Louth County Council

Establishment of Groundwater Source Protection Zones

Collon Water Supply Scheme

Collon Boreholes

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Revision: B

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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.

Louth County Council contracted the GSI to delineate source protection zones for nine groundwater public water supply sources in Co. Louth. The sources comprised Ardee, Cooley (Carlingford and Ardtullybeg), Collon, Termonfeckin, Omeath (Esmore Bridge and Lislea Cross), Drybridge and Killineer.

This report documents the delineation of the Collon source protection zones.

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

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1 INTRODUCTION

Groundwater Source Protection Zones are delineated for the Collon Borehole sources according to the principles and methodologies set out in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999) and in the GSI/EPA/IGI Training course on Groundwater Source Protection Zone Delineation.

Three abstraction wells are used to supply the Collon Public Water Supply Scheme. The Collon borehole sources supply domestic water to the town of Collon and its environs.

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the area surrounding the source.
- To delineate source protection zones for Collon WSS boreholes.
- To assist the Louth County Council in protecting the water supply from contamination.

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

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

2 METHODOLOGY

A desk study of existing data sources relevant to the source was carried out prior to a site visit. A site visit, site walk-over and field mapping of the study area were conducted between 8th and 15th December, 2009. An interview relating to the source was also carried out with the source caretaker. A depth to bedrock drilling programme was carried out by the GSI during 2007 to investigate the subsoil geology, the hydrogeology and vulnerability to contamination of the study area. No water quality testing was carried out; however field parameter sampling was undertaken. A pumping test was undertaken on 11-12-2009 at location PW3 to allow for assessment of drawdown and well recovery. Analysis of the data was undertaken to delineate appropriate protection zones around the public water supply wells at Collon. The sub-catchment outline by JOD (2005) was used as an initial area of focus in this report.

3 LOCATION, SITE DESCRIPTION AND WELL PROTECTION

Collon is located approximately 10km northwest of Drogheda on the N2 route. The three boreholes are located south of the main town centre in the base of a steep-sided valley, and are closely spaced near the Mattock River.

All three boreholes are active but pump for varying amounts of time each day: PW1 (pump house) and PW2 (GAA gateway) act on a duty/standby basis, while PW3 (sewage treatment works) operates on a continuous 24-hour basis. These wells supply a combined total daily output of approximately 1,300 m^3/d (source: Louth County Council).

Water is pumped to a clear water tank (capacity of 20 m^3) adjacent to the pump house. In this tank pressure transducers record water levels, so that when the water reaches a certain level the pumps in boreholes PW1 and PW2 cut out. These data, together with pumping rate data, are transmitted continuously to the pumping station computer. Water in the tank is treated with chlorine gas and then drawn out to a reservoir approximately 1 km away, with a storage capacity of approximately 1,000 m^3, equal to 1-2 days' water supply. The daily volume pumped to the reservoir, however is approximately 70 m^3/hr or 1,680 m^3/d.

A summary of the abstraction wells is presented in Section 4. The local and site setting of the boreholes is shown in Figure 1 and Figure 2. Selected images are shown in Appendix 1.

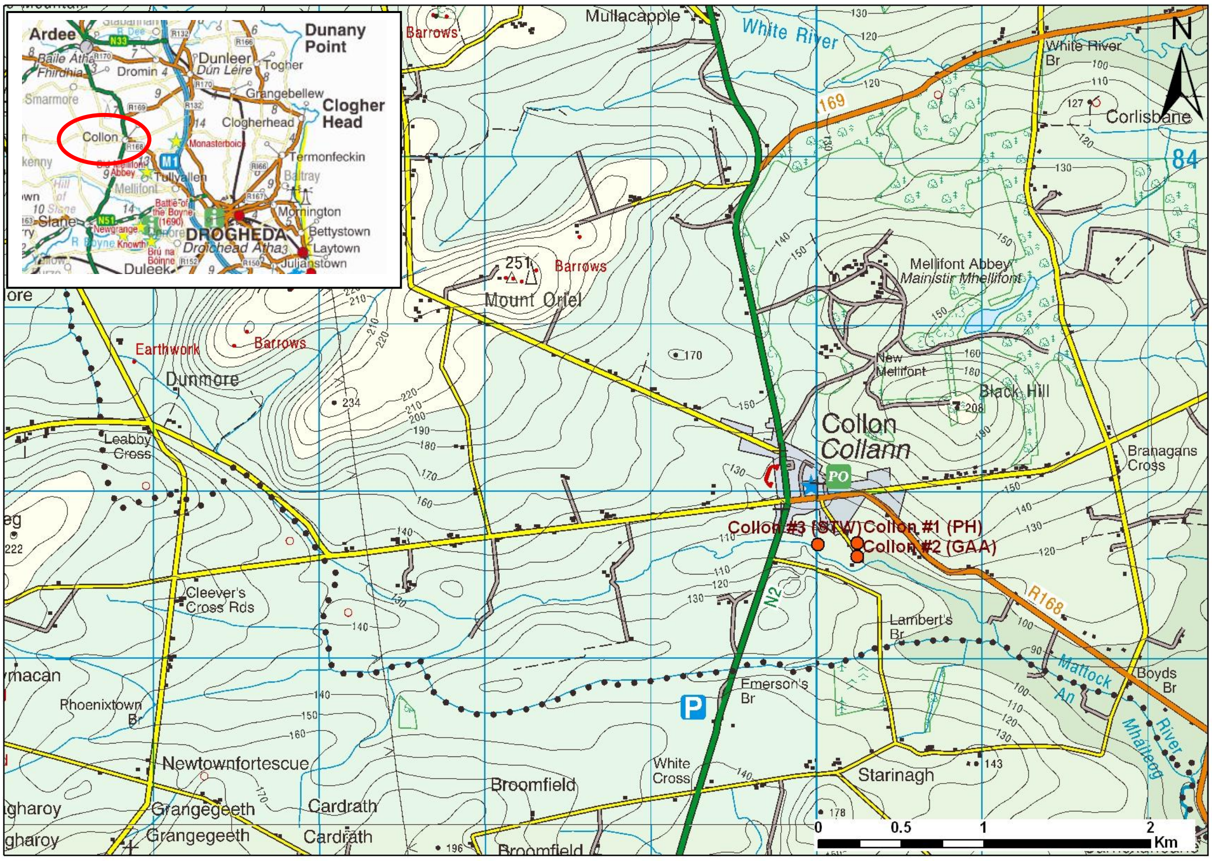


Figure 1 Location of Collon public water supply boreholes – local setting

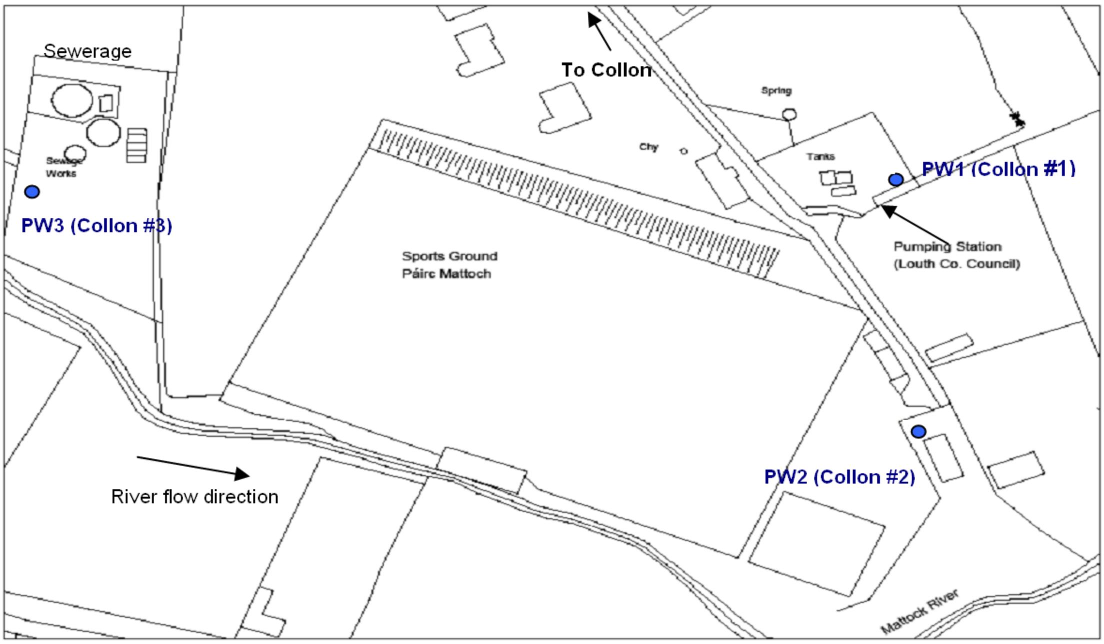


Figure 2 Location of Collon public water supply boreholes – site setting

The pump control equipment is housed in the pump house which is situated on the small road (past the school in the direction of the river), near to the Mattock Rangers ground. Excess abstracted water overflows from the tank next to the pump house into the adjacent field drains, then on to the Mattock River. Well head protection is summarised as follows:

- Borehole PW1 (adjacent to pump house) is covered by a cast iron manhole cover and is not locked or secured in any way. The cover is at ground level, on level grass and is not bunded to prevent ingress of surface water, which may also enter the chamber through the block work.
- Borehole PW2 (GAA) is also covered by a cast iron manhole cover. It is flush with the ground surface (tarmac) at the car park entrance. Surface run-off could enter the chamber around the edges of the manhole cover on what is a gently sloping surface.
- Borehole PW3 (sewage treatment works) is enclosed in a raised concrete chamber approximately 1m high, and 1.5m x 2m in plan view. The chamber is covered by securely-locked galvanised steel lids.

4 SUMMARY OF BOREHOLE DETAILS

At the request of Louth County Council, two production wells (PW1 and PW2) were drilled at Collon in March 1983. The location and preliminary design of these wells were based on the results of four wells previously drilled in the same area (K.T. Cullen, 1983). Other records show that originally five boreholes were drilled, together with two other boreholes (one on the site of pump house and one inside Mattock Rangers field). Subsequently, three boreholes were completed in 1985 by Site Investigations Limited (SIL) (perhaps for ground investigation purposes). Summary details of the three production wells owned by Louth Co. Co. are given in Table 1.

Table 1 Summary of abstraction wells at Collon

Well Reference No.	PW1	PW2	PW3
GSI Well Number	Collon #1	Collon #2	Collon #3
Grid Reference	300244, 281691	300246, 281612	300008, 281684
Location	Adj. pump house	GAA grounds	Sewage TW
Well type/ drill date	Bored/ March 1983	Bored/ March 1983	Bored/ April 2001
Ground elevation (mAOD)	102.04	99.12	105.00
Well elevation (mAOD) * (Elevation reference level)	100.65 (Top of casing)	98.12 (Top of casing)	104.89 (Top of casing)
Depth of borehole (m)	19.80	20.87	21.33
Diameter of hole (mm)	250	250 down to 200	200
Diameter of casing screen (mm)	200	150	150
Screened interval -Upper (mbgl)	Approx. 7.6 - 11.0	Approx. 3.5 - 8.5	Approx. 1.5 - 5.2
Screened interval -Lower (mbgl)	Approx. 17.0 - 19.4	Approx. 17.7 – 20.8	Approx. 15.2 - 18.3
Screened length approx. (m)	U: 3.4/ L: 2.4	U: 5.0/ L: 3.1	U: 3.7/ L: 3.1
Depth to rock (m)	Approx. 19.4	Approx. 17.7	N/A
Abstraction system	Submersible pumps to clear water tank and drawn to storage reservoir		
Pumping water level (mbgl) (date) *	10.26 (20-05-2007)	5.15 (20-05-2007)	8.12 (20-05-2007)
Pumping water level (mbgl) (date) (**mAOD**) (date)	8.78 (10-12-2009) **93.26** (10-12-2009)	4.88 (10-12-2009) **94.24** (10-12-2009)	6.80 (10-12-2009) **98.20** (10-12-2009)
Hours pumped per day (average) *	21	19	24
Average current abstraction (m^3/d) *	1,300 (combined yield from PW1, PW2, PW3)		
Water treatment	Blended water supply treated with chlorine gas		

** Source of data Louth County Council file note*

An additional borehole, PW3, was drilled and successfully installed in 2001, following abandonment of a planned borehole at the old reservoir site due to estimated low yields. All three production wells have been in operation since then as the combined source for the Collon Public Water Supply Scheme, with water extraction essentially from the sands and gravels overlying the bedrock.

For PW1 and PW2, screened sections were installed in the cleaner and more productive upper glacio-fluvial gravels, as well as slotted sections in the lower clayey gravels/broken rock. At PW3, it appears that water is pumped from slightly confined gravels at 1.5 - 5.2m and 15.2 - 18.3m (JO'D, 2005).

The locations of the production wells (PW1-PW3) are shown on all the maps in this report, and are labelled as Collon #1, Collon #2 and Collon #3.

5 TOPOGRAPHY, SURFACE HYDROLOGY AND LAND USE

The three production wells are located towards the bottom of a valley sloping towards the Mattock River, at a ground elevation of approximately 100-110 mAOD (Figure 3). While the topography of the general area is predominantly rolling hill land, ground levels often slope steeply from >200m (Black Hill) and 130 mAOD near the town to 90 mAOD south east of the wells and nearer the river. Further west of Collon, topographic heights range from 130 mAOD to a maximum of 251 mAOD at Mount Oriel. The land immediately south of the pump house has been lowered in elevation with possible land infilling over a previously marshy landscape and is waterlogged in places. Figure 3 also shows the surface water sub-catchment (JO'D, 2005).

All production wells are located north of the Mattock River (Figure 3), the main surface water feature in the area and a tributary of the River Boyne. Flow direction is west to east, with the river passing south of Collon. The catchment area contributing to the Mattock River up to Boyd's Bridge was calculated at 17.6 km^2 by JO'D (2005), with sub-catchment boundaries also delineated. The catchment boundary is influenced by regional topography and represents most of the upland areas of the Mattock catchment. Other drainage (extending from Collon to Dunmore in the west) consists of a number of smaller streams which generally drain NW-SE to the Mattock River, including a tributary of the river (crossing the Kells Road) with an estimated flow of >2,000 m^3/d (on 15-12-2009).

Local drainage features and the sub-catchment boundary which includes an extent of the Mattock River are also presented in Figure 3. A public road (School Lane) passes next to wells PW1 and PW2, linking the GAA grounds to Drogheda Street in the town. Collon town and environs are generally urban with domestic dwellings and retail outlets, and no major industry present. Some additional house construction has been undertaken to date while foundation works have been completed at other locations.

The waste water treatment works (location of PW3) is part of the Collon Sewerage Scheme. Effluent treated to meet environmental quality standards is discharged to the Mattock River to the south of the site, and approximately 10m downstream of a permanent weir.

Generally, the land immediately around Collon is used for grassland farming with some crop cultivation. An aerial view of land use is presented in Figure 4.

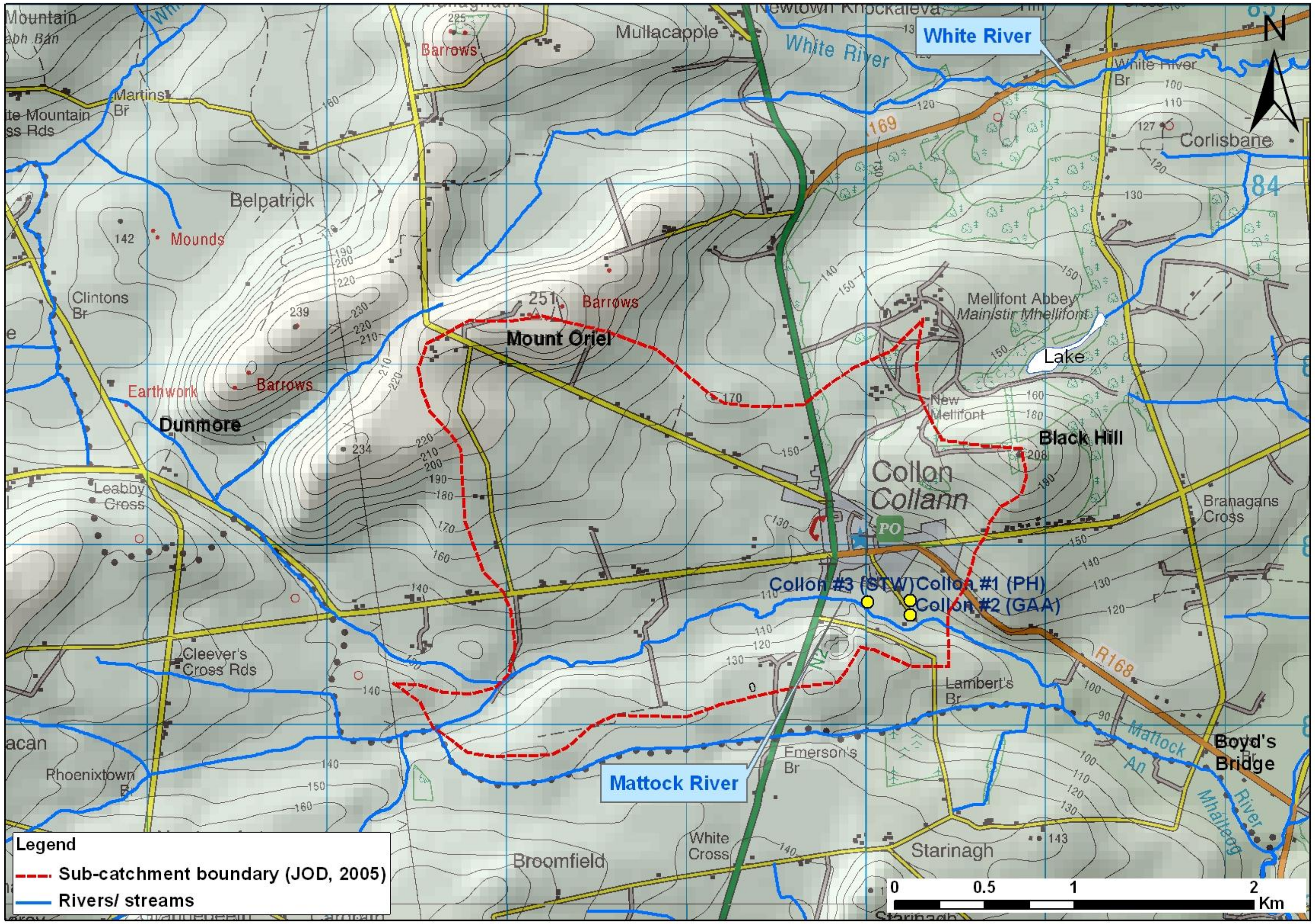


Figure 3 Topography of the Collon area, showing regional surface drainage patterns (including cross section line A-A[1])

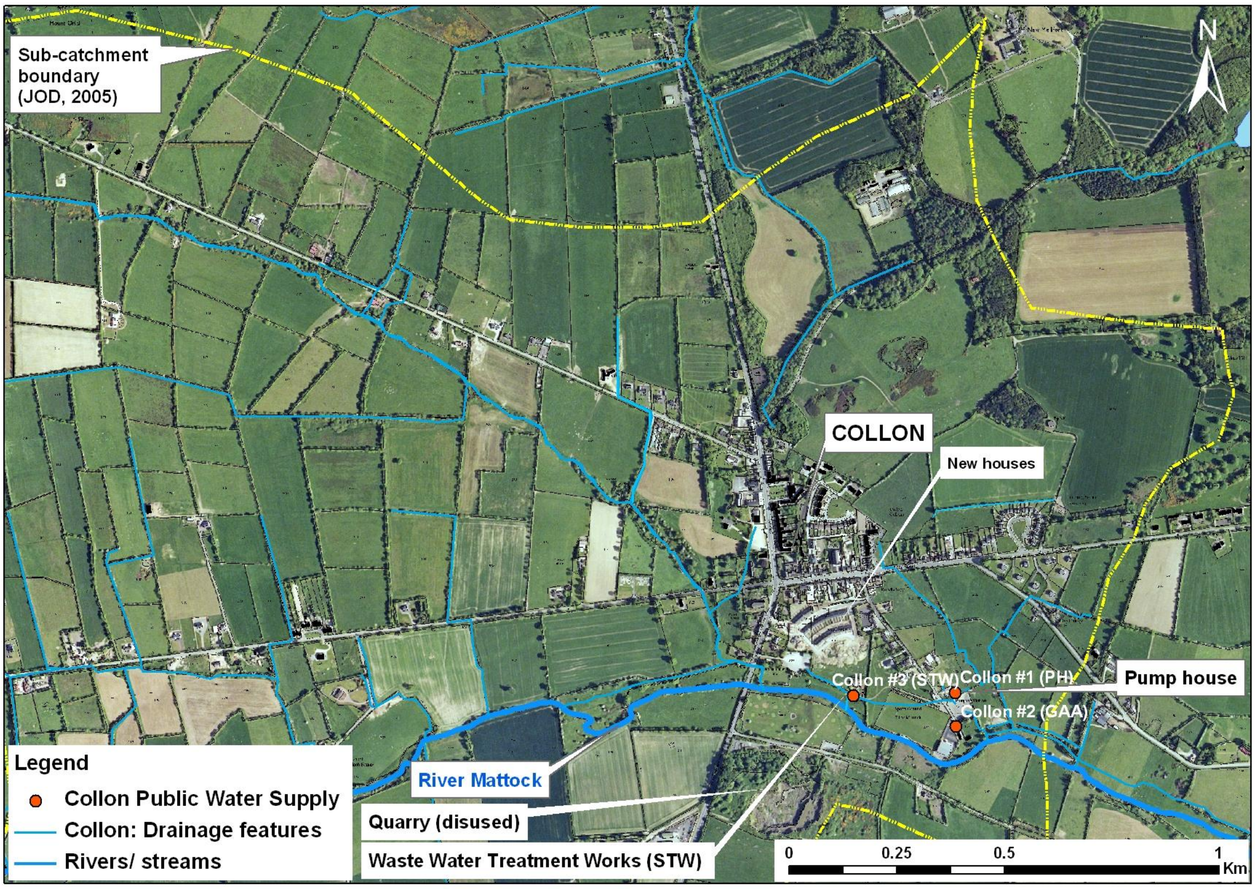


Figure 4 Land use around the pumping wells with local drainage features (OSi, 2004)

6 HYDRO-METEOROLOGY

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

Annual rainfall: 800 mm. The closest meteorological stations to Collon WSS are Collon G.S. about 350 m northwest of the boreholes, and Mellifont Abbey 1.5 km to the north of the source. Average rainfall between 1970 and 1990 was 800 mm/yr (Fitzgerald and Forrestal, 1996).

Annual evapotranspiration losses: 416 mm. The closest synoptic weather station to the study area is Dublin Airport, 35 km to the south. However, data from Clones station, to the northwest, are considered to be more representative of this hilly, cooler area. Average potential evapotranspiration (P.E.) at Clones between 1961 and 1990 was 438 mm, based on Met Éireann data. Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits, giving an Actual Evapotranspiration of 515 mm.

Annual Effective Rainfall: 384 mm. This is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is equivalent to this.

7 GEOLOGY

This section briefly describes the relevant characteristics of the geological materials that underlie the area surrounding the Collon Public Water Supply boreholes. This provides a framework for the assessment of groundwater flow and source protection zones that will follow in later sections. Information was taken from a variety of sources including:

Bedrock:

- GSI publication on the bedrock geology of the region (McConnell *et al.*, 2001);
- Reports and borehole logs from Aspinwall (1981), and KTC (1983); and
- GSI 6" geological mapping (*ca.*1866).

Subsoil:

- Quaternary mapping undertaken by the GSI;
- Teagasc subsoils mapping (Meehan, 2004);
- Permeability mapping by Tobin Environmental Ltd. field personnel in 2007;
- Shell & auger and rotary holes drilled by SIL (1982 & 1985) and KTC (1983);
- Site investigation data, including geotechnical descriptions and tests (e.g., particle size distributions) (Aspinwall, 1981; SIL, 1982 & 1985).

7.1 BEDROCK GEOLOGY

Bedrock formations in the vicinity of Collon are summarised in Table 2 below.

Table 2 Summary of geological succession

Formation	Code	Thickness	Description	Occurrence
Collon Formation	CM	Approx. 800m	Andesite breccias/ conglomerate/ sandstone	Underlies PW1, PW2 and PW3 and the Mattock River to the west; most of Collon town; south of Black Hill
Knockerk Formation	KC	Approx. 65m	Tuffaceous sandstone, shale	Most of the Mattock River valley north of Lambert's bridge; north of Emerson's bridge
Brittstown Formation	BW	>510m	Coarse to fine-grained tuff	Small area west of Collon
Hill of Slane Formation	HS	55m	Massive lapilli tuff	Small area south of BW Formation, west of Collon
White Island Bridge Formation	WI	345m	Tuff, tuffaceous siltstone, mudstone	Sloped valley of Mattock River southwest of Collon

The dominant rock unit underlying the three production wells is the Collon Formation, as shown in Figure 5. This unit is part of the Ordovician Rock Unit Group and is composed of andesite breccias, pebble to boulder conglomerates, minor tuffs and, locally at the top of the rock unit, massive poorly bedded volcaniclastic sandstones. Early GSI mapping indicates grey and purple-grey feldspar/felstone porphyry (a type of volcanic rock with large crystals) to the north of Drogheda Street which was observed in exposures as decomposing, very weathered and rusty with dark green granular specks. Felstone porphyry was also recorded just south of the Mattock River and GAA grounds, along with hardened grey grit, dipping south at 40°, and with thin seams of dark purple clay bedding.

Collon is situated in an area of extensive bedrock faulting with a general NE-SW orientation, and west of the Tinure Fault. Production wells PW1 and PW2 are sited along and near a major NNE-SSW trending fault (Figure 5). Extensive splay faulting along the extremities of the major faults in the area around Collon and intense fracturing would also be expected.

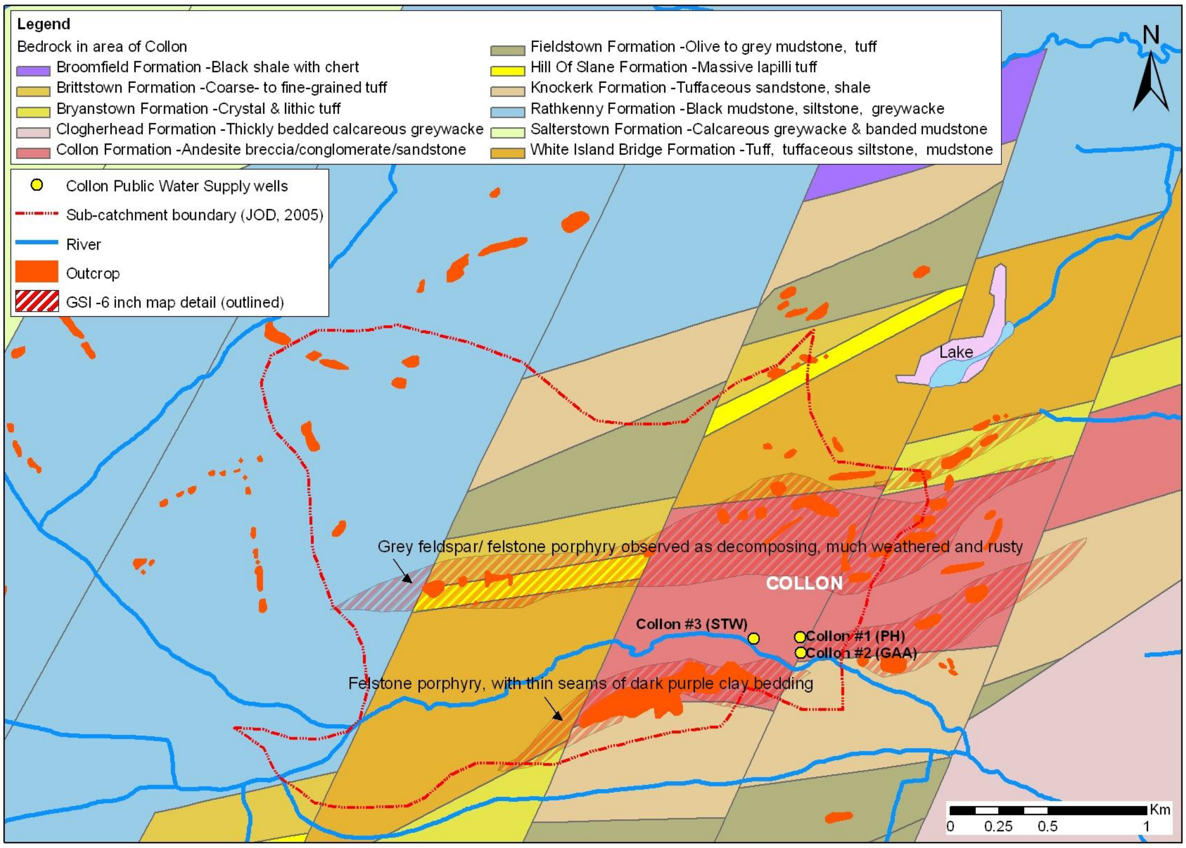


Figure 5 Bedrock geology in the area of Collon

7.2 SOILS AND SUBSOILS

In the lowland area of the catchment, the soils predominantly comprise gley (wet) soils and brown earths derived from Silurian shale parent material. The upland area is comprised of brown podzolics and associated gleys (JO'D, 2005). The subsoils (Figure 6) are Tills derived from Palaeozoic sandstones and shales (TLPsSs), Alluvium (A), and Gravels derived from Palaeozoic sandstones and shales (GLPSsS). Made ground is delineated around Collon village. The characteristics of the principal subsoil categories are described below:

Alluvium (river deposits) occupies the low lying area to the south of the wells but generally follows the line of the river. Alluvium is also found at intermittent locations along some streams draining to the river. Typically, the deposits range from SILT to CLAY with occasional gravel and cobbles. Organic SILT/CLAY is also found.

Glacial tills (sandstone and shale till, or 'boulder clay') are the dominant material in the Collon area, including the lowland areas of the Mattock River catchment. Boreholes in the area of the three production wells indicate an unsorted mixture of fine to coarse-grained sandy gravelly CLAY, clayey GRAVEL, and CLAY/GRAVEL stratifications, with cobbles and boulders also observed. Firm to stiff CLAY with varying thicknesses (e.g. 0.2 to 17.4 m) has also been recorded around Collon with thicknesses of up to 27.4 in places, and often deeper to the northwest. In addition, SILT/CLAY strata were noted to the east beyond Collon town centre. Historical laboratory testing for boulder clay north of Collon gave permeability values in the range 10^{-4} to 10^{-5} m/d (Aspinwall, 1981). Under GSI investigations the overall subsoil permeability of the till units in the study area has been classed as 'Low'.

Glacio-fluvial sands and gravels have been recorded in the area, notably to the southwest of Collon and south of the Mattock River. These deposits comprise sandstone and shale SAND and GRAVEL. Borehole logs for the area indicate GRAVEL with cobbles and boulders or medium to coarse sandy GRAVEL with cobbles and boulders. Clayey GRAVEL was also logged at both PW1 and PW2 locations, and observed along the river bank (see plates in Appendix 1). Generally, observed thicknesses of granular deposits can vary with up to 11.7 m clayey GRAVEL recorded at PW2. Gravel, cobbles and boulders were also noted in this area. These deposits are mapped by the GSI as 'High' subsoil permeability.

It is likely from review of past trial investigations and the digital elevation model for the area that the gravels may be more extensive than initially envisaged. The gravel terrace may include an area south-southeast of the town where gravelly SAND with cobbles was logged in the area of PW1. Uniform and well-graded gravels with little or no fines were also noted, together with occasional 'dirty' gravels with inter-bedding of till. Thickness ranges of between 5-8 m were recorded with gravels capped often by <3m of generally low permeable clayey till cover. The apparent extent of the gravels in the area is shown in the inset on Figure 6.

7.3 DEPTH TO BEDROCK

Depth to bedrock (DTB) has been interpreted across the study area based on bedrock outcrops mapped by the GSI, outcrops mapped during site visits, and logs from GSI auger holes and other site investigation boreholes in the vicinity of the source.

DTB is quite variable (Figure 6), ranging from 19.4–20.0 mbgl (location PW1) and 16.6–20.8 mbgl (location PW2) in the area of the pump house, to 10.0 mbgl nearer the village. Where refusal on dense granular materials exists, then specific DTB is unavailable and is indicated as such. DTB was not proven at location PW3. Further from the village, DTB appears to be shallower at 7.5 mbgl (west) and at 2.9 mbgl (east) – where there is a notable occurrence of exposed outcrop.

Observations during drilling indicated a weathered rock zone ('transition zone') below the predominantly boulder clay glacial deposits. This layer has often been referred to as rock or broken rock and gravel, with varying transition zone thicknesses recorded of between 0.7 m–2.5 m.

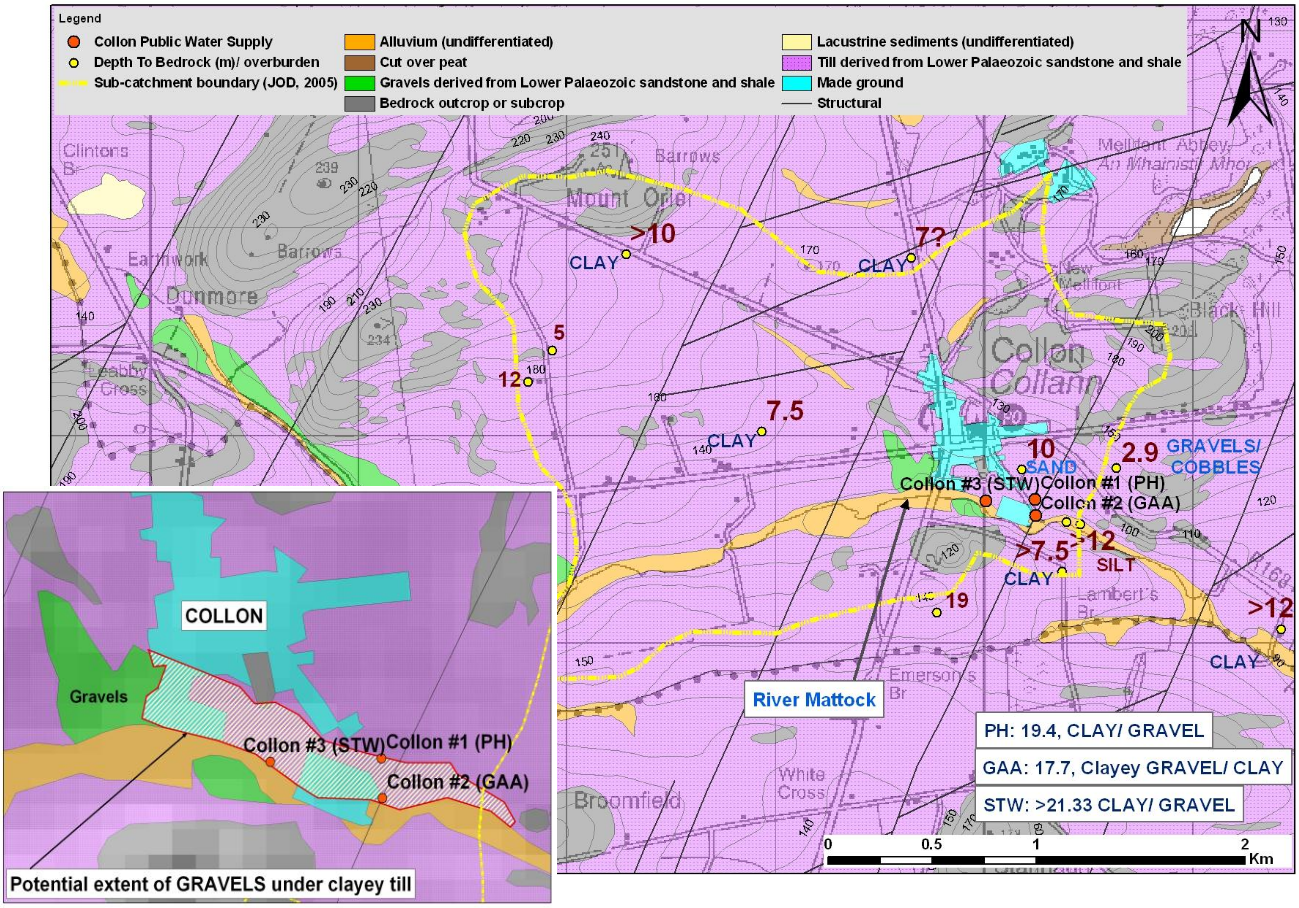


Figure 6 Subsoil geology and DTB with principal overburden type (possible gravel extent also delineated)

8 GROUNDWATER VULNERABILITY

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. In this area this means that vulnerability relates to the permeability and thickness of the subsoil. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DELG/EPA/GSI, 1999) and in the draft GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination (Fitzsimons et *al.*, 2003).

Depth to bedrock generally varies across the area around Collon with recorded overburden thicknesses ranging from 46m (north) to 2.9m (east), with shallower subsoil cover also present. Further north and east away from the source, and at higher elevations, subsoil cover again varies and becomes thin in places with outcrop evident. Groundwater vulnerability classification for the area around the source varies as a function of the subsoil thickness and permeability. Groundwater vulnerability to potential pollution around Collon is shown in Figure 7.

The area immediately around the boreholes is classified as extreme vulnerability. Near boreholes PW1 and PW2, the 'target groundwater' is taken to be the top of upper gravel layer, as recorded on drilling logs. This is less than 3m below surface, resulting in an extreme groundwater vulnerability classification. (Groundwater, however, is also be drawn from the confined lower gravel/ broken rock stratum.) Other extreme (E and X) vulnerability areas lie close to the well field, notably to the immediate south of the river and north-northwest of Collon. Low vulnerability areas occur upgradient of the boreholes, but mainly lie to the west and east of the source.

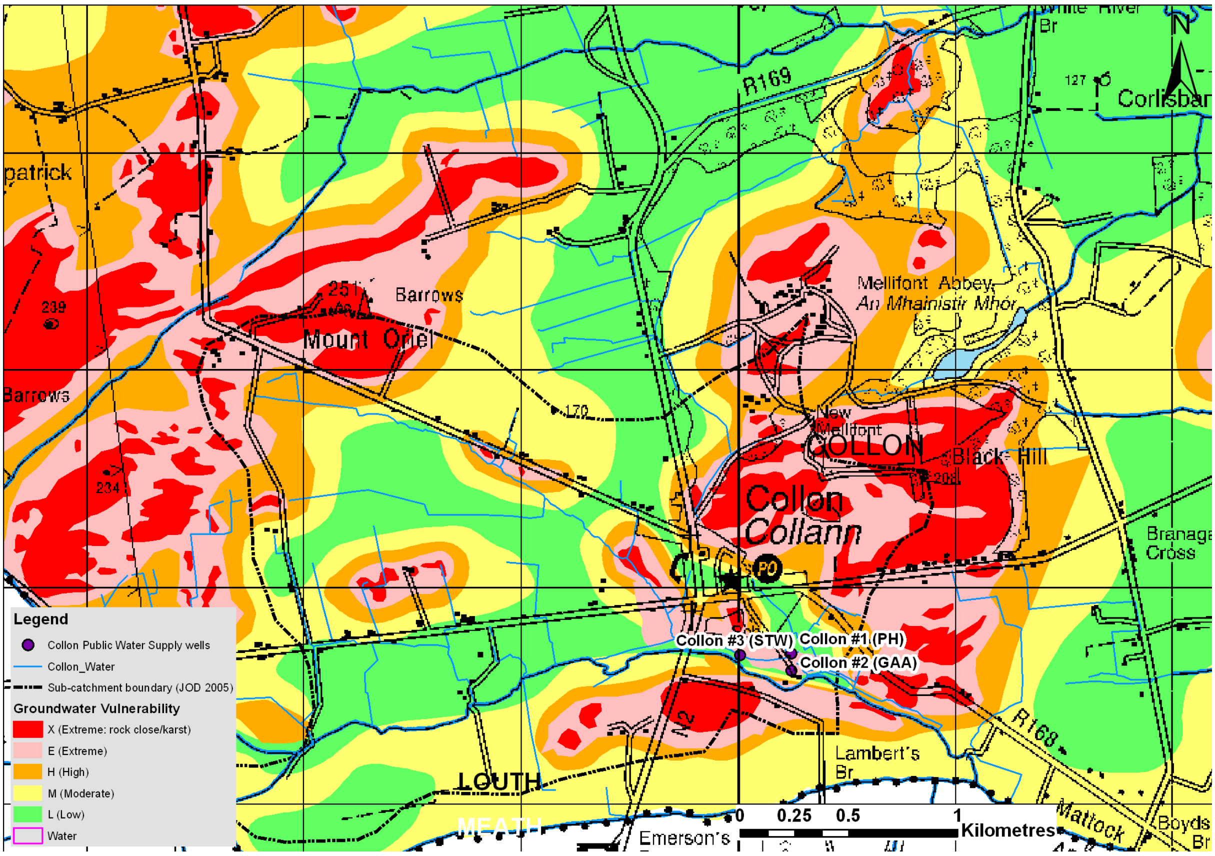


Figure 7 Groundwater vulnerability in the vicinity of Collon

9 HYDROGEOLOGY

This section presents the current understanding of the hydrogeology at Collon. Following assessment of regional and local groundwater characteristics, together with a review of hydrochemistry for the area, a conceptual model is proposed for the study area. Hydrogeological and hydrochemical information for this study were obtained from the following sources:

- GSI groundwater and related files and archival Louth County Council data;
- GSI publication on the bedrock geology of the region (McConnell *et al.*, 2001)
- Collon Sewerage Scheme –Upgrade of WWTW: Preliminary outline design report (JO'D, 2005);
- Report on Site Investigation at White River and Outline Landfill Design (Aspinwall, 1981);
- Field work carried out between 08-12-2009 and 15-12-2009.

9.1 GROUNDWATER BODY AND STATUS

Collon WSS boreholes are located in the Wilkinstown groundwater body (GWB) (IE_EA_G_010), which has been classified as being of Good Status. The groundwater body description is available from the GSI website: www.gsi.ie and the 'status' is obtained from the Water Framework Directive website: www.wfdireland.ie/maps.html.

9.2 GROUNDWATER LEVELS, FLOW DIRECTIONS AND GRADIENTS

Few groundwater level data are available for the area around the abstraction wells. PW1-PW3 are not generally monitored for rest water levels given the on-going pumping activities at all three locations.

Groundwater levels follow ground surface elevation. There is evidence of confining conditions across the area, particularly at PW3 where groundwater is artesian at some times of the year. Records show standing water levels in two boreholes (approx. 300m from PW2) north and south of the Mattock River, at 2.10 and 2.95 mbgl, respectively and may reflect the proximity of the watercourse. Generally, water strikes (where recorded) were in medium to coarse sandy gravels.

Measured groundwater levels for all supply well locations are shown in Table 3. Pumping water levels ranged from 97.8-92.6 mAOD at PW1 (gravels), and 93.2 -93.7 mAOD at PW2 (clayey gravels), respectively. Approximate pumped water levels for the same period for PW3 ranged from 96.1 - 98.3 mAOD. The artesian effects observed at location PW3 may reflect winter conditions with prolonged wet periods and hence groundwater build-up in the area around and upstream of this point.

Table 3 Groundwater levels (mbgl) observed at Collon supply wells

Detail	**PW1**		**PW2**		**PW3**	
Pump	ON	OFF	ON	OFF	ON	OFF
08-12-2009	8.06	-	4.46	-	8.80	-
08-12-2009	-	7.93	-	4.33	-	-
10-12-2009	8.78	-	4.88	-	6.80	-
11-12-2009	-	8.16	-	4.54	6.57	Artesian
15-12-2009	8.81	-	4.92	-	8.78	-

It is assumed that regional groundwater flow direction is a subdued reflection of the topography around Collon. In this respect, groundwater flow directions are assumed to reflect the natural drainage patterns in the area, as shown in Figure 3 and Figure 4. On the basis of the watershed divide for the sub-catchment, then groundwater flow directions would be expected to flow southwards towards the Mattock River from the northeast, north and northwest, following the changes in elevation and slope. The general NE-SW trending orientation of bedrock faulting around Collon (Figure 5) may also influence the regional flow regime. Groundwater flow through fissures and fractures in shallow bedrock could also be quite heterogeneous, depending on fracture distribution and orientation.

To the immediate south of the Mattock River, groundwater flow would also be expected to reflect the topography, flowing generally northwards to the river. There is potential for surface water interaction with groundwater in the gravels, particularly in the area of PW3 (sewage treatment works), and possibly at PW2, which is downstream of a bend in the river. Groundwater flow directions in the vicinity of abstraction points will be towards the boreholes. Local variations in topography as well as drainage features found in granular horizons may also influence groundwater flow at a local scale.

The average topographic gradient north of the boreholes is about 0.1 while, to the west of PW3, a more gentle gradient of <4% is evident with a ground slope of c. 2.4% between PW3 and PW2; this flattens out nearer the floodplain of the Mattock River.

Hydraulic gradients for the gravel aquifer in the area of the wells are difficult to constrain. Between PW3 and PW2, the rest groundwater gradient in the gravels is about 0.04; this is steep for gravels and is likely to reflect the upward groundwater flow at PW3. When PW3 and PW2 are pumping, the groundwater gradient in the gravels is c. 0.008. The pumping water level at PW1 appears to be lower than at PW2 and PW3; however, the groundwater is flowing generally southwards. In the absence of specific field measurements, a groundwater gradient in the gravels of 0.024 is deemed appropriate. Groundwater gradients in the bedrock aquifer will be significantly steeper, on the order of 0.06.

Pumping tests and abstraction

A 72-hour pumping test carried out by KTC in June 1983 utilised locations PW1 and PW2, with the latter taken to be the observation well. It is assumed that abstraction was from the glacial gravels. Maximum drawdown at PW1 was 1.13 m, while <100m away at PW2, it was 0.72 m. The cone of depression at location PW1 showed an increased rate of drawdown following groundwater flow through the aquifer (Appendix 2, points 1-2), where a barrier boundary (Appendix 2, point 3) may have been intercepted.

Pumping rates at PW1 varied from 2,244 m^3/d to 1,570 m^3/d, while the second pump, at PW2 abstracted water at 916 m^3/d. Final pumping rates gave a combined abstraction volume of 1,616 m^3/d.

A 5-hour pumping test was undertaken on 11-12-2009 at location PW3 where the pump was turned off at 16:00 on 10-12-2009 and switched on again at 08:15 on 11-10-2009 (16.25 hours overnight) to allow for assessment of drawdown and well recovery. Observations of water levels at PW1 and PW2 were not noted, however. Maximum drawdown over a 5-hour pumping test was 6.51m with some stabilisation of water levels at approximately 2 minutes, following a rapid decline in level due to well loss effects (Appendix 2).

Following the pumping test, a recovery test was undertaken where a quick rebound was observed with groundwater overflowing the casing head after approximately 1.5 minutes. This may reflect groundwater convergence at this particular location together with recent heavy rainfall for the area in general, leading to possibly high transmissivity (T) values. (Note: no comment was made on artesian flow at PW1-PW2 in the KTC report, 1983). The pump was switched on again and after 30 minutes a maximum drawdown of 5.89m was noted. It is likely that the pumped water level would eventually drop to the levels observed in the initial test.

Spot discharge readings from the adjacent meter gave 336 to 360 m^3/d, with the latter yield more representative. Statistics provided by Louth County Council for general production at Collon show average daily abstraction volumes of between 1,200 – 1,400 m^3/d. However, a volume of 1,300 m^3/d represents a recent evaluation of combined abstraction rates for the three wells, despite water spilling from the clear water tank at the pump house.

There is the possibility of hydraulic connection between the Mattock River and locations PW2 and PW3 as stated by JO’D (2005). The invert level of the river along this extent is approximately 2.5 mbgl (opposite PW2) and 1.5 mbgl (opposite PW3). Records show upper glacial gravels for well PW2 at 4.3 mbgl and for PW3 at 1.5 mbgl which, if high conductivity does exist, could infer that both wells potentially draw water from the river. This may be more likely at location PW3 at a distance of 30 m from the river with similar gravel stratum elevation, however not enough data exist to verify this.

9.3 HYDROCHEMISTRY AND WATER QUALITY

The EPA carries out both raw and treated water quality audits in the area supplied by the three wells. Available raw water data for locations PW1 to PW3 were analysed against current water quality standards (Category A1-A3), under the guidance of the EPA Regional Inspectorate.

Table 4 summarises EPA laboratory and field results for monitoring undertaken between March and December 2009, with minimum and maximum values.

Table 4 Summary of water sampling results for Collon supply wells 2009

Parameter	Units	PW1		PW2		PW3	
		Min	Max	Min	Max	Min	Max
Dissolved Oxygen	% Saturation	39	66	44	73	51	58
Temperature	°C	10.5	12.0	10.5	12.0	10.6	10.6
Odour	-	n/d	n/d	n/d	n/d	n/d	n/d
pH	pH	7.0	7.2	7.0	7.1	7.4	7.6
Conductivity (25°C)	µS/cm 20°C	359	412	358	422	426	435
True colour	Hazen	<5	9	<5	8	<5	<5
BOD	mg/l O_2	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
COD	mg/l O_2	<10	19	<10	15	<10	<10
Chloride	mg/l Cl	19	25	20	26	20	20
Ammonia	mg/l NH_4	<0.04	0.03	<0.04	<0.04	<0.04	<0.04
Ortho-phosphate (P)	mg/l P_2O_5	<0.09	0.1	<0.09	0.11	<0.09	0.11
Total Oxidised Nitrogen (N)	mg/l N	3.02	4.3	3.59	4.64	2.73	3.01
Alkalinity – Total (as $CaCO_3$)	mg/l $CaCO_3$	150	170	145	180	162	188
TOC	mg/l C	<1.5	2.5	<1.5	4.6	-	-
TSS	mg/l	<5	<5	<5	<5	<5	<5

Note: *F -Final results; I -Interim results; BOD -Biological Oxygen Demand; COD -Chemical Oxygen Demand; TOC –Total Organic Carbon; TSS –Total Suspended Solids; n/d –none detected;* ***Bold*** *values indicate exceedances of standards.*

The following key points are identified from the data for the Collon Public Water Supply Scheme:

- Dissolved Oxygen levels are indicative of reasonably well oxygenated waters with no reducing conditions evident from these particular results, despite a minimum of 39% at PW1. The highest value was recorded at PW2, the least confined well.
- Chloride values range between 19 and 26 mg/l Cl, and are generally below the EPA threshold value of 25 mg/l Cl. All results are well within the EU Maximum Admissible Concentration (MAC) of 250 mg/l Cl.
- Ammonia levels averaging at <0.04 mg/l NH_4 (with the exception of PW1) are within the EPA Category A1 standard as well as the EU MAC of 0.3 mg/l.
- Ortho-phosphate values range from <0.09 to 0.11 mg/l P_2O_5 and are within all EPA water quality categories A1-A3.
- Hydrochemical analyses show hardness as $CaCO_3$ is within the EPA threshold and Drinking Water Standard of 200 mg/l $CaCO_3$, despite a value of 188 mg/l detected at PW3 on 09/12/2009. Lower limits of 150 and 145 mg/l were observed at PW1 and PW2, respectively.
- Nitrogen is below the Drinking Water Standard of 50 mg/l NO_3.

In summary, the parameters tested and presented in Table 4 are generally below specified limits. This would indicate that no significant contamination or pollution events have occurred within the zone of contribution of the wells tested, although this does not include an assessment of bacteriological quality. While this represents the situation for 2009, it does not infer that contamination is absent within the zone of contribution or that the potential for contamination is low.

Field parameters were also assessed and included for conductivity, temperature, pH and TDS (total dissolved solids) and are summarised in Appendix 2. Conductivity values were generally consistent at all three pumping locations, as well as the two groundwater points (springs). Surface water measurements tended to be lower and consistent at the various sampling points despite an elevated value of 593 μS/cm in the slow flowing stream near location PW3.

Water temperatures were typical of groundwater at the three boreholes and the flowing spring south of Drogheda Road, and averaged at about 10.6-10.7°C, compared to the lower surface water values for this time of year. pH values for all locations were within acceptable limits.

9.4 AQUIFER CHARACTERISTICS

Collon Public Water Supply wells abstract water from a saturated sand and gravel deposit, although this is not currently classified as a Locally Important Sand & Gravel Aquifer (Lg). This deposit may extend beyond the well field *c.* 1 km to the west, and to the east following the topography along the river (Section 5). The gravel deposits overlie volcanic rocks/conglomerate/sandstone bedrock which is currently classified by the GSI as a **Poor bedrock aquifer which is generally unproductive except for Local Zones (Pl)**. This Pl bedrock aquifer classification covers the area surrounding Collon and is shown in Figure 8. There are indications that the volcanic bedrock is slightly more transmissive than the Pl aquifer classification suggests. Appropriate aquifer parameter values for this type of bedrock aquifer are: transmissivities in the order of 2 – 15 m^2/d, bulk hydraulic conductivities in the range 0.2 – 0.5 m/d, and effective porosities of 0.01.

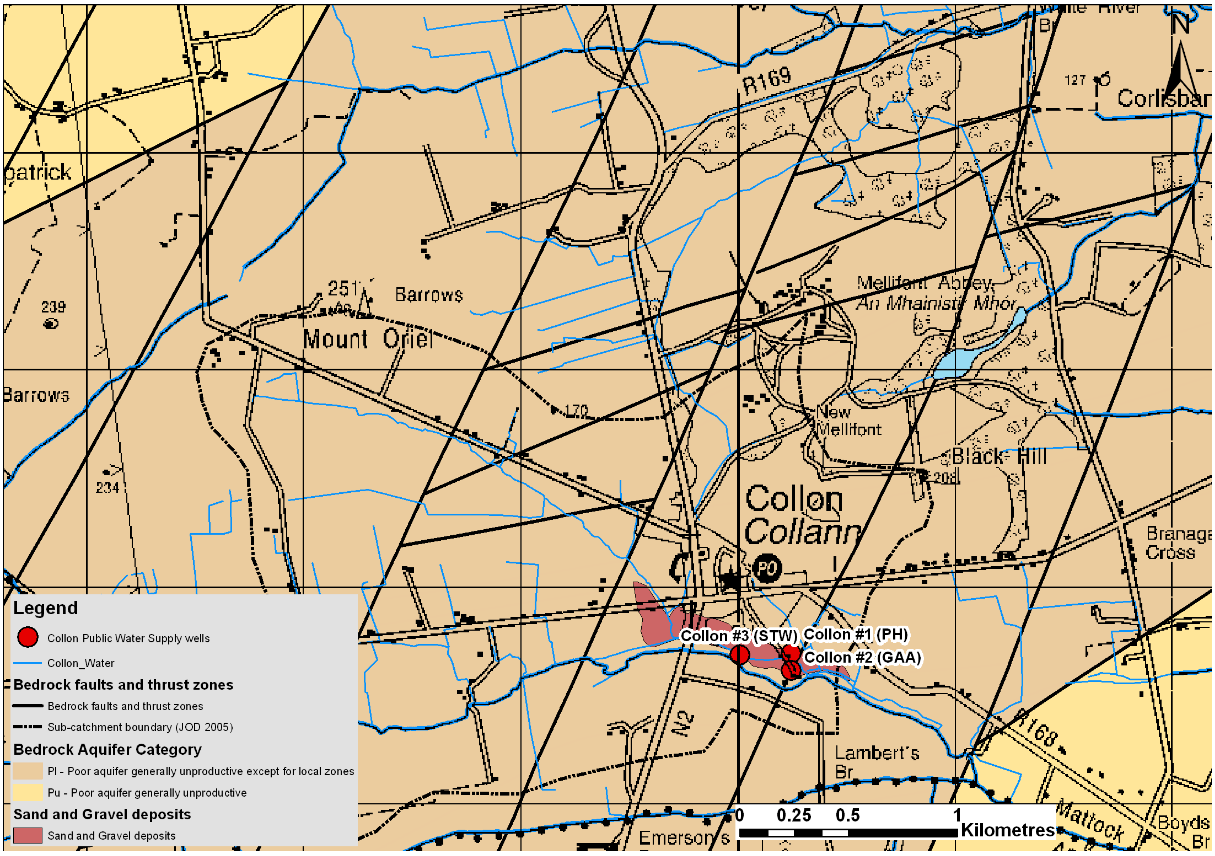


Figure 8 Aquifer categories in the vicinity of Collon

The upper gravel deposit at Collon ranges in thickness, with 11.7 m recorded at PW2, although saturated thickness is less than this. The thickness of the lower gravel/broken rock aquifer was observed ranging up to 2.7 m during past drilling, but again this refers to localised characteristics. It is important to note that no water strike details were recorded in the borehole logs (KTC, 1983) for PW1 and PW2. There are limited data on aquifer properties for the area. Historical in-situ permeability tests on similar type sands and gravels to the north of Collon (near White River) gave permeability values in the order of 0.1 – 10.0 m/d (Aspinwall, 1981), with the lower value reflecting the fine-grained content. Effective porosities typically in the order of 0.15 would be expected for medium to coarse, poorly sorted gravels.

Analysis using the Cooper-Jacob method of the pumping tests carried out (KTC, 1983, see Section 9.2 and Appendix 2) gave an average transmissivity (T) of 641 m^2/d for PW1 but >1,000 m^2/d for PW3, situated further west. The differences in values may reflect the variation in season and the different duration of each test. However, the potential for flowing faults and fractures in the region of PW2 (as well as at PW3) and hydraulic connection with the Mattock River should not be overlooked. Taking an approximate sand/gravel thickness of 10 m, the bulk permeability ranges from approximately 60-100 m/d. The layered, but less clayey, sands and gravels at Ardtully Beg on the Cooley Peninsula, have a transmissivity of about 1,000m^2/d, and a specific yield of 0.1 (An Foras Forbatha/GSI, 1980) and a bulk permeability of about 65 m/d.

Assessment of the yield at PW3 against the maximum drawdown achieved gave an estimated specific capacity of approximately 55.3 m^3/d/m. This gives some indication of both the efficiency of the well under the current pumping rate, and indirectly of the capacity of the aquifer to transmit water to well PW3.

10 ZONE OF CONTRIBUTION

This section describes the delineation of the area around the abstraction wells that is believed to contribute groundwater to the wells, and that therefore requires protection. The Zone of Contribution (ZOC) is the complete hydrologic catchment area to the source, or the area required to support an abstraction from long-term recharge. The size and shape of the ZOC is controlled primarily by (a) the total discharge, (b) the groundwater flow direction and gradient, (c) the subsoil and rock permeability and (d) the recharge in the area. This section describes the conceptual model of how groundwater flows to the source, including uncertainties and limitations in the boundaries, and the recharge and water balance calculations which support the hydrogeological mapping techniques used to delineate the ZOC.

10.1 CONCEPTUAL MODEL

- The boreholes are situated near the bottom of a valley, adjacent to the Mattock River. The topography of the valley sides is 'basin-like', with the slope direction around the valley crest directed towards the boreholes.
- Groundwater recharge occurs across the area in varying amounts, depending on the permeability of the subsoils and on the ability of the bedrock aquifer or sand/gravel deposits to accept the recharge.
- Groundwater flows southwards towards the river from the ridge to the north. The three boreholes at Collon abstract groundwater from a sand and gravel deposit, and also from the top of the bedrock at the pumphouse borehole.
- The sand and gravel deposit overlies a bedrock aquifer comprised of Ordovician-age volcanic and sedimentary rocks. The bedrock aquifer is currently classified as a Poor aquifer, generally

unproductive except for local zones (Pl). Collon is located in geological setting of extensive faulting. Groundwater flowing along fracture zones, NE-SW trending faults, and in the weathered zone at the top of the bedrock aquifer is considered to flow into the overlying sand and gravel deposits.

- The groundwater in the vicinity of PW3 is artesian, at least some of the time. Groundwater levels at PW1 and PW2 are below the ground surface. Artesian flow at PW3 may be seen following periods of prolonged rainfall; this may also be due to its location at a possible groundwater convergence point in the valley.
- Upward groundwater flow from the deeper part of the geological sequence is suggested by artesian conditions, which indicates that two groundwater systems are present: the sands/gravels and the fissured bedrock aquifer, which flows into the sand/gravel aquifer at this location before discharging into the Mattock river/being abstracted.
- Bedrock is relatively close to the surface in the Collon area to the north and south of PW3, but is deep within the source area itself (17.7 to 19.4 mbgl), giving a ‘basin-like’ valley profile. It is assumed that the bedrock within the catchment contributes little baseflow to the Mattock River.
- Groundwater is thought to be ‘funnelled’ beneath (semi-)confining tills towards the well field, following the topographical profile in the Collon area. This appears to the general case at Collon apart from points where groundwater ‘rises’ exist to the west of the town on higher slopes, and groundwater discharge in the form of springs have been observed to the east.
- Potential exists for hydraulic connection between the upper gravels and the river in the area of wells PW2 and PW3 in particular, given their close proximity to the Mattock River. This is further substantiated by exposed and recorded granular horizons at similar elevations at these locations. However, measurements of conductivity and temperature in groundwater and nearby surface water reveal differences between the two waters.

Figure 9 presents a conceptual understanding of the situation at Collon where a cross section (see also Figure 2 for line A-A[1]) through PW3 is shown from north (near the town centre) to south (near the disused quarry).

10.2 BOUNDARIES OF THE ZOC

The boundaries of the area contributing to the boreholes are considered to be as follows, and are determined using hydrogeological mapping techniques, water balance estimations, and a conceptual understanding of regional and local groundwater flow. Topographical gradients and divides are taken into account, as are the influence of fault direction in the bedrock and the extent of the gravels to the west of PW3 and east of PW2.

Northern boundary:

The northern extent of the ZOC is mainly coincident with the northern limit of the Mattock River sub-catchment. It runs from the high point of Black Hill, crossing to Mellifont Abbey and in the direction of Mount Oriel to the northwest.

Southern boundary:

The southern boundary is influenced by local surface water recharge characteristics and is based on the assumption that there is hydraulic connection between the productive layers in boreholes PW2 and PW3 and the adjacent watercourse. This boundary coincides with the Mattock River southwest and south of abstraction borehole PW3. South of PW2, the Uniform Flow Equation (Todd, 1980) is used to guide downstream limit of the ZOC, although a slightly conservative distance of 40 m is chosen. Between the boreholes, the boundary departs from the course of the river, and is drawn to account for the possibility that upstream river water flows into the gravels at a bend in the river.

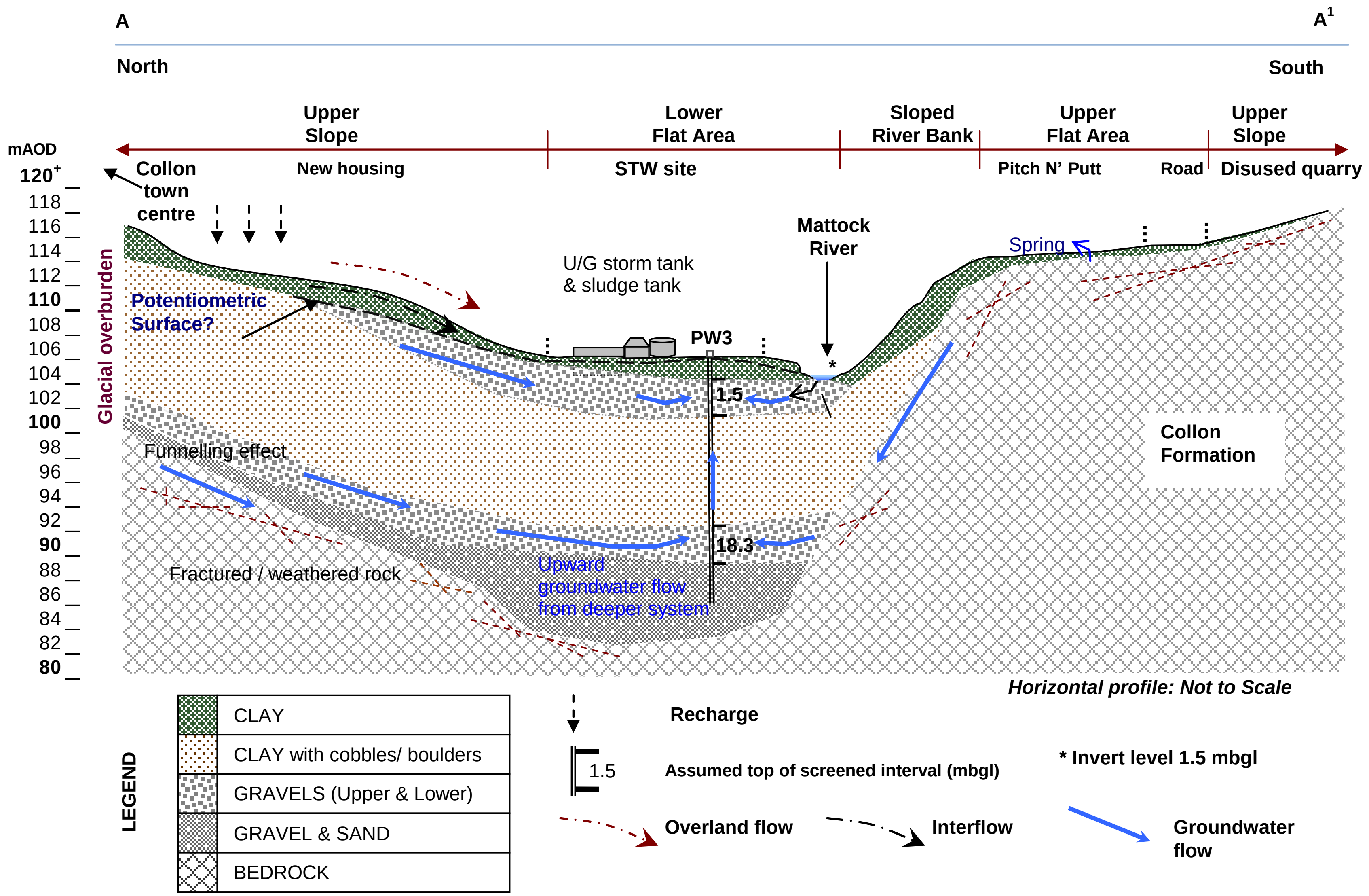


Figure 9 Schematic cross section through well PW3

Eastern boundary:

The eastern boundary of the ZOC is generally controlled by the sub-catchment boundary but tapers southwest towards location PW2 following inferred groundwater flow direction to this well. It is finally delineated at a distance of approximately 40m from the borehole. This is a slightly greater distance than that estimated using the Uniform Flow Equation (Todd, 1980), but given uncertainties in abstraction rates and aquifer parameter values, a conservative distance of 40 m is considered to be appropriate.

Western boundary:

The western boundary, near the Mattock River, is constrained by the local topography and the tributary (crossing the Kells Road) draining along this extent to the Mattock River. This lateral boundary generally follows a topographical line to the east of the tributary and extends to an area in the NW where ‘rises’ (groundwater discharges) were noted, possibly reflecting water recharged further west at Mount Oriel.

The ZOC and SO area for the Collon Public Water Supply are shown in Figure 10.

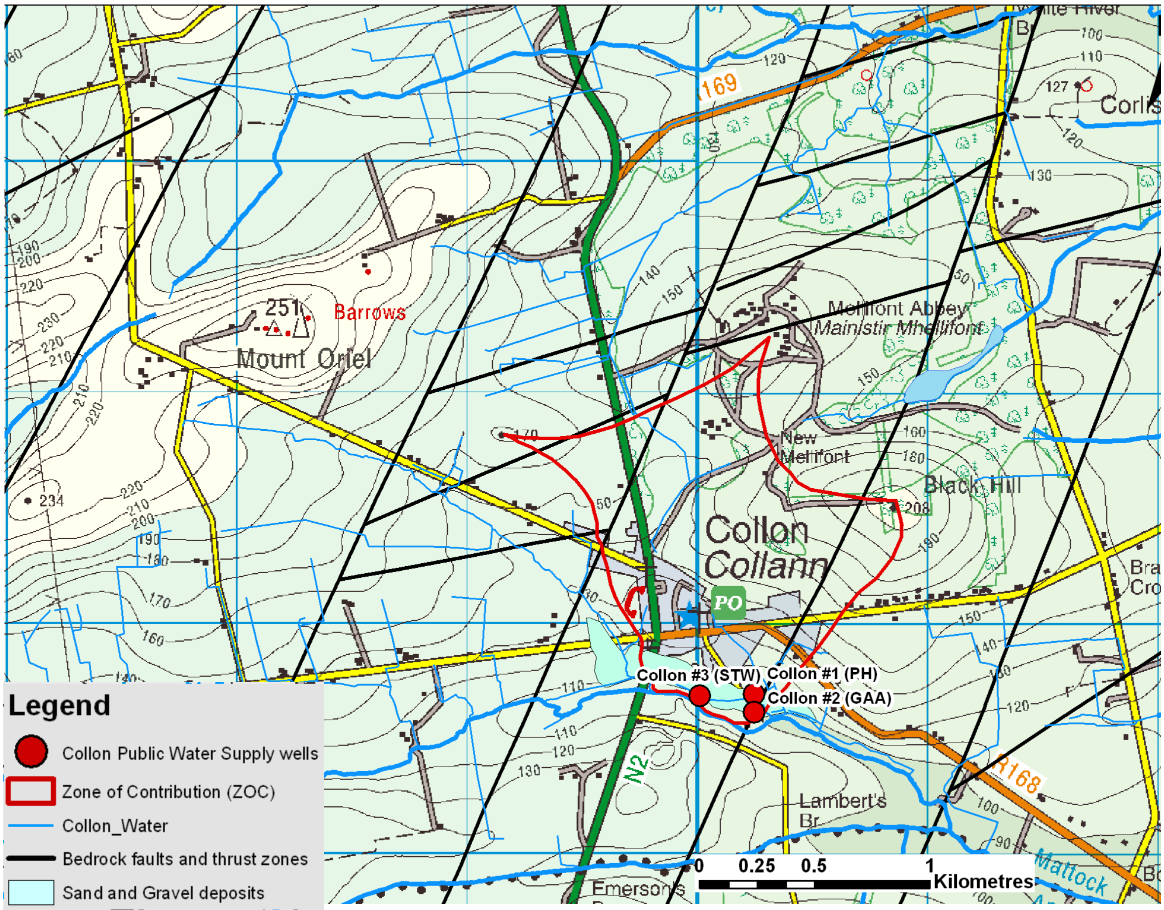


Figure 10 Zone of Contribution to the Collon boreholes

10.3 RECHARGE AND WATER BALANCE

The term ‘recharge’ refers to the amount of water replenishing the groundwater flow system. The recharge rate is generally estimated on an annual basis, and assumed to consist of input (i.e. annual rainfall) less water loss prior to entry into the groundwater system (i.e. annual evapotranspiration and runoff). The estimation of a realistic recharge rate is critical in source protection delineation, as it will dictate the size of the zone of contribution to the source (i.e. the outer Source Protection Area).

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 384 mm/yr (i.e. Annual Effective Rainfall as outlined in Section 6).

Estimated recharge: 145 mm/yr (Potential recharge x recharge coefficient)

The Draft National Recharge Map (GSI, 2012) indicates a recharge rate near the source at Collon of between 90 - 110 mm/yr, with the assumption of a predominantly thick, low permeability till as overburden in the area, and also low transmissivity bedrock aquifer that is unable to accept all potential recharge. However, the local recharge pattern is probably more varied with differing recharge coefficient values for the tills, gravels, shallow bedrock in the area and over the extent of made ground. Much of the groundwater is assumed to be recharged in the bedrock aquifer in the area uphill of the sand and gravel deposit that the boreholes abstract from. This area has a high slope, variable development of a fractured, weathered layer (transition zone), and is either covered in tills of various thicknesses (ranging from low to high vulnerability; 45% of the ZOC), or has thin subsoil cover, resulting in extreme groundwater vulnerability (40% of the ZOC). Poor aquifers are assumed have an upper limit on the amount of recharge they can accept irrespective of the amount estimated to percolate through the soil and subsoils overlying them; the typical value is 100 mm/yr. However, although runoff is indicated on the upper slopes by streams, recharge is capped at 160 mm/yr. This is to allow for very shallow groundwater flowing downhill in the weathered/fractured zone at the top of the bedrock aquifer; much of that flow becomes trapped below tills on the lower flanks of the hill, and then flows into the sand and gravel deposit.

Approximately 10% of the ZOC is occupied by Made Ground. This area, whilst paved, does have green areas that allow percolation of water into the groundwater system. Made Ground areas have recharge coefficients of 20%

The sand and gravel deposit occupies about 5% of the ZOC and is, for some of its area, covered by low permeability clays, and has a high water table.

Combining the factors outlined above, the **bulk recharge** coefficient for the area is estimated to be 38%.

Runoff losses: 239 mm. Runoff losses are assumed to be 62% of potential recharge.

These calculations are summarised as follows:

Average annual rainfall (R)	800 mm
Estimated P.E.	438 mm
Estimated A.E. (95% of P.E.)	416 mm
Effective rainfall	384 mm
Potential recharge	384 mm
Runoff losses	62%
Bulk recharge coefficient	38%
Assumed Recharge	**145 mm**

Using the water balance calculation, a recharge of 145 mm/yr and the current abstraction rate of 1,300 m^3/d would require a catchment area of 3.3 km^2. The ZOC delineated using hydrogeological mapping (section 10.2) is 1.3 km^2. This infers that there is either a higher influence of fracture flow on the supply than is accounted for in the bulk recharge assessments, that the recharge into the bedrock is higher than estimated, and/or that a partial source of water to wells PW2 and PW3 could be the Mattock River providing flow into the sand and gravel deposits from the upgradient direction.

11 SOURCE PROTECTION ZONES

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

The Inner Protection Area (SI) is designed to protect the source from microbial and viral contamination and it is based on the 100-day time of travel to the supply (DELG/EPA/GSI 1999). Based on the indicative aquifer parameters presented in Section 9.4, in the sand/gravel deposits, the bulk permeability is 65 m/d, with an effective porosity of 0.1. In the upper zone of the bedrock aquifer, the bulk permeability estimate is 0.5 m/d, and effective porosity is estimated as 0.01.

Average groundwater velocity = permeability x hydraulic gradient)/effective porosity

Velocity (sand/gravel deposit) = (permeability x hydraulic gradient)/ effective porosity

= (65 x 0.024)/ 0.1 = 15.6 m/d

Velocity (bedrock aquifer) = (0.5 x 0.06)/ 0.01 = 3.0 m/d

Because the gravel deposit is narrow, and irregularly shaped, the travel time of groundwater traversing the both the gravels and the bedrock is calculated. The “100 day time of travel distance” ranges from 430 to 590 m from the abstraction boreholes. The Inner Protection Zone (SI) and Outer Protection Zone (SO) are illustrated on Figure 11.

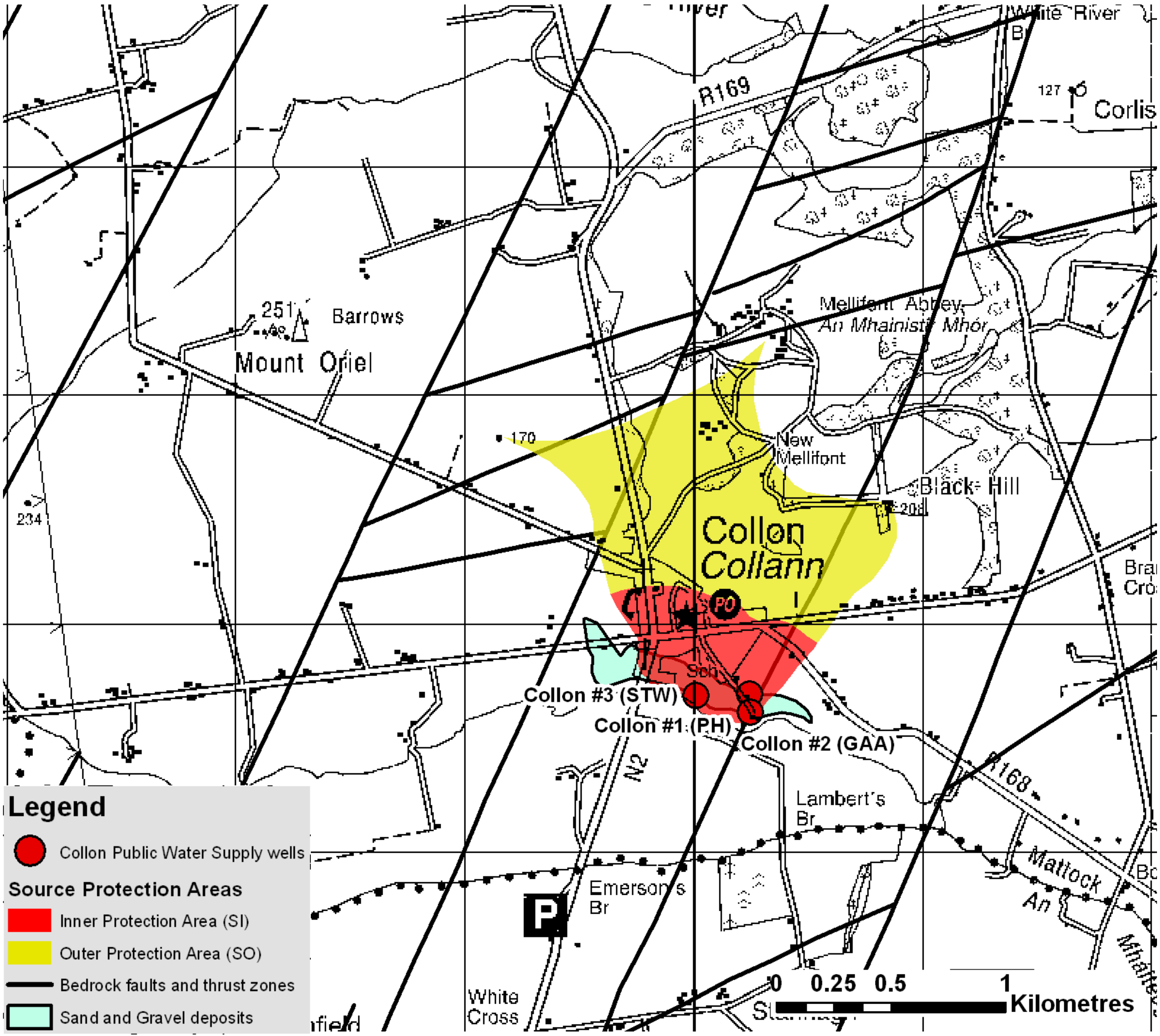


Figure 11 Zone of Contribution (ZOC) showing the Outer (SO) and Inner (SI) protection areas for the Collon Public Water Supply Scheme

The groundwater Source Protection Zones (SPZs), which are created by combining the SPAs with groundwater vulnerability across the catchment to the source (the ZOC), are shown in Figure 12 and are listed in Table 5. The majority of the ZOC is designated as SO/X and SO/E.

Table 5 Source Protection Zones

Source Protection Zone		% of total area (km^2)
SI/X	Inner Source Protection area / ≤1 m subsoil	0.4% (0.006km^2)
SI/E	Inner Source Protection area / <3 m subsoil	7% (0.086 km^2)
SI/H	Inner Source Protection area / High vulnerability	6% (0.076 km^2)
SI/M	Inner Source Protection area / Moderate vulnerability	4% (0.054 km^2)
SI/L	Inner Source Protection area / Low vulnerability	8% (0.11 km^2)
SO/X	Outer Source Protection area / ≤1 m subsoil	20% (0.26 km^2)
SO/E	Outer Source Protection area / <3 m subsoil	28% (0.36 km^2)
SO/H	Outer Source Protection area / High vulnerability	10% (0.12 km^2)
SO/M	Outer Source Protection area / Moderate vulnerability	6% (0.083 km^2)
SO/L	Outer Source Protection area / Low vulnerability	10% (0.13 km^2)

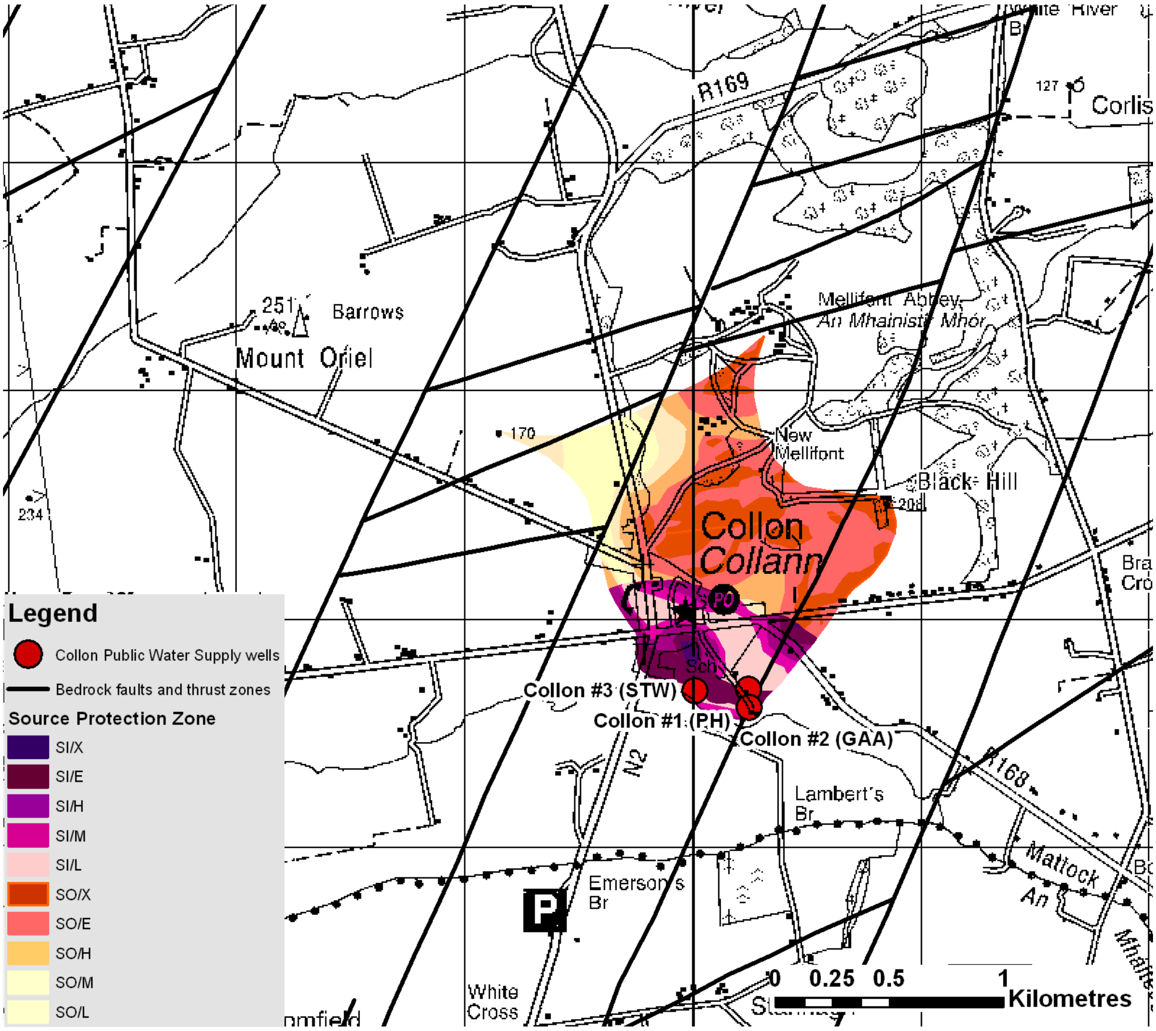


Figure 12 Source Protection Zones for the Collon Public Water Supply Scheme

The response measures indicating the level of management required for certain developments and activities within the different Source Protection Zones are included in the publication 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999). The response measures indicate the degree of investigation recommended in each zone for different land use activities.

12 POTENTIAL POLLUTION SOURCES

There is a relatively new housing complex to the north of the sewage works and location PW3. It is understood that this area is connected to the public waste water system. However, private septic tanks are used at locations up-gradient of the wells, while some buildings near locations PW1 and PW2, such as the Mattock Rangers premises, also use septic tank systems which represent a potential risk where tank seals are compromised, or effluent treatment is insufficient.

The location of PW3 within the footprint of the sewage works (STW) makes this supply borehole extremely vulnerable to potential breaches in this treatment system. The borehole is protected by a raised chamber which would provide some protection against surface ingress of contaminant. However, this will not protect the well from potential waste water contamination breaches at depth, where productive gravels at PW3 extend to 5.2 mbgl. Furthermore, a drainage ditch draining from the village runs west-east towards and in close proximity to PW3 (before diversion to the Mattock River) which may pose a pollution threat to groundwater if it were contaminated. The potential for movement of river water below the STW outlet into the gravels that supply PW2 should also be borne in mind.

13 CONCLUSIONS

- The Zone of Contribution to the Collon Public Water Supply scheme is approximately 1.3 km^2, and is controlled essentially by topographic and hydrogeological boundaries.
- Groundwater is abstracted via three boreholes from a sand and gravel deposit. Groundwater in the sands and gravels comes from direct recharge through soils into the sands and gravels, and from groundwater flowing laterally and upwards into the sands and gravels from the underlying bedrock.
- Hydraulic connection between the upper gravels and the Mattock River in the area of the wells may exist, such that the watercourse may be recharging the aquifer.
- Well head sanitary protection at locations PW1 and PW2 appears unsatisfactory with easy ingress of surface water and possible contaminants at both locations. The well-head protection at PW3 is good, with a raised, enclosed and lockable chamber.
- On the basis of data available during the study, there appears to be no contamination issues within the immediate area of the well field. However, the proximity of the boreholes to the STW and the drainage ditch, particularly in view of the potential interaction between river and groundwater, should be borne in mind.

14 RECOMMENDATIONS

- Well head protection at locations PW1 and PW2 needs to be reviewed with regard to observed surface water ingress through the chamber cover. General security around the pump house and these two wells should also be re-assessed.
- Previously drilled boreholes near the GAA grounds and now covered should be located and either backfilled or protected against surface water ingress.
- Annual or once-off summer/winter assessment of a full suite of groundwater chemistry parameters at individual boreholes and the river would allow the sources of the groundwater to be better understood. Raw water sampling taps for each abstraction point are required.
- It is recommended that water quality monitoring include for periodic coliform bacteria analysis (particularly at location PW3) and other indicators of agricultural contaminants such as potassium. Furthermore, water quality records for the Mattock River upstream and downstream of the STW discharge point should be maintained.
- The nature of surface water and groundwater exchange along the extent of the Mattock River within the sub-catchment should ideally be investigated further. Groundwater and surface water hydrograph analysis should be assessed against meteoric data for a suitable monitoring period to include for winter recharge assessment against summer recharge patterns. Field parameters, such as transmissivity and porosity should be assessed locally.

- Records of abstracted raw water volumes at each borehole are needed to better understand the groundwater flow system and well field operation. This could be achieved by installation of meters at locations PW1 & PW2.
- Groundwater levels should be monitored regularly, with an indication of pumping activity including time since pump ON/OFF. This would allow for future well hydrograph analysis and also enable assessment of dry weather spells and lower water tables.
- Further assessment of drainage and water quality near PW3 needs to be carried out, given the proximity of a drainage ditch in line with this abstraction point.
- A detailed assessment of the potential hazards to the supply scheme would prove beneficial.

15 REFERENCES

Aspinwall, (1981). *Proposed land filling at White River, Volumes I & II,* Report No. 3.723/R/2, for Louth County Council; Aspinwall & Company, UK.

BSI, (1999). *BS 5930:1999, Code of practice for site investigations*. British Standards Institution, London.

DELG/EPA/GSI, (1999). *Groundwater Protection Schemes*. Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland.

ERBD, (2007). *Draft National Recharge Map,* produced by CDM Ireland and Compass Informatics.

Fitzsimons, V., Daly, D. and Deakin, J. (2003). *GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination.* Geological Survey of Ireland.

Hunter Williams, N. and Lee, M., (2007). *Ireland at risk – Possible implications for groundwater resources of climate change.* Geological Survey of Ireland, Groundwater section.

KT Cullen, (1983). *Report on the drilling of two production wells at Collon, Co. Louth*. June, 7th 1983, p.1.

McConnell, B., Philcox, M. and Geraghty, M., (2001). *A Geological Description to Accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 13, Meath.* Geological Survey of Ireland.

Meehan, R.T., (2004). *Subsoils map of County Louth.* Map produced as part of EPA Soils and Subsoils Mapping Project. Teagasc, Kinsealy, Dublin.

Todd, D.K. (1980) Groundwater Hydrology, 2nd ed. New York: JohnWiley.

WFD, (2005). *WFD Pressures and Impacts Assessment Methodology: Guidance on the Assessment of the Impact of Groundwater Abstractions.* Paper by the Working Group on Groundwater (WGGW), Guidance document no. GW5.

APPENDIX 1

COLLON – SELECTED PLATES

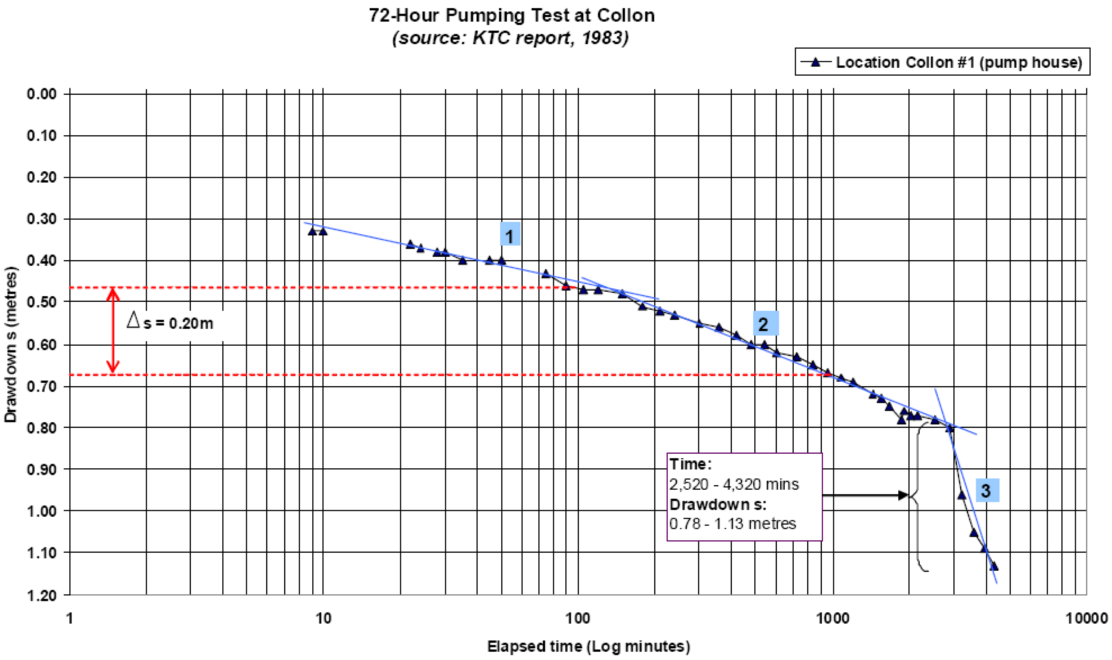

View north to STW (PW3) site
N
new houses
PW3
stream
Mattock River
slope


outfall
Mattock River
SE
NW
exposed gravels

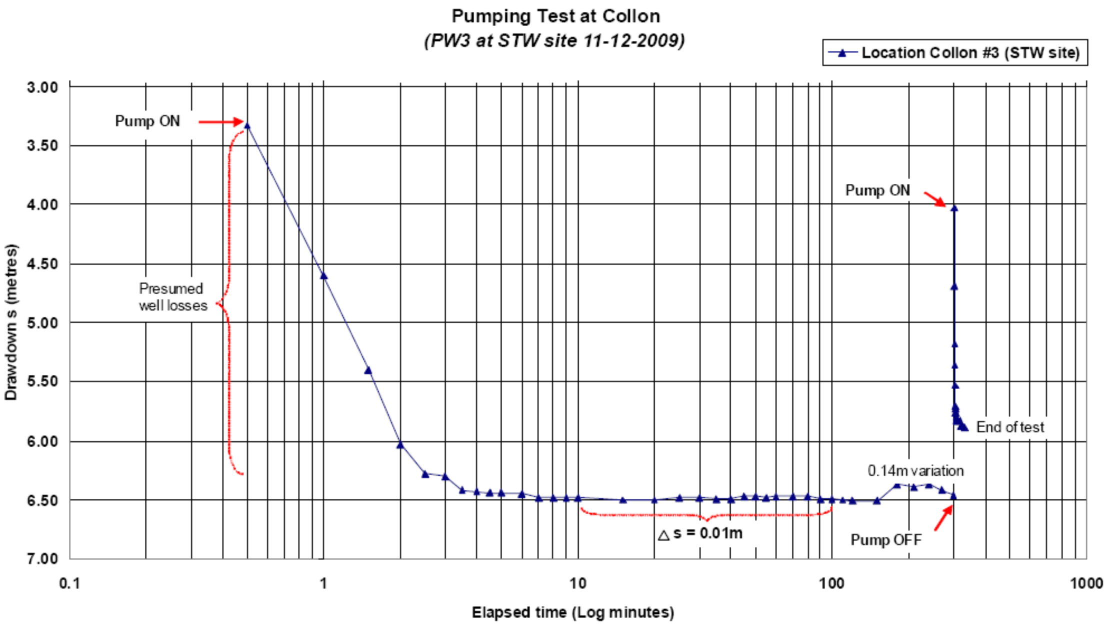

Pump house (PW1) site
PW1
clear water tank
to PW2

APPENDIX 2

COLLON – PUMPING TEST RESULTS



Pumping test analysis at location Collon #1 (PW1)



Pumping test analysis at location Collon #3 (PW3)

APPENDIX 3

COLLON – SUMMARY OF FIELD PARAMETER MEASUREMENTS

Location ref.	Location at Collon	Parameter Type	EC (µS/cm) Min	EC (µS/cm) Max	Temp (°C) Min	Temp (°C) Max	pH 1 Reading	TDS (ppm) 1 Reading
PW1	PH	GW	359	447	10.7	10.9	7.16	210
PW2	GAA	GW	330	487	10.6	11.6	7.08	249
PW3	STW	GW	449	453	10.2	10.8	7.73	246
1	Stream at PW3	SW	551	593	7.3	9.8	7.97	298
2	Stream at PW1	SW	388		8.6		7.7	195
3	Mattock River at PW2	SW	276	315	6.7	8.0	8.1	159
4	Stream at Oriel Heights	SW	342		7.9		7.93	175
5	Spring	GW	343	367	5.6	6.1	7.28	171
6	Tributary at Kells Road	SW	320		6.2		8.12	164
7	Spring (flowing)	GW	521		10.7		6.99	263
8	Mattock River at PW3	SW	264	303	6.5	7.9	8.25	167

Sample dates: 08-12-2009 to 15-12-2009
***Note:** Refer to map below for location of sampling locations; Groundwater points in blue*