI/E, SI/H and SI/M. The majority of the area is designated SI/E.

Table 10-1 Source Protection Zones

Source Protection Zone	**% of total area (0.2 km^2)**
SI/Extreme	60%
SI/High	25%
SI/ Moderate	5%

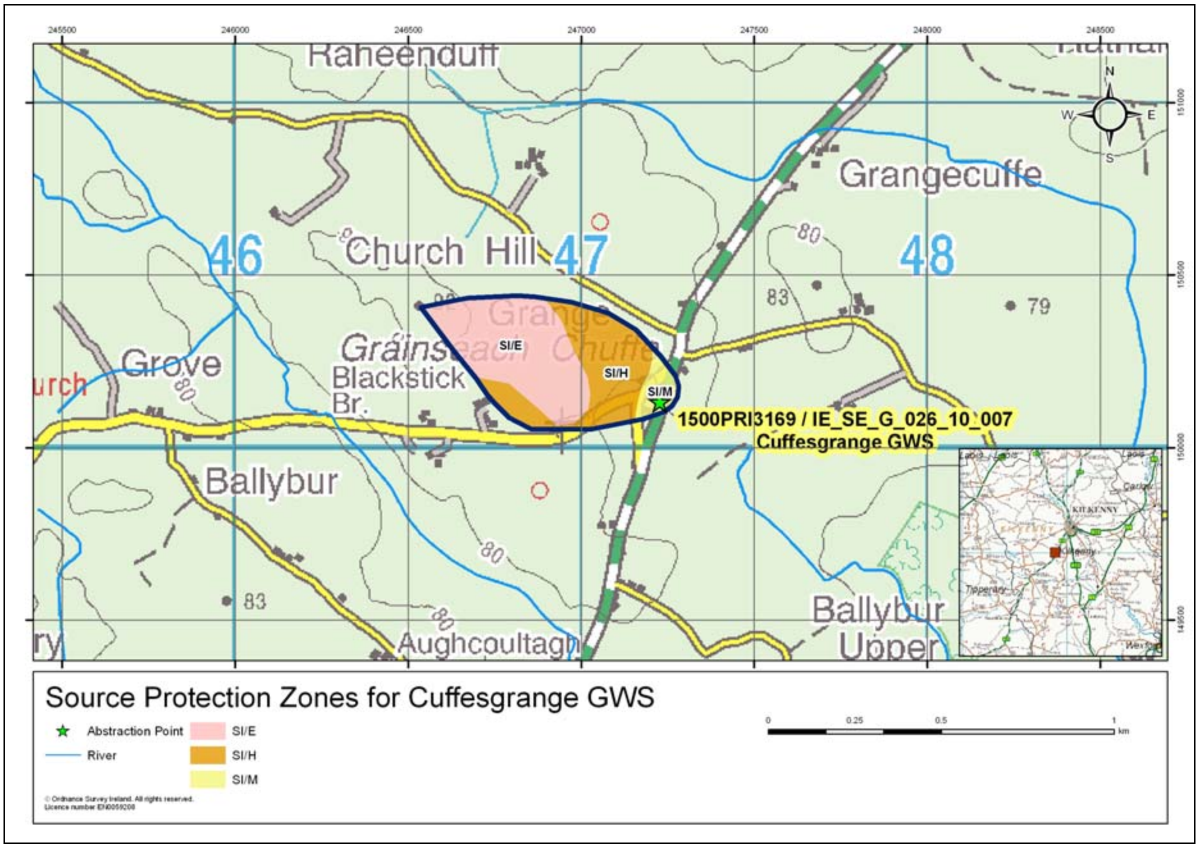


Figure 8 Source Protection Zones for Cuffesgrange

11 POTENTIAL POLLUTION SOURCES

The main potential sources of contamination within the ZOC are:

- All private residences/small businesses within the ZOC are serviced by septic tank systems or similar wastewater treatment discharging percolation areas. The main potential contaminants from this source are ammonia, nitrates, phosphates, chloride, potassium, BOD, COD, TOC, faecal bacteria, viruses and cryptosporidium. A number of dwellings and small businesses are located within 300m of the well.
- Roadways are present within the ZOC. The Kilkenny to Clonmel National road (N76) is located approximately 10 m from the well. The main potential contaminants from this source are hydrocarbons and heavy metals.
- Many private home heating fuel tanks are located within the catchment area. The main potential contaminants from this source are hydrocarbons.
- The majority of land within the zone of contribution is agricultural land, primarily grassland with some smaller areas of tillage land. A number of farming operations are located within the source protection zone. The main potential contaminants from these sources are ammonia, nitrates, phosphates, chloride, potassium, BOD, COD, TOC, pesticides, faecal bacteria, viruses and cryptosporidium.
- The Cuffesgrange Cemetery is located upgradient of the borehole source. The main potential contaminants from these sources are chloride, potassium, ammonia, nitrates, phosphates, metals, BOD, COD and TOC.

12 CONCLUSIONS

- The untreated groundwater at the Borehole source at Cuffesgrange is currently impacted by microbial contamination. Available data suggests that there is contamination of the source occurring probably from organic waste sources.
- Due to the rapid groundwater velocities, it is considered that groundwater in any part of the ZOC could potentially reach the borehole within 100 days. Therefore the entire ZOC should be classified as the Inner Protection Area.
- The SPZ delineated is based on the current understanding of groundwater conditions and bedrock geology; and on the available data. The conclusions should not be used as the sole basis for site-specific decisions.

13 RECOMMENDATIONS

- Continued monitoring water levels and flow data during the operation of the scheme should be carried out to develop a real-time database of hydrogeological information.
- The depth to bedrock should be investigated surrounding the source to provide greater certainty to the conceptual model.
- The ZOC of the source includes an extensive area of Extreme Vulnerability with a significant proportion of it comprising shallow rock. It is recommended therefore that an adequate barrier to Cryptosporidium must be installed as part of the water treatment system for the supply. A hazard survey is also recommended.

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