8 ATHY TC WATER SUPPLY

8.1 Introduction

The objectives of the report are as follows:

- To delineate source protection zones for the Athy Town Council Water Supply; namely the Infiltration Gallery, "Woodstock" Borehole and the new Barrack Lane Borehole.
- To outline the principal hydrogeological characteristics of the surrounding area.
- To assist Kildare County Council in protecting the water supply from contamination.

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

The report forms part of the groundwater protection scheme for the county. The maps produced for the scheme are based largely 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 county 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.

8.2 Summary of Supply Details

	"Woodstock"	**Barrack Lane**	**Infiltration Gallery**
GSI no.	2619SWW388	2619SWW520	2619SWW541
Grid ref. (1:25,000)	S ^{2}6790 ^{1}9450	S ^{2}6793 ^{1}9446	S^{2}6809 ^{1}9436
Townland	Townparks	Townparks	Townparks
Source type	Borehole	Borehole	Infiltration Gallery
Drilled	23/6/1977	6/3/2001	Unknown
Owner	Athy Town Council	Athy Town Council	Athy Town Council
Elevation (ground level)	~ 56.0 m O.D. (Malin Head)	~ 57 m OD (Malin Head)	~56.8 m O.D. (Malin Head)
Depth (Daly, 2002)	38.4 m	50.3 m	4.7 m
Depth of casing	13 m	12.2 m	N/a
Diameter	305 mm (12")	250 mm (10")	N/a
Depth to rock	8.0 m	12.2 m	Unknown
Static water level	Ground level	0.67m	0.8 m
Depth of pump	12.0 m below ground	40.0 m below ground	4.0 m below ground
Pumping water level	7-8.5 m (Daly, 1987)	7.41 m below ground (Daly, 2002)	
Consumption (from CoCo records)	700-900 $m^3 d^{-1}$	500-700 $m^3 d^{-1}$	900-1200 $m^3 d^{-1}$
Pumping test summary:			
(i) abstraction rate $m^3 d^{-1}$	1496 (16-21/6/1977 GSI files)	1010 (26/3/2001 Daly, 2002)	
(ii) specific capacity	107	150	
(iii) transmissivity	150	200	

8.3 Methodology

8.3.1 Desk Study

Details about the boreholes such as depth, date commissioned and abstraction figures were obtained from County Council personnel and reports written by E. P. Daly (1981, 1987, 2001, 2002). Additional geological and hydrogeological information was provided by the GSI mapping programmes (Glanville (1997), Mc Connell et al. (1994)).

8.3.2 Site visits and fieldwork

This included the following:

- Meetings with Athy Town Council Staff 31/1/2002 and 30/10/02.
- Water sampling by South Western Area Health Board staff in July 2002.
- Drilling of one depth to bedrock hole and field mapping walkover on 27th May 2002 to further investigate the subsoil geology, the hydrogeology and vulnerability to contamination.

8.3.3 Assessment

Analysis of the data utilised field studies and previously collected data to delineate protection zones around the source.

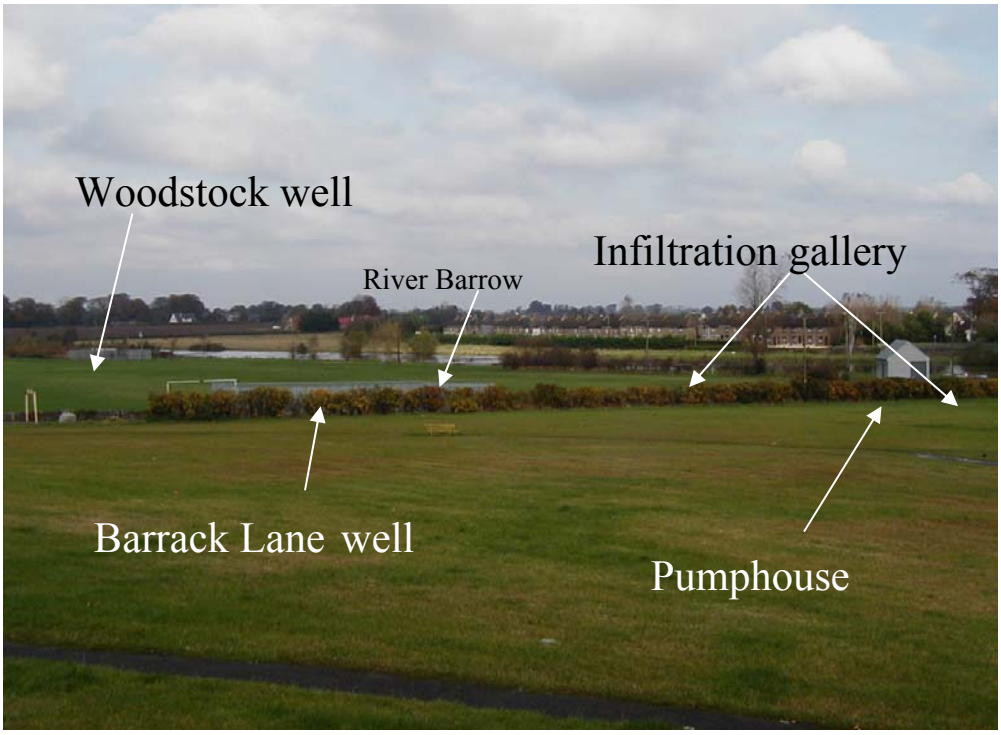
8.4 Location & Site Description

The well field is located in the townland of Townparks, Athy, Co. Kildare. The site is situated at Barrack Lane, which is on the north side of Athy, off the Stradbally Road, on the western side of the River Barrow. Figure 8-1 provides an overview of the site. The main pump house is located at the end of Barrack Lane, The Barrack Lane supply borehole is located alongside Barrack Lane. The infiltration gallery is located between the pump house and the River Barrow. The "Woodstock" borehole is approximately 200 m north of the main pump house close to Woodstock Castle.

Each well site ("Woodstock" and Barrack Lane wells) is located inside an area that is secured by a 2 m high galvanised fence. Each well head and access point for the infiltration gallery is secured by a galvanised cover that is either padlocked or bolted fast. The "Woodstock" well head is raised to approximately 0.5 m above ground level, presumably for added protection against possible flooding from the River Barrow. In times of extreme flooding the water level in the river has been reported by Co. Co. staff to be above the top of the sump.

Each of the abstraction points pumps water directly into the main distribution system which covers the main Athy urban area, supplying water to approximately six thousand people. From the caretakers records consumption in 1995 was approximately 1800 $m^3 d^{-1}$, in October 2002 the consumption was approximately 2700 $m^3 d^{-1}$, which is an approximate increase of 50% over a seven year period. To meet the increase in demand the new production well (Barrack Lane) was installed. According to council staff each of the abstraction points pumps continuously over the entire day and there is chlorination treatment at each point.

Figure 8-1 Photograph showing Athy Well Field



8.5 Topography, Surface Hydrology and Land Use

The topography in the vicinity of the source is flat or undulating with an altitude of approximately 50 to 60 m O.D. The general lie of the landscape is a very gentle dip toward the River Barrow. There is a series of hills approximately 10 km to the west in county Laois. The highest points in this range of hills are approximately 260 m O.D.

The River Barrow is the largest surface water feature in the area and can be seen in Figure 8-1. The land appears to be free draining with only occasional ditches.

Land use in the vicinity of the well field is generally urban: housing estates, streets, the canal and some parkland. Approximately 1 km north and west of the site the land use becomes agricultural - dominated primarily by tillage and grassland. There are also a few sand/gravel pits in the locality (some disused) and there is a large limestone quarry at Ballyadams, Co. Laois.

8.6 Geology

8.6.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the site. It provides a framework for the assessment of groundwater flow and source protection zones that will follow in later sections.

Geological information was taken from a desk-based survey of available data, which comprised the following:

- Bedrock Geology 1:100,000 Map Series, Geological Survey of Ireland. (Mc Connell et al., 1994).
- Information from geological mapping in the nineteenth century (on record at the GSI).
- Reports by GSI on the well drilling and a pollution incident in the 1980's. (Daly, 1981, 1987) Geological Survey of Ireland.
- Subsoil mapping by the GSI, Glanville (1997).

8.6.2 Bedrock Geology

The Milford Limestone Formation occupies the area around the source. It is generally regarded as being a clean, often karstified and dolomitised shelf (shallow water) limestone (refer to Section 3 of Volume I).

8.6.3 Subsoil (Quaternary) Geology

The main subsoil categories in the vicinity of the source are till ('boulder clay') and sand/gravel. The characteristics of each category are described briefly below:

- 'Till' or 'Boulder clay' is an unsorted mixture of coarse and fine materials laid down by ice. Till is at the surface to the north of the sources, but also occurs at varying depths below the sand/gravel. At the "Woodstock" and Barrack Lane boreholes, till occurs in a layer approximately 2 m thick at the surface and in a layer approximately 4 m thick at the top of the rock. It is not classed as an aquifer in the area and its significance is mainly in relation to groundwater vulnerability and the protection of the sand/gravel and rock aquifers from surface contaminants.
- Sand/gravel is widespread in south Kildare and is the dominant subsoil around Athy and the River Barrow. It occurs in all three sources and is mapped as a **regionally important sand/gravel aquifer (Rg)** in the Barrow valley. Section 4 of Volume I provides further details.
- Alluvium occupies a narrow floodplain (250-400 m) along the River Barrow. The alluvium is thin - in the order of 0.25-0.42 m (E.P. Daly 1987). Its main significance is in vulnerability classification.
- A depth to bedrock drilling programme was carried out to ascertain the subsoil thicknesses in Kildare. In Athy there is good depth to bedrock information available from previous

investigations. The depth to bedrock varies from 5-20 m in Athy. At the source the depth to bedrock is reported to be 12-13 m (E. P. Daly, 1987).

8.7 Groundwater Vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. In areas where the sand/gravel aquifer is exposed or covered by less than three metres of till this will be the main target and vulnerability will be dictated by the mapped thickness of the unsaturated zone.

Generally the depth to the water table in the sand/gravel in the vicinity of the infiltration gallery is less than 2 m below ground. The water table is estimated to be within 3 m of the ground surface up to 400 m west of the gallery. Therefore, the groundwater vulnerability in the area closest to the gallery is classed as 'extreme'. Thus the vulnerability to contamination of groundwater feeding the infiltration gallery is extreme but becomes less vulnerable moving upslope away from the gallery.

In areas away from the sand/gravel aquifer (i.e., to the west of the sources) bedrock is the main target and the vulnerability will be dictated by the mapped depth to rock and the permeability of the subsoil. In the vicinity of the source, the permeability of the subsoil is mapped as moderate and the mapped depth to bedrock varies from 10 m at the edge of the sand/gravel aquifer to less than 1 m 2 km west of the source. Thus, the vulnerability ranges from moderate to extreme moving westwards from the sand/gravel aquifer towards higher ground. The distribution of the vulnerability is presented in Maps 6 and 8. Note that, though the vulnerability of groundwater at the source is mapped as extreme, this refers to the uppermost groundwater "target" in the sand/gravel. The gallery draws from the sand/gravel but the boreholes draw from the rock, which is confined by a deeper layer of till (see section 8.8). As such, the vulnerability of groundwater supplying the boreholes will be lower than that represented in Map 6 and 8.

Depth to rock interpretations are based on the available data cited here. However, depth to rock can vary over a small scale. As such, the vulnerability mapping provided will not be able to anticipate all the natural variation that occurs in an area. The mapping is intended only as a guide to land use planning and hazard surveys, and is not a substitute for site investigation for specific developments. Classifications may change as a result of investigations such as trial hole assessments for on-site domestic wastewater treatment systems. The potential for discrepancies between large scale vulnerability mapping and site-specific data has been anticipated and addressed in the development of groundwater protection responses (site suitability guidelines) for specific hazards. More detail can be found in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

8.8 Hydrogeology

8.8.1 Introduction

This section presents our current understanding of groundwater flow in the area of the well field.

Hydrogeological and hydrochemical information for this study was obtained from the following sources:

- GSI files and archival Kildare County Council data.
- Athy U.D.C. Trial & Production Wells. Eugene Daly Associates (2002).
- E.P. Daly (1981, 1982, 1987) Geological Survey of Ireland.
- Kildare County Council drinking water returns for 2002 and 2001.
- Hydrogeological mapping carried out by GSI on 9th, 10th, 27th & 28th May 2002 and 30th October 2002.
- A drilling programme carried out by GSI to ascertain depth to bedrock and subsoil permeability (1 hole within 2 km of the source).
- A Groundwater Protection Scheme for Co. Laois (Deakin, 2002).

8.8.2 Rainfall, Evaporation and 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 generally assumed to consist of an input (i.e. annual rainfall) less water losses 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; along with the rate of abstraction at the source it will dictate the size of the zone of contribution to the source. In areas where point recharge from sinking streams, etc., is discounted, the main parameters involved in recharge rate estimation are annual rainfall, annual evapotranspiration, and annual runoff and are listed as follows:

- *Annual rainfall:* 750 mm.
  Rainfall data for gauging stations around Athy (from Fitzgerald, D., Forrestal., F., 1996) are as follows:

Gauging Stations	Grid reference	Elevation OD (m)	Approximate distance & direction from source	Annual precipitation 1961-1990
Athy (Voc.Sh)	S656933	61	2.5 km west	746 mm
Kilberry	S663999	61	5 km north west	745 mm

  As the borehole is closest (in terms of distance and altitude) to the Athy and Kilberry gauging stations the precipitation is assumed to be about 750 mm annually. This is supported by the interpreted contour maps of precipitation presented in the "Agroclimatic Atlas of Ireland" (Collins and Cummins, 1996).

- *Annual evapotranspiration losses:* 400 mm. Potential evapotranspiration (P.E.) is estimated to be 425 mm $yr.^{-1}$. Actual evapotranspiration (A.E.) is estimated as 95 % of P.E., to allow for seasonal soil moisture deficits. More local measurements of evapotranspiration are not available.

- *Potential recharge:* 350 mm $yr.^{-1}$. This figure is based on subtracting estimated evapotranspiration losses from average annual rainfall. It represents an estimation of the excess soil moisture available for either vertical downward flow to groundwater or runoff and is commonly referred to as "Effective Rainfall".

- *Annual runoff losses:* ~35 mm. The slopes and the nature of the deposits around the source need to be considered in order to give a representative value for the runoff during rainfall events. The subsoils are thought to be free draining (refer to Section 8.6.3) with very little surface drainage and a representative value for the runoff is estimated to be in the order to 10%.

These calculations are summarised as follows:

Average annual rainfall (R)	750 mm
Estimated P.E.	425 mm
Estimated A.E. (95% of P.E.)	400 mm
Potential Recharge (R – A.E.)	350 mm
Runoff losses (10% of recharge)	35 mm
Estimated Actual Recharge	**315 mm**

8.8.3 Groundwater Levels

A GSI well survey was carried out in the 1970's in County Kildare, from which broad estimates of the groundwater levels & directions and gradients can be made. Detailed hydrogeological work was carried out on the "Woodstock" borehole and the Infiltration Gallery by the GSI in 1987, in response to an enquiry by Kildare County Council due to a potential pollution incident in the River Barrow (Daly, E.P., 1987). In 1999, 2000 and 2001 further work on the area was carried out by E.P. Daly Associates in helping Athy TC to locate a new supply borehole (Barrack Lane) to augment the supply to the town.

Barrack Lane Well: on 21/3/2001 static water levels were less than 1 m below ground for the Barrack Lane well and a trial well (40 m away). The pumping water level for the supply borehole is approximately 7 m below ground. During test pumping in March 2001 the pumping water levels never went below 8.5 m below ground (Daly, E.P., 2000). Both the static and pumping water levels are above the top of the rock (11 m and 3.5 m respectively) suggesting that the groundwater in the vicinity of the supply borehole is confined.

Woodstock Well: Daly (1987) states that the piezometric surface of the bedrock is close to the ground level in the area around the Townparks borehole and suggests groundwater in the vicinity is confined. During the initial pumping test in 1977 it is reported that the water level rose during the five day constant rate test and that the static water level was above ground level. Daly (1987) suggests that the groundwater becomes unconfined approximately 3 km further to the south and toward the river.

Infiltration Gallery: It is assumed that the main sump and the three legs that make up the gallery are entirely excavated in sand/gravel. Static water levels are reported to be less than 2 m below ground (approximately 56 m O.D.) in the main sump which is two metres higher than the water level in the River Barrow (Daly, 1987). The water level in the sand/gravel is estimated to be less than 3 m from ground surface up to approximately 400 m west of the gallery. It is assumed that there is a hydraulic connection between the water in the sump and the water in the river despite a thin layer of alluvium present between the two. The maximum pumping water level in the sump is approximately 52.5 m O.D. which is approximately 1 m below the water level in the river.

8.8.4 Groundwater Flow Directions:

Static water levels in the Barrack Lane borehole are slightly less than the static water level in the "Woodstock" well, while levels in both wells are above the level of the river. At a local scale, this suggests that groundwater in the bedrock aquifer is moving in a southerly direction to discharge into the river where the groundwater is unconfined. At a more regional scale, groundwater flow is in an easterly/south easterly direction toward the River Barrow. The topographic highs that occur to the west in the townlands of Oughaval, Ballaghmore, Ballintlea and Crannagh are assumed to be surface water and groundwater divides.

Pumping water levels in the gallery and boreholes are lower than those in the river and, in a restricted area near the source, some river recharge to the deep boreholes is likely to occur during pumping. However Daly (1987) estimates amounts will be small.

TC staff carried out an experiment at the infiltration gallery to determine the relationship of the gallery with the river (Daly, 1987). They dug two pits on either side of the gallery and measured how long it took for a salt tracer to appear in the gallery discharge. After one week the tracer from the river bank didn't appear in the gallery. However, tracer from the west side of the gallery appeared in the discharge after only three days. Daly (1987) uses these data to suggest that only a small proportion of water supplying the gallery comes from the river.

8.8.5 Groundwater Gradients:

Gradients are estimated for the piezometric surface in the bedrock aquifer and for the water table in the sand/gravel for both static and pumping conditions.

The static water gradient in the bedrock aquifer is estimated from the reported piezometric levels in "Woodstock" borehole and the Barrack Lane borehole to be in the order of 0.002-0.004. Pumping water gradients are much steeper close to the wells. These are estimated to be in the order of 0.14-0.16.

Static groundwater gradients in the sand/gravel close to the gallery are in the order of 0.05. Moving away from the gallery and the river the gradient decreases becoming similar to the topographic gradient; being in the order of 0.002. During pumping the gradient is reversed and the maximum pumping gradient is about 0.03 (Daly, 1987).

8.9 Hydrochemistry and Water Quality

The following key points have been identified from the data. See Appendix VI for graphs.

- Analysis of hardness indicates a very hard (>350 mg l^{-1} $CaCO_3$) calcium bicarbonate hydrochemical signature. Magnesium levels in the "Woodstock" and Barrack Lane boreholes are above 20 mg l^{-1} in all but one analysis suggesting that the groundwater to the boreholes is coming from the magnesium rich dolomite aquifer.
- Reported nitrate concentrations are in the order of 15-30 mg l^{-1} for the three abstraction points. The average nitrate levels are as follows: Infiltration Gallery (approximately 27 mg l^{-1}); "Woodstock" borehole (approximately 17 mg l^{-1}); and, Barrack Lane (approximately 23 mg l^{-1}). Levels in the infiltration gallery appear to be higher than in either of the two wells, and are generally above the GSI threshold of 25 mg l^{-1}. The nitrate data for the "Woodstock" well is the most extensive, with occasional data covering the last 30 years and it can be seen that overall the nitrate level appear to relatively steady and there appears to be no overall trend in the data.
- Chloride is a constituent of organic wastes and levels higher than 25 mg l^{-1} may indicate significant contamination, and levels higher than the 30 mg l^{-1} usually indicates significant contamination. Chloride data range from 30 to 44 mg l^{-1} (average (35 mg l^{-1}) in the available samples for the "Woodstock" borehole, suggesting that contamination from organic wastes is occurring on a regular basis. Data range from 23 to 25 mg l^{-1} in the Barrack Lane well and from 21 to 38 mg l^{-1} in the infiltration gallery. The data for the infiltration gallery suggests that contamination from organic wastes has also occurred.
- Of the contaminant indicators examined, only chloride was at significant levels in available samples. There is only reported incident of bacteria in the analyses, occurring at the "Woodstock" borehole in 1987. However Daly (1987) concluded that the result was anomalous and is not representative of the groundwater quality at the boreholes and the gallery. Nitrate and chloride in the infiltration gallery and chlorides in the "Woodstock" borehole may reflect localised hazards (perhaps from leaking sewers).

8.10 Aquifer Characteristics

The bedrock (Milford Limestone Formation) is the main aquifer feeding the Woodstock and Barrack Lane boreholes. The bedrock is described in Sections 3 & 4 of Volume 1 of the main report. The Milford Limestone Formation is classed as a **Regionally Important Karstified Aquifer (Rk)** (refer to Section 4.12 of Volume I). The bedrock in the vicinity of the boreholes is dolomitised (Daly, E.P., 1987). Daly (1987, 2002) suggests that the bedrock is fissured and/or karstified up to 56 m below ground. The fissures are frequently filled with sand & clay near the surface (E. P. Daly 1982). Daly (2001) also reports cavernous rock at the bottom of the Barrack Lane borehole. There are five "Excellent" and two "good" yielding wells in the Athy area, all abstracting water from the dolomitised bedrock. Table 4 presents the available range of aquifer parameters for the Milford Formation based primarily on locally derived data. The high productivity of the bedrock in this locality is attributed to the possible presence of a fault or fracture zone along the River Barrow (Daly, 1987, 2000). Faults and fractures are likely to be the focus of groundwater movement and dolomitisation and dissolution of the clean limestone is likely to have occurred preferentially along them. Eugene Daly Associates calculated the transmissivities from the trial well test data to be approximately 140 m^2 d^{-1} which compares favourably with estimates of the transmissivity from specific capacity data.

The infiltration gallery is excavated in a sand/gravel deposit that is classed as a **Regionally Important Sand/gravel aquifer (Rg)**. Further details of this aquifer can referred to in Section 4 of Volume I. The permeability was estimated from salt tracer experiments that were carried out by TC staff (Daly, 1987). Transmissivities were estimated from test pumping of the Graysland Borehole (located in the same aquifer on the southern side of Athy) to be in the order of 200 m^2 d^{-1}.

Table 4 Estimated Aquifer parameters for the Milford Limestone.

Parameter	*Source of data*	*Milford fmn.*
Transmissivity (m^2 $d^{-1)}$ (Daly 1987)	Local	140
Specific Capacities (Daly 1987)	Local	50-150
Permeability (m d^{-1})	Local	5
Porosity	Assumed	0.015

Table 5 Estimated Aquifer parameters for Barrow sand/gravel aquifer.

Parameter	*Source of data*	*Barrow sand/gravel Aquifer.*
Transmissivity (m^2 $d^{-1)}$ (Daly, 1987)	Local	200
Specific Capacities (Daly, 1987)	Local	70
Permeability (m d^{-1})	Local	8
Porosity	Assumed	0.07

8.11 Conceptual Model

- The Athy TC water supply consists of two boreholes and an infiltration gallery.
- The "Woodstock" and Barrack Lane supply boreholes are fed by the Milford Limestone Formation which is classed a **Regionally Important Karst aquifer** (**Rk**). The infiltration gallery is fed by the sand/gravel which is classed a **Regionally Important Sand/gravel aquifer (Rg)**.
- The bedrock aquifer parameters are variable but the permeability is thought to be generally high in the area of the "Woodstock" and Barrack Lane borehole.
- The bedrock aquifer is confined in the vicinity of the two supply boreholes. The piezometric surface for the confined bedrock aquifer is approximately at ground surface. Groundwater flow in the bedrock aquifer is probably via dolomitised and karstified fractures, fissures, joints, bedding planes and the uppermost part of the bedrock.
- The sand/gravel deposit is unconfined. Water levels are estimated to be less than 3 m below ground level up to 400 m west of the infiltration gallery.
- There are few drains and surface streams and the subsoils are moderately-highly permeable.
- It is expected that the regional groundwater flows to the east and discharges to the River Barrow. It is assumed that the gallery is almost entirely groundwater fed and that very little river water is induced into the gallery by pumping.
- Diffuse recharge occurs over most of the land surface through the permeable till. Estimates are in the order of 315 mm yr^{-1}.
- The hydrochemical chemical signature of the groundwater in the boreholes indicates that the groundwater is fed by the bedrock dolomitised aquifer.
- Elevated chloride in the "Woodstock" borehole suggest that there is contamination occurring from organic wastes. Whilst nitrates and chloride levels in the infiltration gallery also suggest that contamination from organic wastes is occurring.

8.12 Delineation of Source Protection Areas

8.12.1 Introduction

This section delineates 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 pattern, and are presented in.

Two source protection areas are delineated:

♦ Inner Protection Area (SI), designed to give protection from microbial pollution;

- Outer Protection Area (SO), encompassing the zone of contribution (ZOC) to each of the boreholes and the infiltration gallery.

8.12.2 Outer Protection Area

The Outer Protection Area (SO) is bounded by the complete catchment area to the well field, 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 pumping rate, (b) the groundwater flow direction and gradient, (c) the subsoil and rock permeability and (d) the recharge in the area. The ZOC is delineated using both analytical modelling and the results of hydrogeological mapping and conceptualisation. The boundaries are shown in Map 8 and are described as follows:

The **western boundary** is delineated using the regional topographic divides that lie to the west in County Laois. It is thought that all shallow groundwater could potentially make its way to the source along an east-west line drawn eastwards from the source to meet the watershed at right angles. This represents maximum flow distances of 9 km. Flow paths of this length are possible, given the karstified and dolomitised nature of the bedrock and the high permeability of the sand/gravel aquifer. Given flat topography and the generally high permeability of the aquifers, it is difficult to justify drawing the western boundary any closer to the well.

The **eastern boundary** is on the down gradient side of the borehole. The test pumping data of the Barrack Lane borehole indicates that it can draw water down by 0.2-0.3 m at a distance of 40 m toward the river. As the river is 110 m to the east of the supply borehole, the boundary is taken as far as the river to allow for errors and variability in the aquifer parameters.

The **northern** and **southern boundaries** are complicated by the presence of the three Castlemitchell supply sources, two of which lie directly upgradient of the Athy source. They are also difficult to determine given the flat topography and the karstified and dolomitised nature of the bedrock. In other words, the ZOC needs to be big enough to incorporate the catchments of several sources and significant safety margins are required to allow for the unpredictability of groundwater flow within karstic bedrock aquifers in areas of flat topography. The proposed boundaries have therefore been extended to incorporate the most significant topographic hills in the plains area whilst allowing for a significant safety margin.

Note that the area delineated by these boundaries is significantly greater than the area required to supply sufficient diffuse recharge to meet the abstraction demand at the various supply sources. However, given the uncertainties outlined above, it is difficult to justify boundaries which delineate a smaller area.

8.12.3 Inner Protection Area

According to "Groundwater Protection Schemes" (DELG/EPA/GSI, 1999), delineation of an Inner Protection Area is required to protect the source from microbial and viral contamination and it is based on the 100-day time of travel (ToT) to the supply. Estimations of the extent of this area cannot be made by hydrogeological mapping and conceptualisation methods alone. Estimations of the extent of this area are made using Darcy's Law as follows:

Sand/gravel: with a permeability (K) value of 40 m d^{-1}, porosity (n) of 0.07 and a gradient (i) of 0.05 the velocity (V) can be estimated as follows;

$V = (K.i) / n$

$V = 8$ m d^{-1}

This means that in 100 days groundwater will move approximately 800 m in the sand/gravel.

Bedrock Aquifer: with a permeability value of 5 m d^{-1}, porosity of 0.015 and gradients estimated using the Theim equation, the 100 day ToT is estimated be approximately 225 m for the Townparks borehole and approximately 165 m for the Barrack Lane borehole.

As the 100 day ToT for the infiltration gallery is greater than for the boreholes, a distance of 800 m has been used to delineate the 100 day ToT for the source as a whole.

8.13 Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the two elements of land surface zoning (source protection areas and vulnerability categories) – a possible total of 8 source protection zones. In practice, the source protection zones are obtained by superimposing the vulnerability map on the source protection area map. Each zone is represented by a code e.g. **SI/H**, which represents an Inner Protection area where the groundwater is highly vulnerable to contamination.

Four groundwater protection zones are present around the source. The final groundwater protection zones are shown in Map 8. The matrix of source protection zones is given in Table 6. The vulnerability ratings for County Laois are take directly from the Laois Groundwater Protection Scheme (Deakin, J. *et al*, 2002). Due to shallow rock and outcrop in the western part of the source protection area these areas are extremely and highly vulnerable to contamination.

Table 6 Matrix of Source Protection Zones for Athy Well field.

VULNERABILITY RATING	SOURCE PROTECTION	
	Inner	***Outer***
Extreme (E)	**SI/E**	**SO/E**
High (H)	**SI/H**	**SO/H**
Moderate (M)	**SI/M**	**SO/M**
Low (L)	Not present	Not present

8.14 Potential Pollution Sources

Agriculture is the principal activity in the ZOC. Most of the land is used for tillage, although a small proportion is used for pasture. The well field (Barrack Lane, Townparks and the infiltration gallery) is located in an urban environment, close the river Barrow. Potential hazards include farmyards, septic tank systems, application of fertilisers (organic and inorganic), pesticides, possible spillages along the roads and leaky underground sewers. Potentially the infiltration gallery is under threat from the River Barrow when it is in high flood stage. Of the contaminant indicators examined, none were at significant levels in available samples. Nitrate and chloride in the infiltration gallery are elevated and may reflect localised hazards (perhaps from leaking sewers). Levels in the deeper boreholes are above background levels but lower than those in the gallery. They may reflect releases from point and diffuse hazards such as septic tank systems and landspreading of organic wastes in rural areas upslope of the wells, along with a component of vertical leakage from those more local hazards affecting the infiltration gallery.

8.15 Conclusions and Recommendations

- Athy TC water supply consists of two boreholes located in a regionally important karstified aquifer (Rk) and an infiltration gallery located in a **regionally important** sand/gravel aquifer (**Rg**).
- The vulnerability of the groundwater in the ZOC varies from moderate to extreme moving west to east.
- Septic tanks, farmyards, landspreading, diesel/oil spills, runoff from the roads, leaky underground sewers and high flood stage of the River Barrow pose a threat to the water quality at the well field.
- The protection zones delineated in the report are based on our current understanding of groundwater conditions and on the available data. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.

- It is recommended that:
  1. A full chemical and bacteriological analysis of the **raw** water at each abstraction point is carried out on a regular basis. The elevated E.coli were found during an incident in 1987. Though these results are believed to be erroneous, there are very few raw water results available since that time to examine this issue further.
  2. particular care should be taken when assessing the location of any activities or developments which might cause contamination at the well field; particularly in relation to underground sewers and waste pipes.
  3. the potential hazards in the ZOC should be located and assessed.
  4. site security is checked to be adequate.
  5. well head protection is checked and improved where necessary.