Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Ironmills Public Water Supply Scheme

Revision B

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Suirbhéireacht Gheolaíochta Éireann

PROJECT DESCRIPTION

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

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

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

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1 Introduction

Groundwater Source Protection Zones (SPZ) have been delineated for the Ironmills Public Water Supply (PWS) according to the principles and methodologies set out in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999) and in the GSI/EPA/IGI Training course on Groundwater SPZ Delineation.

The Ironmills Public Water Supply (PWS) is sourced from two boreholes in the townland of Rahyvira, County Tipperary. The boreholes pumped an average 1,638 m^3/d in 2011, to supply approximately 600 homes and farms.

The objectives of this report are as follows:

- To outline the principal hydrogeological characteristics of the area surrounding the boreholes.
- To delineate source protection zones for the production wells in the Ironmills PWS.
- To assist the Environmental Protection Agency and South Tipperary County Council in protecting the water supply from contamination.

The protection zones are intended to provide a guide in the planning and regulation of development and human activities to ensure groundwater quality is protected. More details on protection zones are presented in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999). The maps produced are based largely on the readily available information in the area, field walkover surveys, drilling results, water level monitoring, and 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

The methodology applied to delineate the SPZ consisted of data collection, desk studies, site visits, field mapping of geological exposures, well audits, surface water flow measurements, as well as subsequent data analysis and interpretation. An initial interview with the caretaker, and site and local area inspection, was undertaken in October 2011. In May 2012 the GSI carried out investigative drilling in the sand and gravel (S&G) deposits in the area surrounding the PWS.

3 Location, site description and well head protection

The Ironmills PWS is located near Ironmills Bridge on the Tipperary to Hollyford Road (R497), less than 5 m from the west bank of the Multeen River (**Figure 1)**. It serves an estimated 600 homes, including all of the dwellings within the village of Cappagh White.

The PWS has been in operation since 1983 and consists of two boreholes, BH1 and BH2 which are about 2 m apart. Both are constructed inside a block-built chamber that is flush with the ground surface and measures 370 cm (L) by 180 cm (W) by 150 cm (D). Each borehole has a metal locked manhole cover for access. Photographs of the PWS are included in **Appendix A**. Neither of the wellheads are sealed. There is a visible water line on the inside walls of the concrete chamber approximately 35 cm above the base of the chamber floor, suggesting that surface runoff may be flowing into the chamber during wet weather events. Both wells are, therefore, susceptible to surface water ingress into the wells.

There is a raw water sampling tap located on the discharge line from the wells inside the pump house. BH2 serves as the main production well. BH1 serves as the "standby" or backup well. Whereas BH2 turns on/off automatically based on water level switches, BH1 is turned on/off manually. Both wells are fitted with submersible pumps, with pump intakes reportedly at approximately 20 m below ground level in BH2 and 15 m in BH1.

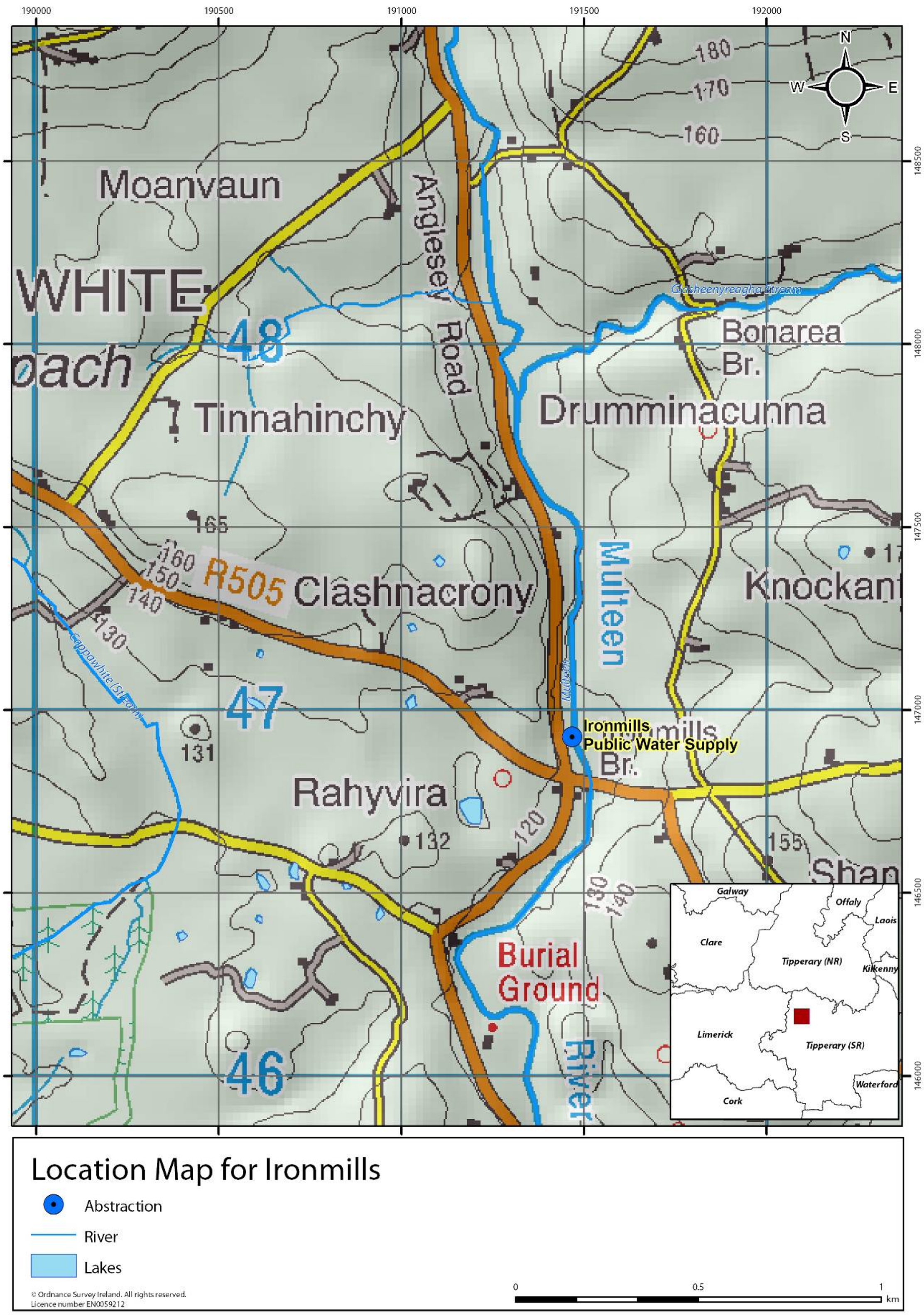


Figure 1: Location Map for the Ironmills PWS.

The water is treated with chlorine and ultraviolet (UV) light at the source, and is then pumped (*via* onsite booster pumps) to twin 680 m^3 reservoirs off-site, approximately 1.2 km west-northwest of the PWS.

4 Summary of borehole details

Table 1 provides a summary of boreholes BH1 and BH2 with currently known information. The production well BH2 was drilled in 1986 and the standby well BH1, was drilled in 1983. Construction records are not available for either of the two boreholes and the information provided below is based on observations during a site inspection and interviews with county council staff and the caretaker of the facility.

The average abstraction rate from production well BH2 was 1,638 m^3/d in 2011, with a recorded maximum in August 2011 of 1,843 m^3/d. The pump operates for approximately 20 hours each day. The caretaker reports a steady, reliable supply even during prolonged dry weather conditions such as those experienced during the summer of 2010. Using the EPA HydroTool for ungauged catchments (*watermaps.wfdireland.ie/**HydroTool***), the estimated 95-percentile flow (Q_{95}) of the Multeen River at the same location is 0.312 m^3/s (26,957 m^3/d). The daily average abstraction rate of 1,638 m^3/d is therefore only 6 % of the Q_{95} flow.

5 Topography, surface hydrology and landuse

The Ironmills PWS is located at an elevation of approximately 120 mOD within the Multeen River catchment. The Multeen River rises in the hills surrounding the town of Hollyford, nearly 10 km north of the PWS. Numerous small tributaries contribute flow to the Multeen River along its course, draining slopes on both sides of the steep-sided river valley. The highest hills within the catchment approach or exceed elevations of 400 mOD, with a maximum 457 mOD at Tooreen, approximately 2.8 km to the northwest of Hollyford.

The Multeen River is a fast-flowing, gravel-bottomed river. As it flows south from Hollyford, it 'exits' its steep-sided river valley near Lackenacoombe approximately 2 km north of the PWS. At this location, its catchment characteristics change dramatically, and at an elevation of approximately 170-180 mOD, topography becomes flatter and more hummocky, characterised by 'low hills' and shallow hollows which each have their own small localised drainage patterns. These tend to end at rushy hollows with no outlets where, in a few instances, localised fen populations have developed. To the south of Ironmills, the Multeen River starts to meander southwards on account of shallower slopes and lower flow velocities. The Glasheenyreagha stream drains a significant area to the east of the Multeen River and flows into it at Tinnahinchy. In turn, the Multeen River flows into the Suir River near the town of Golden, approximately 12 km to the southeast of the PWS.

Land use in the uplands to the north of the PWS comprises blanket bog and forestry. Shallower slopes and the lower part of the catchment along the Multeen River are dominated by agricultural land uses, comprising livestock pasture and some tillage. There are several farmyards and one-off houses in the catchment, and no industrial or commercial activity with the exception of an active sand and gravel (S&G) quarry at Tinnahinchy, near the confluence between the Multeen River and Glasheenyreagha stream. A scrapyard used for dismantling old plant equipment, is located approximately 500 m north-northeast of the PWS. South Tipperary County Council noted improper storage of oil and chemical containers during a recent site inspection at this location (STCC, 2010). Finally, an inactive (disused) S&G quarry is located approximately 1.3 km to the west–northwest of the PWS.

6 Hydro-meteorology

Establishing groundwater source protection zones requires an understanding of general meteorological patterns across the area of interest. Meteorological information was obtained from Met Éireann.

Table 1: Well Details

	Production well (BH2)	Standby (BH1)
Reporting code	IE_SE_G_130_23_007	
Groundwater body	Unclassified sand and gravel	
Grid reference	E191439 N146944	E191439 N146945
Townland	Rahyvira	Rahyvira
Source type	Borehole	Borehole
Drilled	1986	1983
Owner	South Tipperary County Council	South Tipperary County Council
Elevation (mOD)	c. 120	c. 120
Total depth (m bgl)	20.57	16.32
Construction details	350 mm diameter borehole. 250 mm diameter steel casing to unknown depth. Well is reportedly screened from 13.17-18.17 m[4], but details of slot types and sizes are unknown. The screen is reportedly filter-packed with pea gravel. The casing was reportedly grouted in place, but there no obvious indication of a grout seal at the ground surface (may be 'masked' by soil/dirt/rust on the chamber floor).	250 mm diameter steel casing to 15.32 m. Well is reportedly screened from15.32-16.32 m[4] but details of slot types and sizes are unknown. The casing was reportedly grouted in place, but there no obvious indication of a grout seal at the ground surface (may be 'masked' by soil/dirt/rust on the chamber floor).
Depth to bedrock (m)	20.57[4]	16.32[4]
Static water level (m bgl)[1]	2.91[3] 4.21[4]	2.78[2] 2.87[3] 4.23[4]
Pumping water level (m bgl)	6.7[4] Estimated from specific capacity information at 2011 abstraction rate	7.72[4]
Pump intake depth (m bgl)	c. 20, *i.e.* below reported screen	c. 15
Current abstraction rate (m^3/d)	1,638	-
Reported yield (m^3/d)[5]	3,052	--
Estimated specific capacity ($m^3/d/m$)	874[5]	--
Estimated transmissivity (m^2/d)	860[5,] , 980[5]	860[5,] , 859[5]

Notes:

1. *As the wells are equipped with submersible pumps, water level readings could not be taken during the site visits, as the water level meter could not be lowered past the pump discharge line and electrical cables.*
2. *South Tipperary test pumping records, 18/11/1986, may not be true rest water level as well was in a recovery phase.*
3. *South Tipperary test pumping records, 20/08/1987, may not be true rest water level as well was in a recovery phase.*
4. *GSI Well database*
5. *Keegan, 1993*

Annual rainfall: This is approximately 1,200 mm at the PWS. The contoured data map of rainfall in Ireland (Met Éireann website, data averaged from 1961–1990) shows that the source is located near the 1,200 mm average annual rainfall isohyet. Average rainfall increases to 1,400 mm/yr in the upland hills of the Multeen River catchment.

Annual evapotranspiration losses: 494 mm. The contoured mean annual potential evapotranspiration for Ireland indicates that Ironmills is close to the 520 mm/yr contour. Actual evapotranspiration (A.E.) is then estimated as 95% of P.E. to allow for seasonal soil moisture deficits, giving an A.E. of 494 mm.

Annual Effective Rainfall: 706 mm. The annual average effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Effective rainfall, or potential recharge, is therefore equivalent to 706 mm/yr.

Reference is made to Section 9 on recharge which estimates the proportion of effective rainfall (potential recharge) that enters the groundwater system.

7 Geology

This section outlines the relevant characteristics of the geology of the immediate study area. It provides a framework for the assessment of groundwater flow and source protection zones. The geological information presented is based on:

- Archer, J.B., Sleeman, A.G., and Smith, D.C., 1996. Geology of Tipperary. Bedrock Geology 1:100,000 Scale Map Series, Sheet 18. Geological Survey of Ireland;
- Daly, D., Keegan, M., and Wright, G., 2001. County Tipperary (South Riding), Groundwater Protection Scheme, Main Report. Geological Survey of Ireland, August 2001;
- Groundwater Vulnerability Map for County Tipperary Digital Map, Geological Survey of Ireland (Draft, 2011);
- Sand and Gravel Pit Planning Application. South Tipperary County Council (2002) Planning System ref. 0218;
- Bedrock and subsoil exposures noted during site visits; and
- Drilling at Ironmills by the GSI, May 2012 – see **Appendix B**.

7.1 Bedrock Geology

As shown in **Figure 2**, the study area is mostly underlain by red and white sandstone and conglomerate of Devonian age, classified by the GSI as Devonian Old Red Sandstones (ORS) belonging to the Cappagh White Sandstone Formation. According to GSI mapping, rocks dip gently (< 10 degrees) to the south/southeast, with an approximate east-west strike. There are no bedrock outcrops in the immediate vicinity of the PWS. The nearest, clearly exposed sandstones are found on the steeper hillsides along the Multeen River valley more than 2 kms to the north of the PWS.

There is no mapped faulting in the bedrock within the immediate catchment area of the PWS. The Cappagh White Sandstone Formation rests with angular unconformity on the underlying Silurian Metasediments and Volcanics of Lower Paleozoic age which belong to the Hollyford Formation. Extensive fracturing and fissuring is noted in the upper few metres of exposed bedrock surfaces in some of the local disused quarries, along with associated groundwater seeps.

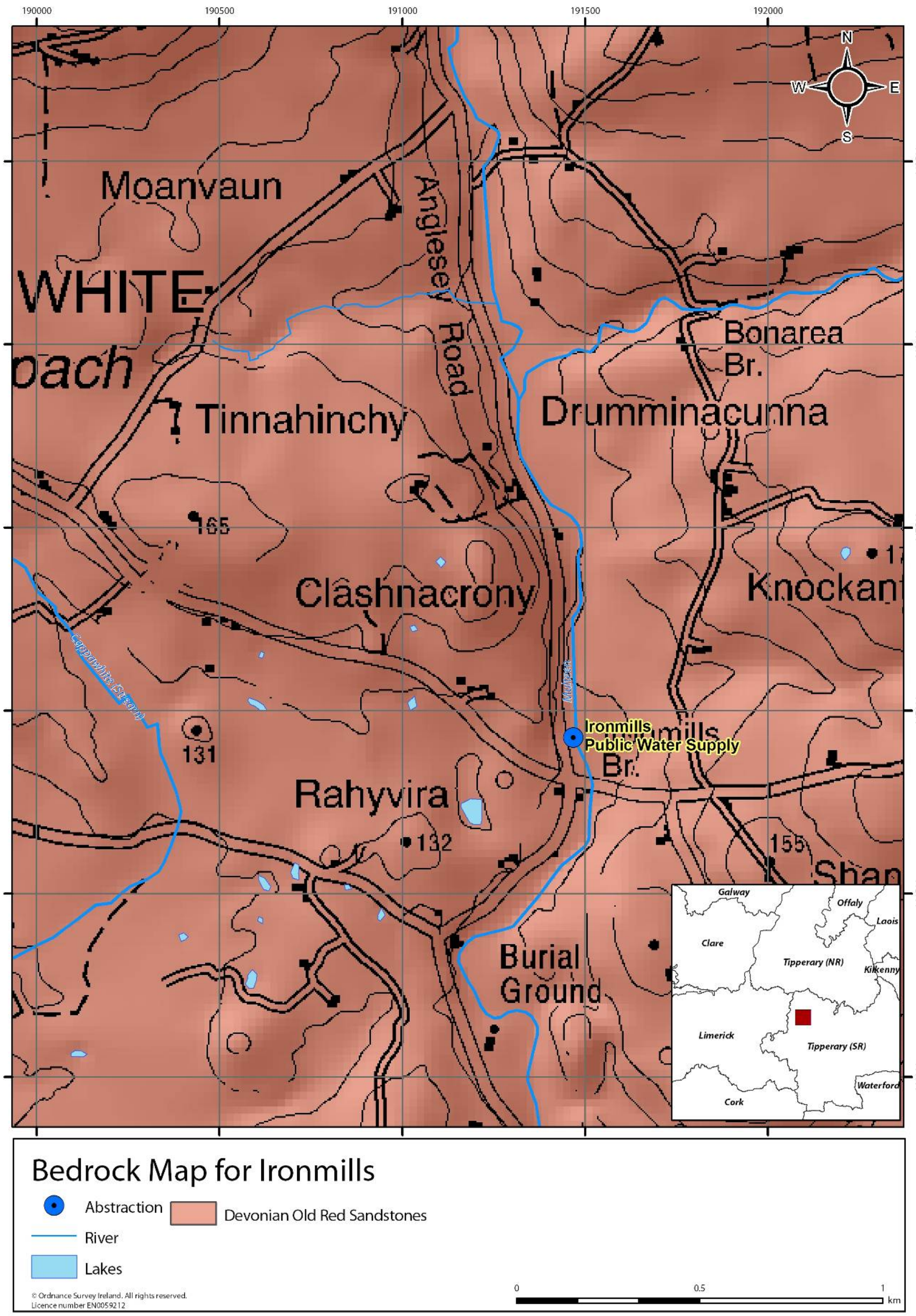


Figure 2: Bedrock/Rock Unit Map for the area around the PWS

7.2 Depth to bedrock

Depth to bedrock varies considerably across the study area, from nil (where it outcrops on the steep hills, mostly above elevation 180 mOD) to a reported 61 m bgl in a borehole located within the active Tinnahinchy S&G quarry property just north of the PWS (STCC, 2002 – Planning System ref. 0218).

With the realisation that depth to bedrock is poorly defined across the study area, the GSI assisted the project by conducting hollow-stem auger drilling at five locations near the PWS (see **Appendix B)**. The total attained drilled depths ranged from 13 to 26 m below ground level (m bgl), and bedrock was only inferred to have been encountered in one borehole (at 12 m bgl) located near a disused S&G quarry approximately 3 km to the west of the PWS. Less than 30 m from the PWS, drilling ended at 18 m bgl upon encountering a dense stony till (not bedrock). Despite these additional data, exact depths to bedrock remain poorly defined across the study area.

7.3 Soil and Subsoil Geology

As shown in **Figure 3,** subsoil types vary across the study area. Upland areas are dominated by blanket peat and glacial till derived from Lower Palaeozoic and Devonian sandstones (TLPDSs). At lower elevations, below approximately 180 mOD, subsoils consist of till, S&G deposits, and pockets of peat. The till is incised by small streamlets that collect and drain surface runoff towards the Multeen River during wet weather events. The till is classically heterogeneous, with pebbles and boulders lodged in a finer grained (often clayey) matrix.

Two sand and gravel pits, one active at Tinnahinchy and one disused at Glassdrum (see **Figure 3**), point to the presence of significant S&G deposits to the west of the Multeen River. A 15+ m section of S&G deposits is currently exposed in the unstable (partly slumped) east- and south-facing walls of the Tinnahinchy pit. Seventeen metres of S&G deposits are described in a log from on-site borehole GW2 at the northwestern end of the pit property (STCC, 2002 – Planning System ref. 0218). This is reportedly underlain by 44 m of glacial till (‘clayey, silty, gravelly cobbles and boulders’). A second onsite borehole GW1 located at a lower elevation and only about 10 m from the Multeen River describes 9 m of S&G, underlain by silt/clay (to total depth of 12 m).

Within the pit, the exposed sections show a variety of lithologies, from thin but irregularly shaped (erosive) cobble-gravel beds to thicker and consistently cross-bedded fine- to coarse-grained sands (see **Appendix A**). The pit faces at Tinnahinchy were too high and loose to allow accurate measurement of the dip of beds safely. An iron pan and overlying podzols are visible near the top of the exposed sands (within 2 m of ground surface). Similar deposits and features are not exposed east of the Multeen River but sandy deposits are present as evidenced by borehole No. 2 drilled by GSI in May 2012 and borehole ‘MS_TS_BH102’ also drilled by the GSI previously (see **Appendix B**). There are also a small number of shallow, dug wells into sands on the floodplain of the river. Several exposures of S&G deposits are noted further downstream of the PWS, especially in a south and southwesterly direction. Whether or not these are continuous with the deposits at the PWS or at Tinnahinchy and Glassdrum is not known. If they are, then the Multeen River valley could host a gravel aquifer of sufficient size to be designated as such by the GSI (*i.e*. greater than 1 km^2).

Within and/or above the till and S&G deposits, pockets of peat occupy small, shallow depressions in the landscape. The peat is sometimes covered or accompanied by rushes and wetland vegetation. To the west of the PWS, on relatively elevated ground at Clashnacrony, rushy hollows sometimes represent the terminus of internal streams that only flow during very wet weather events. As such, they represent locations where event-based streams literally disappear underground (*i.e*. sinking streams, see **Appendix A**). These hollows may represent glacial kettle holes. Alluvial sediments are mapped by the GSI along the Multeen River valley and other water courses within the study area, such as the Glasheenyreagha stream.

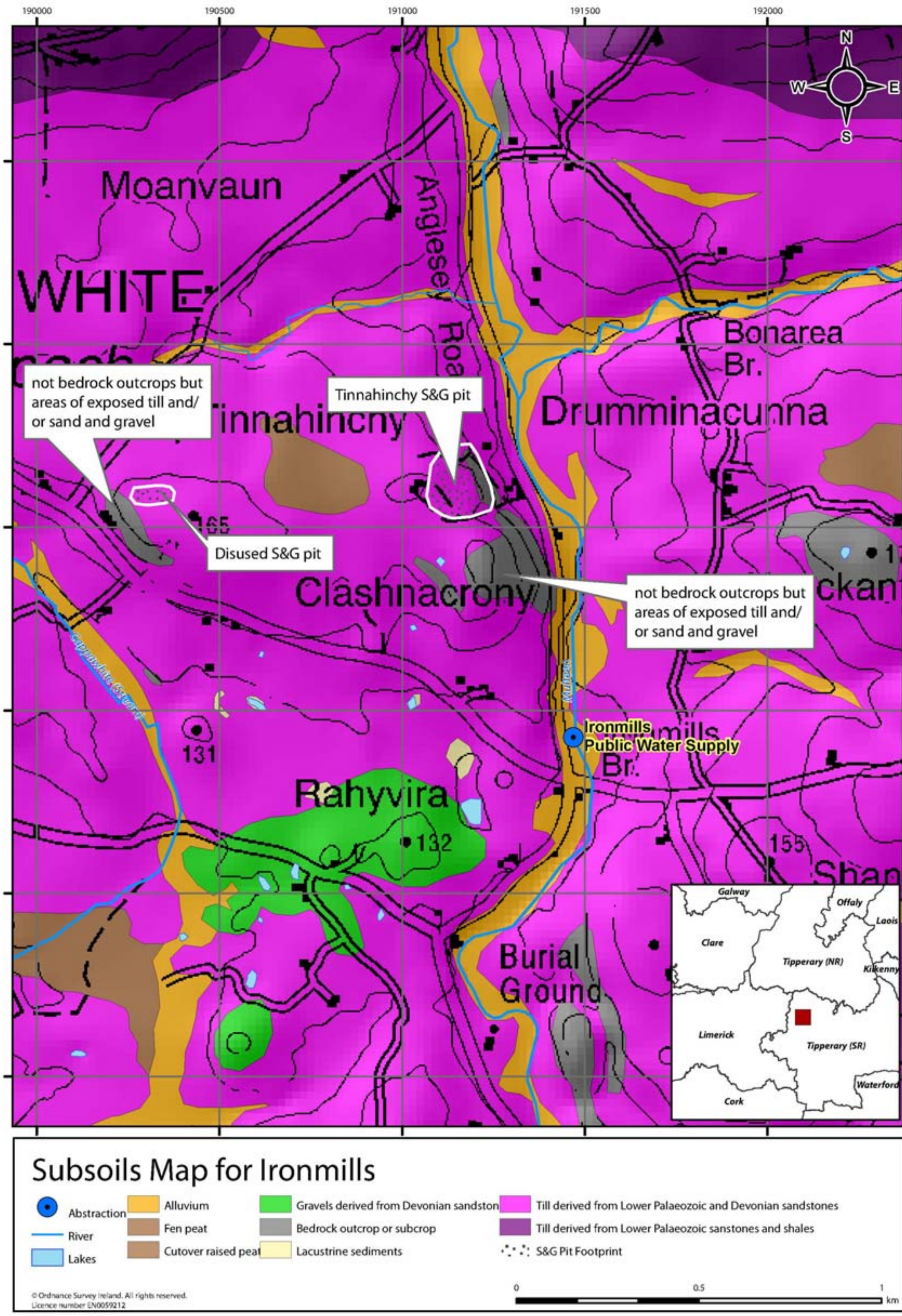


Figure 3: Subsoils Map of the area around the PWS

Finally, it should be pointed out that the existing subsoil map appears to misclassify exposed till as bedrock outcrop at two locations highlighted in **Figure 3.** Although depth to bedrock is probably small at these locations, there is no apparent bedrock exposed and the maps should be amended accordingly in the future.

Mapped soils in the immediate study area, shown in **Figure 4**, consist primarily of deep well drained mineral soils (AminDW) derived from the underlying glacial till and S&G deposits. Poorly drained mineral soil (AminPD) and blanket peat occupies higher ground, as well as the shallow topographic depressions described above.

7.4 Groundwater vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. In the case of the Ironmills PWS, this relates to the thickness of the unsaturated zone in the S&G aquifer and the permeability and thickness of the subsoil in areas where S&G aquifers are absent. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DELG/EPA/GSI, 1999) and in the draft GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination (Fitzsimons et al, 2003).

A draft groundwater vulnerability map for Co. Tipperary has been developed by the GSI. As shown in **Figure 5**, the vulnerability along the Multeen River valley is primarily mapped as 'high'. Within the river valley and within the Tinnahinchy quarry especially, there are areas where the depth to groundwater may be less than 3 m, in which case such areas should be re-mapped as 'extreme'.

8 Hydrogeology

This section describes the known and inferred hydrogeology in the vicinity of the Ironmills PWS. Hydrogeological and hydrochemical information was obtained from the following sources:

- GSI and EPA websites, databases and reports;
- County Council staff and drinking water quality data;
- Met Eireann rainfall and evapotranspiration data;
- Test pumping records: South Tipperary County Council (1986 and 1987) and Keegan (1993); and
- Field mapping, drilling, and stream flow measurements.

8.1 Groundwater body and status

The boreholes at Ironmills pump water from S&G deposits. These deposits overlie bedrock, specifically the Templemore_A Groundwater Body (GWB). Whereas the sands and gravels have not yet been designated as an aquifer or groundwater body (subject to additional investigation by the GSI), the Templemore_A GWB has been classified by the EPA as being of Good Status. Individual GWB descriptions are available from the GSI website: www.gsi.ie and 'status' descriptions are obtained from the Water Framework Directive website: www.wfdireland.ie/maps.html

8.2 Groundwater levels, flow directions and gradients

Groundwater in the vicinity of the PWS initially flows downwards through pore spaces within the soil and S&G deposits until it reaches the groundwater table, where it then moves laterally towards the PWS. Groundwater to the east and west of the Multeen River are at marginally higher elevations than the river. As such, the groundwater tends to flow towards the river before turning and continuing to flow in a southerly direction along the river valley. At first glance, the river appears to be a gaining river (i.e. groundwater discharges laterally into the river). Partial evidence of this is provided in **Appendix C** which presents spot

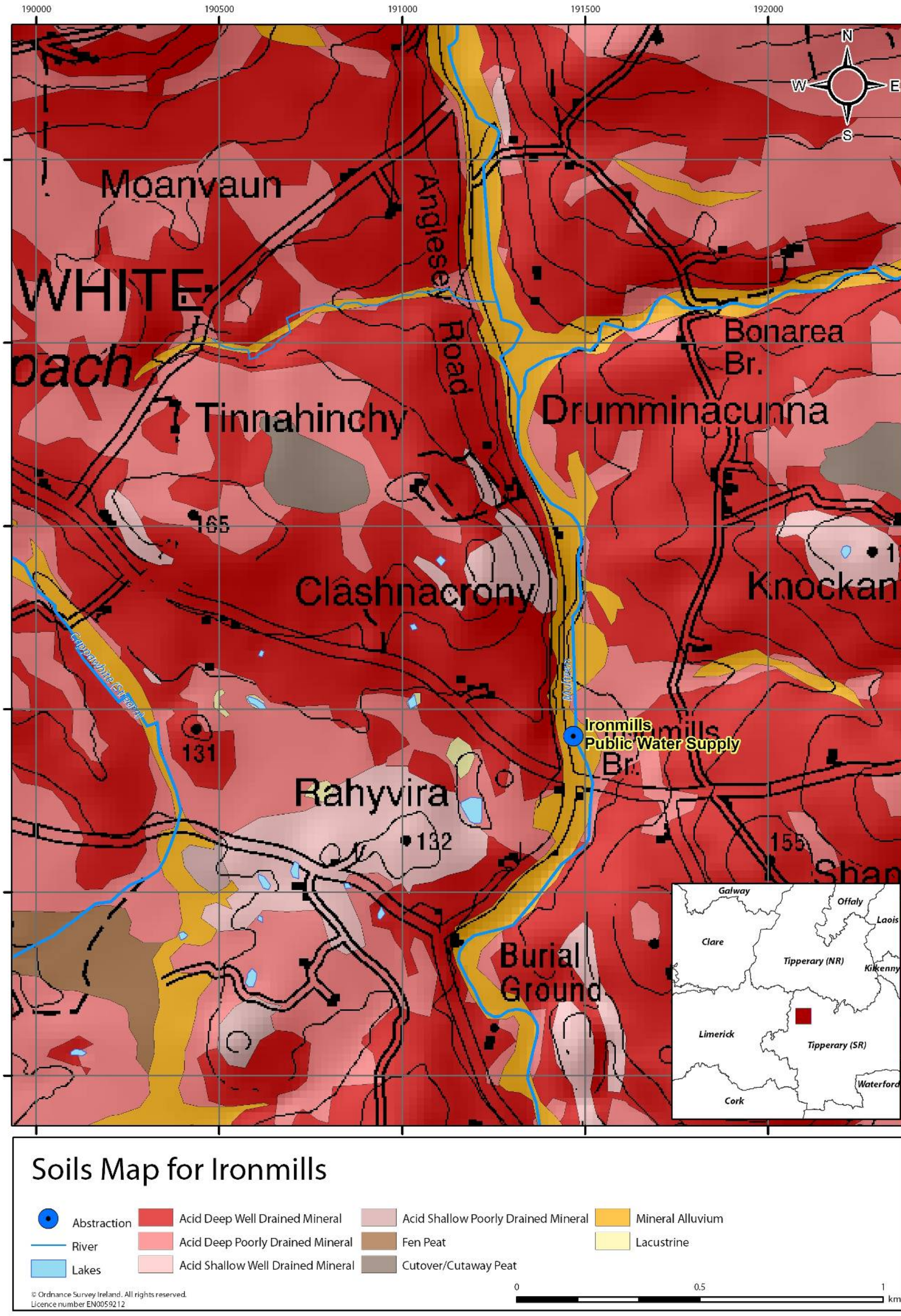


Figure 4: Soils Map of the area around the PWS

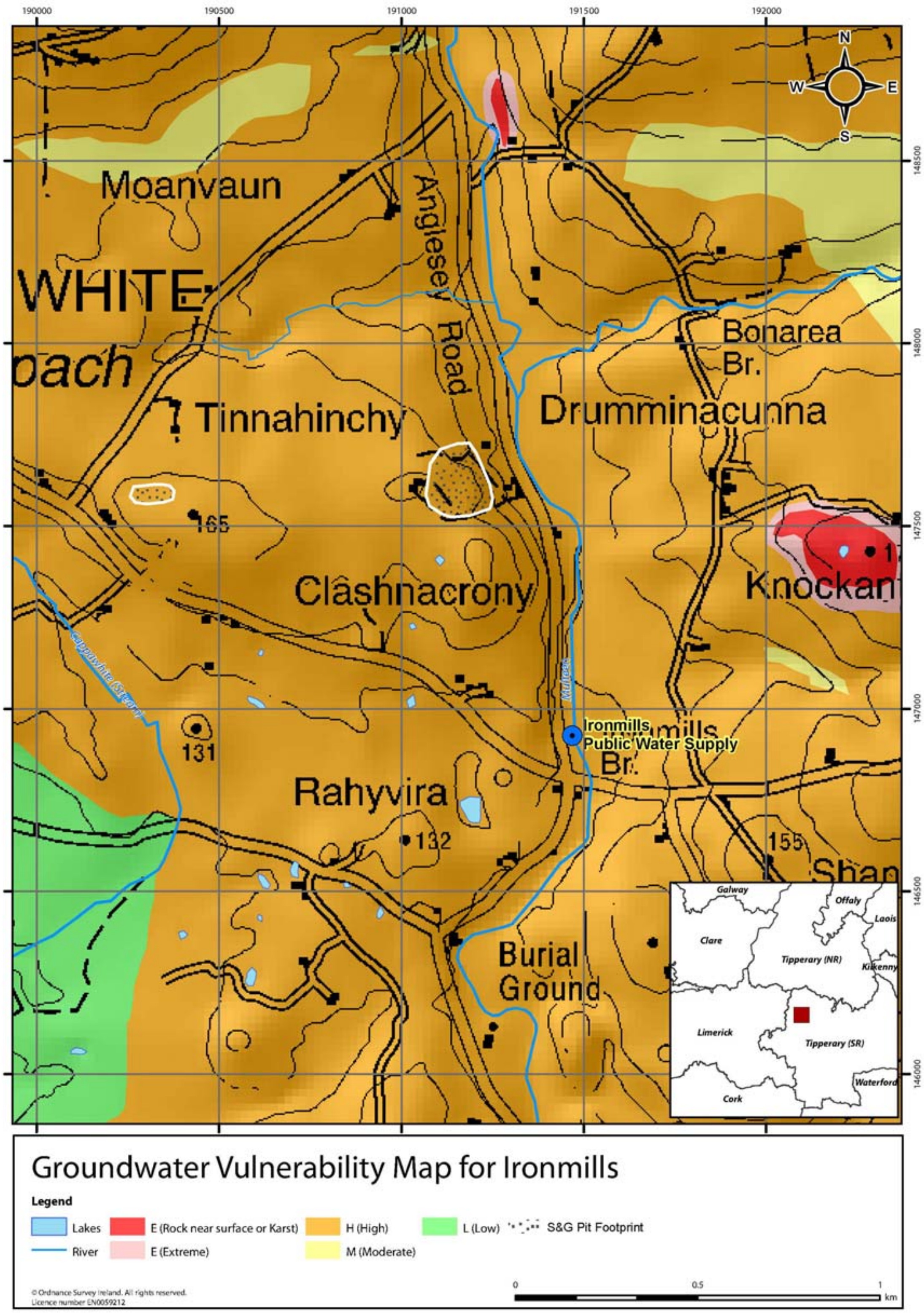


Figure 5: Groundwater Vulnerability Map of the area around the PWS

flow measurements taken at several points along the river in late March 2012 at the end of a prolonged period (approximately 3 weeks) of no rainfall. These measurements represent flow during a stream hydrograph recession event and, in March 2012, the flow data indicate an increase in flow by approximately 60 l/s per km of river length to the north of the confluence between the Multeen River and the Glasheenyreagha stream.

In contrast, the Multeen River appears to lose water near the confluence, before once again gaining flow in the direction of Ironmills Bridge. There are several possible explanations for the apparent decrease in flow: either a) stream water infiltrates into the permeable underlying S&G aquifer along this section of the river; b) water is removed or diverted from the river at this locality; and/or c) there is a proportion of bypass flow moving through the S&G in the streambed material just below the surface. Some percent of flow measurement error can also not be discounted but on balance, the former (i.e. infiltration through the streambed) is considered to be a feasible explanation. It should also be mentioned that some abstraction may be taking place from the river near this location. According to information received from Tinnahinchy S&G pit application files, river water is periodically pumped to on-site sediment settling ponds which hold an estimated 1,500 m^3 of pit process water used for washing purposes. The ponds reportedly lose water both through the S&G washing process (runoff, evaporation) and to ground (percolation/infiltration). As much as 135 m^3/hr of water is reportedly used during the washing process, and losses may account for up to 25% of the total quantities used. This would imply that up to 34 m^3/hr (0.01 m^3/s) would be abstracted from the Multeen River, which does not account for the measured decrease in flow. It is, therefore, considered more likely that the section of river near the confluence is a naturally losing section of river. Similar flow measurements from November 2011 are less instructive as they were taken during wet weather (flood) conditions.

Table 2 summarises groundwater level measurements that are reported from wells in the area. Unfortunately, it has not been possible to take recent measurements from production wells BH1 and BH2, or monitoring wells GW1 and GW2 associated with the Tinnahinchy pit. Wells BH1 and BH2 are fitted with submersible pumps and the associated riser pipe and electrical cables prevent suitable measuring tapes from being lowered into the wells. Monitoring wells GW1 and GW2 have been backfilled with stones. From the data in **Table 2**, a generalised, composite groundwater level contour map has been prepared (see **Figure 6)**, which depicts inferred groundwater level contours and flow directions under pumping conditions at the PWS. The inferred contours in **Figure 6** indicate converging groundwater flow on the Multeen River which is consistent with a GSI map that was prepared in the mid-1980s in connection with the drilling of BH1 and BH2 at Ironmills (see **Appendix D)**. Within the Tinnahinchy pit, water levels are influenced by both dewatering and recharge back to the aquifer near the settling ponds, and the resulting groundwater levels are interpreted to be relatively flat within the pit footprint. There are few groundwater level data from which to estimate groundwater gradients with any degree of accuracy. Gradients are no doubt very steep from the sides of the valley towards the river. The estimated gradient along the river valley between Tinnahinchy and the PWS is approximately 0.01.

8.3 Hydrochemistry and water quality

The untreated water quality of the Ironmills PWS has been monitored by the EPA since 1993. The PWS was included in EPA's national WFD monitoring network in 2006 as an operational groundwater monitoring point, and has been monitored on a quarterly basis since 2007. Raw water samples are collected from a tap located on the production borehole discharge line, inside the pump house. Existing laboratory results have been compared to the following thresholds or standards: EU Drinking Water Council Directive 98/83/EC Maximum Admissible Concentrations (MAC); and the European Communities Environmental Objectives (Groundwater) Regulations 2010, which were recently adopted in Ireland under S.I. No. 9 of 2010.

The EPA data are summarised in **Figures 7 to 9**, representing 18 samples in total. Results are highlighted as follows:

Table 2: Summary of Measured Groundwater Levels

Well Name/ Description	Location	Coordinates	Elevation (mOD)	Water Level (m bgl)	Approximate water level elevation (mOD)	Date
Production Well – BH2	Ironmills source	191439E 146944N	119	2.91[1] 4.23[2]	116 114	20-Aug-87[1] 17-Aug-92[2]
Standby Well – BH1	Ironmills source	191439E 146945N	119	2.87[1] 4.21[2]	116 114	20-Aug-87[1] 17-Aug-92[2]
Dug well east of river	190 m east	191618E 146870N	121	3.9	117	16-Nov-11
County Council hand pump	950 m northwest	190539E 147261N	150	12.2	138	16-Nov-11
Domestic borehole	1,300 m northwest	190197E 147473N	149	6.8	142	16-Nov-11
Quarry well – GW1[3]	750 m north	191291E 147690N	128	7.0[3] 5.43[3]	121 122.5	16-Dec-03 9-Feb-04
Quarry well – GW2[3]	150 m NW of GW1	191084E 147748N	149	30.0[4] 35.0[4]	119	19-Dec-03 9-Feb-03
Dug well (Well 1)	1,800 m northwest	190976E 148682N	150		150	19-Oct-11
Dug well (Well 2)	1,000 m north	191281E 147964N	120	--	119[5]	-
Dug well (Well 3)	1,200 m north	191313E 148187N	130	--	129[5]	-
Seep 1	650 m northwest	191370E 147604N	120	--	120	-

Notes:

1. *Reported as static water level - South Tipperary test pumping records from 1987 – no datum reference given, therefore top of casing (TOC) is assumed, which is approximately 1.5 m below ground level.*
2. *Reported as static water level - test pumping analysis, 18/08/1992 (Keegan, 1993) – no datum reference given, therefore TOC is assumed*
3. *Reported as static water level - Sand and Gravel Pit. South Tipperary County Council (2002) Planning System ref. 0218. Datum reference given in m (OD). Water levels may be in recovery phase.*
4. *Reported as static water level – GW2 is open to, and water level is in, boulder clay, not S&G aquifer. Water levels may be in recovery phase.*
5. *Water level observed approx. 1 m below ground surface.*

- The water is moderately hard to hard, with an average of 255 mg/l $CaCO_3$ (range 211–282 mg/l $CaCO_3$). The average electrical conductivity (EC) is 489 µS/cm (range 323–527 µS/cm compared to the field EC which shows a broader range of 372–735 µS/cm). The average pH is 7.4. The hydrochemical signature of the water is calcium bicarbonate.
- There were no faecal coliforms recorded in any of the water samples to date. Ammonium is generally very low with a mean well below the EPA's status Threshold Value of 0.175 mg/l.
- Concentrations of nitrate (as NO_3) range from 11.4 to 18.6 mg/l with a mean of 14.7 mg/l, well below the EU Drinking Water MAC of 50 mg/l and the EPA status Threshold Value of 37.5 mg/l.
- Chloride concentrations range from 11.6 to 35 mg/l with a mean of 17.3 mg/l. There was one instance of chloride concentrations exceeding the Threshold Value of 24 mg/l, at 35 mg/l.
- The mean concentration of Molybdate Reactive Phosphate (MRP), or orthophosphate, was 0.016 mg/l (as P), which is below the EPA status Threshold Value for "Good" groundwater status of 0.035 mg/l P. The MRP concentrations are generally low with a reported maximum of 0.032 mg/l.
- Sulphate, potassium, sodium, magnesium and calcium concentrations are within normal ranges. The potassium/sodium ratio is below its Threshold Value. The concentration of iron and manganese is also within normal ranges. The concentration of all other trace metals are low and/ or below laboratory detection limits. The concentrations of all organic compounds to date are also below respective laboratory limits of detection.

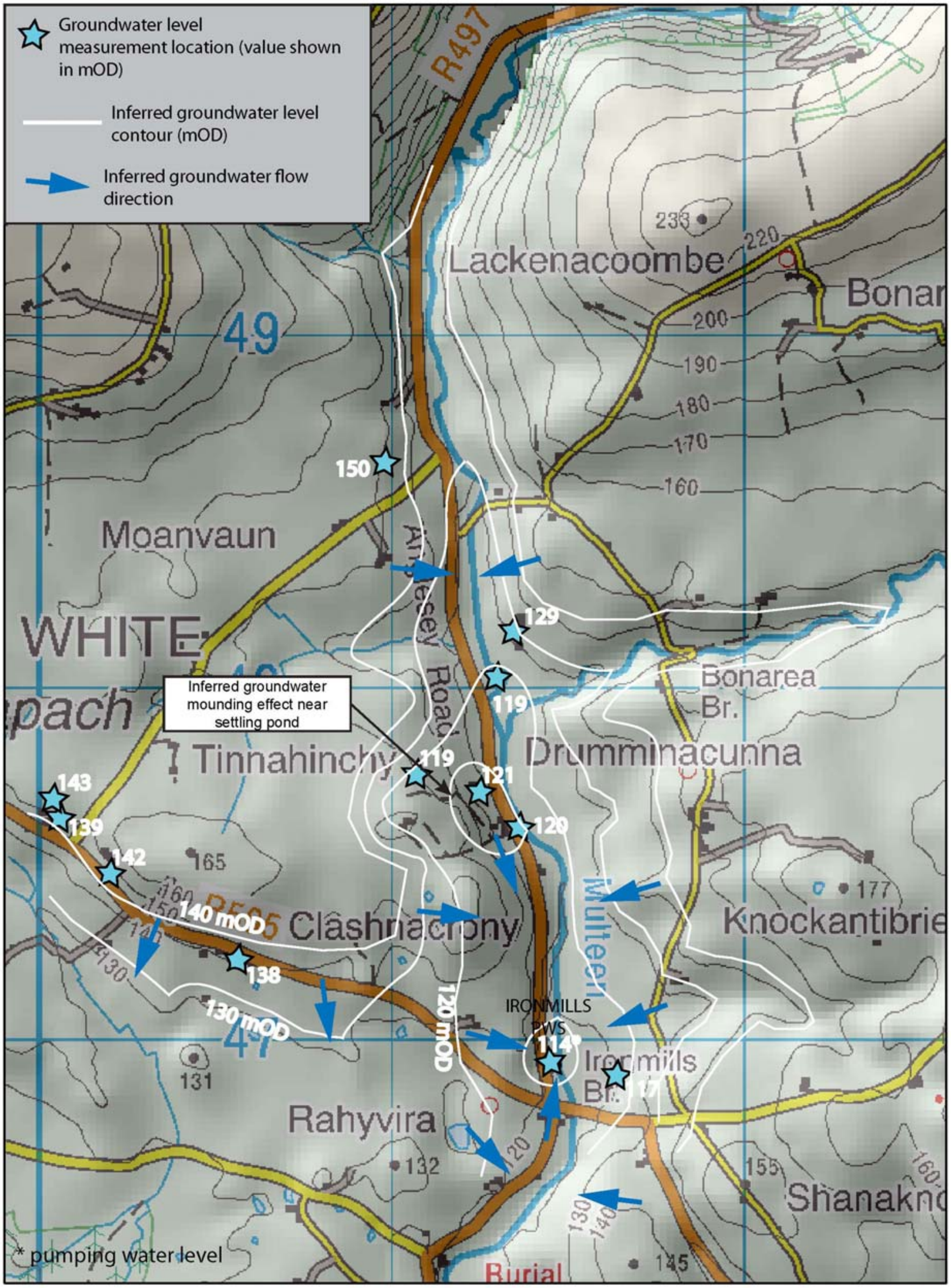
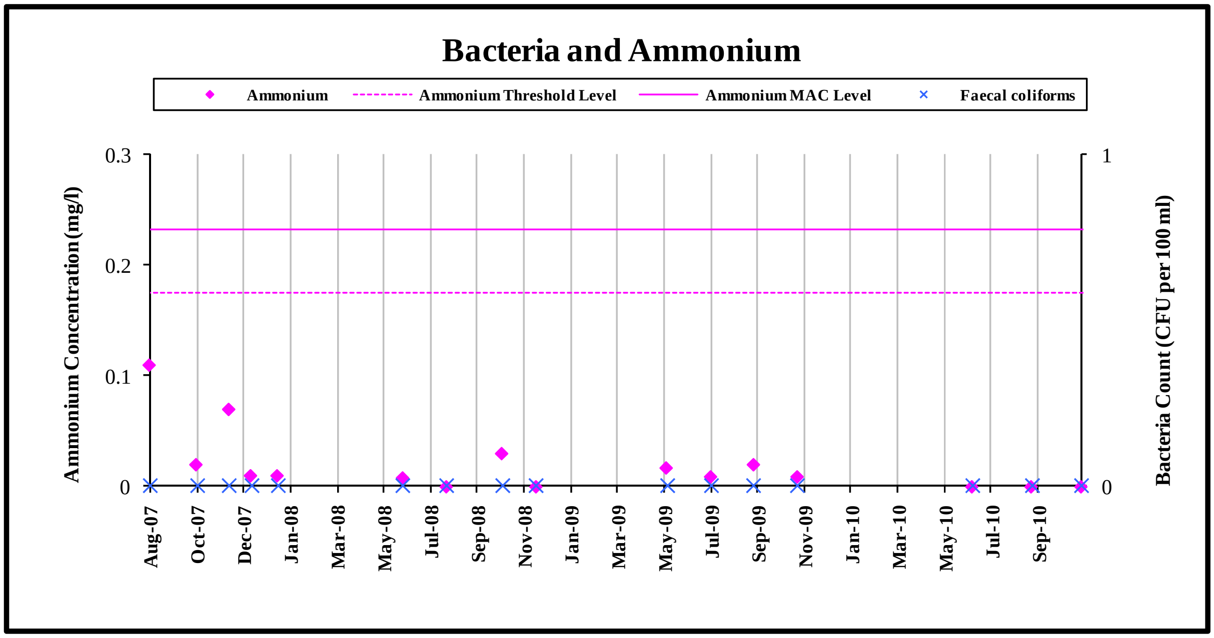


Figure 6: Generalised Groundwater Contour Map of the area around the PWS



A 'zero' value implies the concentration was below the detection limit. Detection limits: Faecal coliforms count of <1; Ammonium <0.007 mg/l N

Figure 7: Bacteria Counts and Ammonium Concentrations at the Ironmills PWS

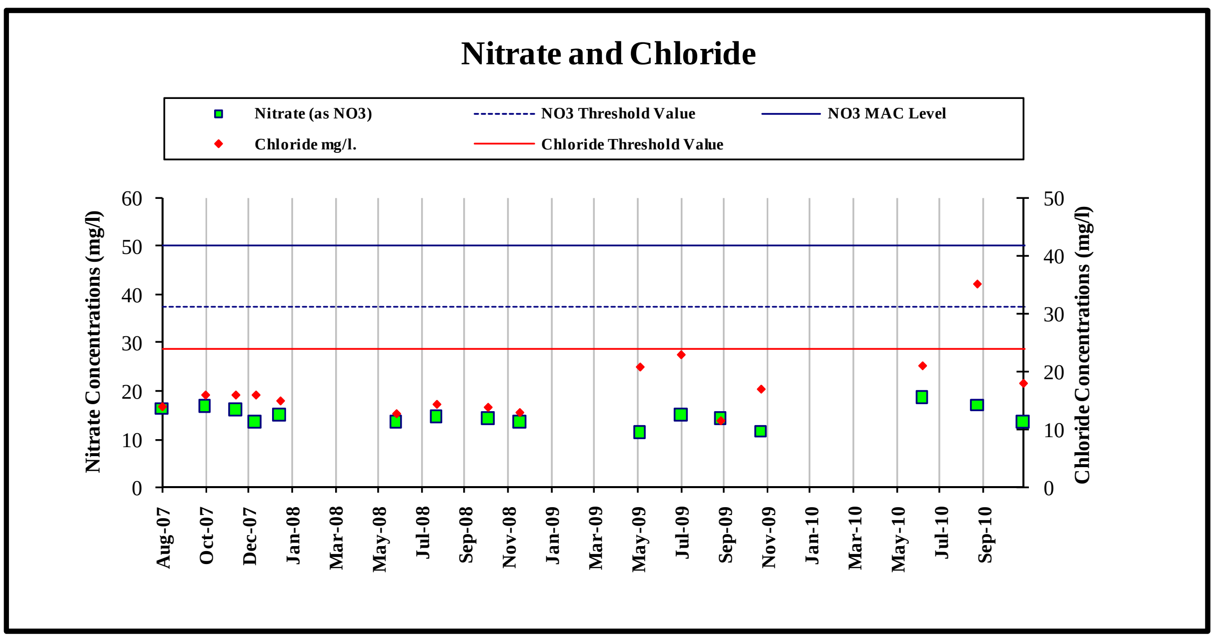
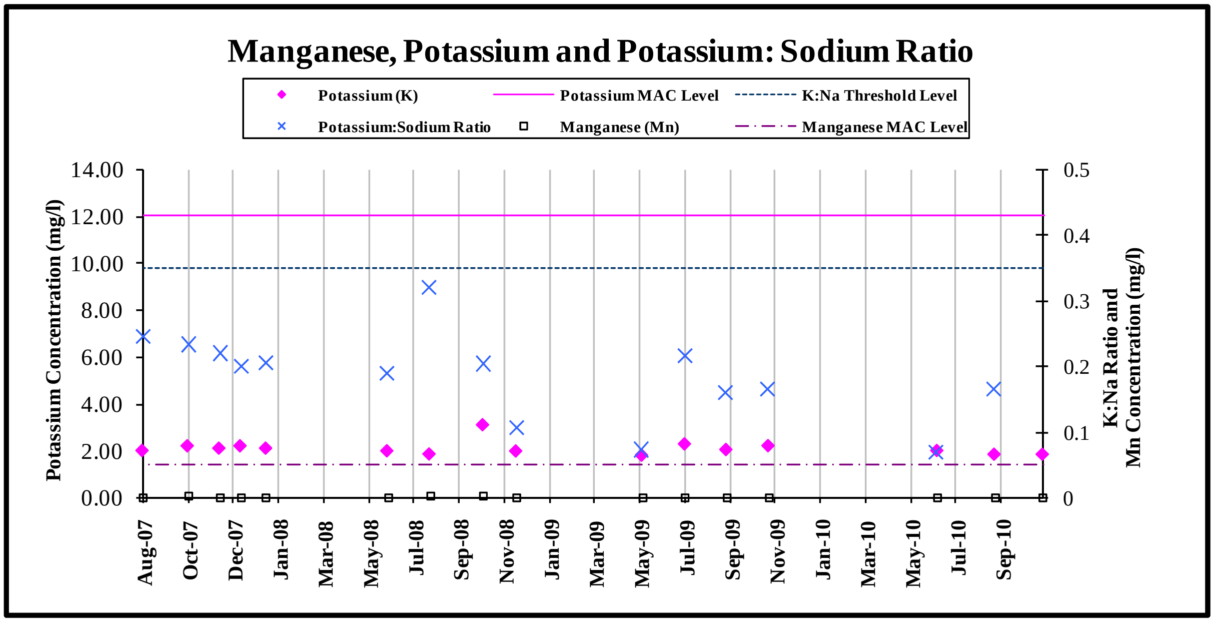


Figure 8: Nitrate (as NO_3) and Chloride Concentrations at the Ironmills PWS



A 'zero' value implies the concentration was below the detection limit. Detection limits: Manganese <1 ųg/l Mn

Figure 9: Manganese, Potassium and K/Na ratio at the Ironmills PWS

In summary, the groundwater quality at the source is generally very good. Nitrate and chloride are present at concentrations that may be considered higher than "natural background", which could suggest that some element of inorganic or organic pollution may be entering the groundwater system from pollution sources within the ZOC. Potential sources of nutrient loading to groundwater would be domestic wastewater treatment systems or diffuse agricultural pollution.

8.4 Aquifer characteristics

The PWS abstracts water from S&G deposits which overlie a Locally Important (LI) Sandstone bedrock aquifer. Although not currently classified by the GSI as an aquifer, the S&G deposits may qualify as a Locally Important Gravel Aquifer (Lg) or even a Regionally Important Gravel Aquifer (Rg) according to GSI's classification criteria for aquifers. These consider S&G deposits to be aquifers if they are greater than 10 m thick, have a known saturated thickness of more than 5 m, and/or are greater than 1 km^2 in spatial extent. To determine if these criteria are met, additional subsurface investigations are needed to map the geometry and spatial continuity of the observed glaciofluvial deposits in the area.

At the PWS location, the S&G deposits are highly permeable, as indicated by the results of three sets of test pumping data from production wells BH1 and BH2. Keegan (1993, see **Appendix E**) analysed test data from BH2 which was pumped continuously for 36 hours at a constant rate of 127.3 m^3/hr (3,055 m^3/d) in August 1992. A change in slope of the late time-series drawdown data was noted, when plotted on semi-logarithmic scale suggesting a potential 'barrier effect' on the measured drawdowns in BH1 and BH2. Between respective straight-line segments (see **Appendix E**), and applying the Cooper-Jacob approximation to the data, Keegan (1993) calculated changes in T values from 1,472 m^2/d to 980 m^2/d in BH1 and 1,862 m^2/d to 859 m^2/d in BH2. Keegan (1993) further noted:

- A measurable 8 cm decrease in water levels in a shallow dug well approximately 200 m east of the PWS (*i.e.* on the opposite side of the Multeen River);

- A slight increase in field temperature (from 10 to 10.5 ˚C) of the discharged water at the end of the test (the river temperature was 1.5-2.0 ˚C higher than the pumped water); and
- No measurable change in electrical conductivity in the pumped water (constant in the range of 500 to 520 µS/cm throughout the 36-hour period).

On the basis of these observations, Keegan (1993) concluded that the abstraction wells and the river are ‘not in hydraulic continuity’. Further test data were obtained from the County Council who completed a 75-hour constant rate test on BH2 in 1987 (see **Appendix F**). BH2 was pumped at 1,440 m^3/d for the first 14 minutes, and at rates ranging between 2,552 m^3/d to 2,624 m^3/d (average 2,590 m^3/d) for the remainder of the test. The measured drawdown after the 75 hours was 4.91 m in BH2 which yields an approximate specific capacity of 527 m^3/d/m. The measured drawdown in BH1 was 2.49 m.

The 1987 drawdown data from BH1, as the observation well, were subsequently analysed using type-curve matching techniques between measured and predicted drawdown responses for different aquifer scenarios. The ‘best fit’ solution was obtained using the Neuman solution for unconfined aquifers (Neuman and Witherspoon, 1969), see **Appendix F**, for an aquifer transmissivity of 714 m^2/d, results being relatively insensitive to specific yield (estimated at 0.22), probably as a function of the close proximity of BH1 to BH2 (only 2 m). A satisfactory type-curve match was obtained for the late time data which is not entirely consistent with influences from barrier effects. A barrier effect (*i.e.* increased drawdown) is induced when a pumping cone of influence reaches lateral aquifer boundaries. At Ironmills, this would be represented by the lower permeability till and/or the ORS bedrock along the margins of the river valley and the S&G deposits. There is no evidence in existing late-time drawdown data of potential leakage from the till and bedrock under pumping conditions, although it is acknowledged that potential leakage quantities would be very minor (insignificant) compared to the freely available groundwater in the S&G aquifer.

Table 3 provides a summary of hydraulic properties that have been estimated from the test pumping data presented in **Appendices E and F.**

Table 3: Summary of Hydraulic Properties of the S&G Aquifer

Parameters	Data Sources	Estimated Values	Selected ‘Representative’ Value
Transmissivity (m^2/d)	Keegan (1993), **Appendix E**	714 (BH1, 1987) 849* (BH1, 1992) 980* (BH2, 1992) (* - using late-time data)	850
Hydraulic Conductivity (m/d)	Representative transmissivity value divided by saturated aquifer thickness, approx. 17 m	-	50
Specific Yield (effective porosity) (m^3/d/m)	**Appendix F**	0.2-0.3	0.2
Hydraulic gradient	**Appendix D**	0.01-0.05	0.01

The most ‘representative’ values are considered to be those obtained from the 1987 test of BH2, using data from BH1, as BH1 served as an observation well and its hydraulic response would have been less influenced by variable discharge rates than BH2. It should be noted that additional tests were carried out in BH1 and BH2 in 1986 and 1992, but tests were shorter in duration and data quality was inferior to the 1987 test, and hence not used for estimation of aquifer properties. For a ‘representative’ transmissivity value of 850 m^2/d for the PWS, and an estimated saturated aquifer thickness of approximately 17 m, the estimated average hydraulic conductivity (K) value of the S&G aquifer within the area influenced by pumping is approximately 50 m/d. Using this K value, the approximate velocity of water moving through the aquifer to the borehole can be estimated from the following equation:

$$\text{Velocity (V)} = (\text{K x groundwater gradient (i)}) / \text{effective porosity } (n_e)$$

Using the K value of 50 m/d, a hydraulic gradient of 0.01, and an effective porosity (equivalent to specific yield) of 0.2, the estimated groundwater flow velocity towards the PWS would be approximately 2 m/d, or 730 m/yr in the S&G aquifer. Any flow contribution via bedrock beneath the S&G deposits would involve slower flow velocities as the K values would be expected to be lower than the in the S&G.

9 Zone of contribution

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.

9.1 Conceptual model

The Ironmills PWS sources its water from S&G deposits which comprise outwash sediments that were deposited by glacial meltwaters at the margins of a retreating ice-sheet. The S&G deposits include heterogeneous and stratified mixtures of sands and gravels that are interbedded with, and that transition laterally to, finer-grained silts and clay. From their depositional history, the coarser outwash sediments can be expected to be channelized and sinuous in a general N-S direction along the river valley. The outwash sediments are generally underlain by glacial till and/or bedrock. Along the Multeen River axis they are also overlain by post-glacial (recent) river alluvium.

The inferred extent of the S&G deposits and conceptual hydrogeological cross-sections in the river valley are summarised in **Figures 10 and 11.** Although the three-dimensional geometry of the Ironmills aquifer has not been mapped in detail, the S&G deposits are present on both sides of the Multeen River. The lateral extent of the S&G aquifer is constrained by its geological contact with glacial till deposits and bedrock. The lateral boundaries are inferred from a combination of existing subsoil information and observed breaks in topographic slope at approximate elevations of 150–160 mOD, where flatter slopes imply the presence of glacial till and S&G deposits. The lateral boundaries of the outwash sediments that form the S&G aquifer are almost certainly gradational with the glacial till. An example of the geological complexity associated with this scenario is provided by the log of GSI borehole no. 3 (see **Appendix B**) which describes silty and sandy clays with ‘occasional layers of pure silty sand’ overlying clay and silty till, in turn overlying ‘pebble layers’.

The bedrock surface varies considerably across the study area from zero where it outcrops to more than 60 m below surface in a borehole drilled near Tinnahinchy S&G pit (see Section 7.3). A bedrock ‘high’ appears to be present immediately west of the PWS, which restricts the S&G aquifer in the same direction. This bedrock ‘high’, however, has a limited northerly extent as evidenced by the thick sediments exposed at Tinnahinchy S&G pit (see also **Appendix A**). Recharge from rainfall to the S&G aquifer occurs diffusely across the entire study area, directly where it is exposed or indirectly *via* the glacial till. Glacial till is present throughout the study area and is believed to separate the S&G aquifer from the underlying bedrock almost everywhere in the immediate study area. Whereas a small proportion of groundwater pumped at the PWS may be sourced as leakage from tills, direct contributions from bedrock would accordingly be small (negligible).

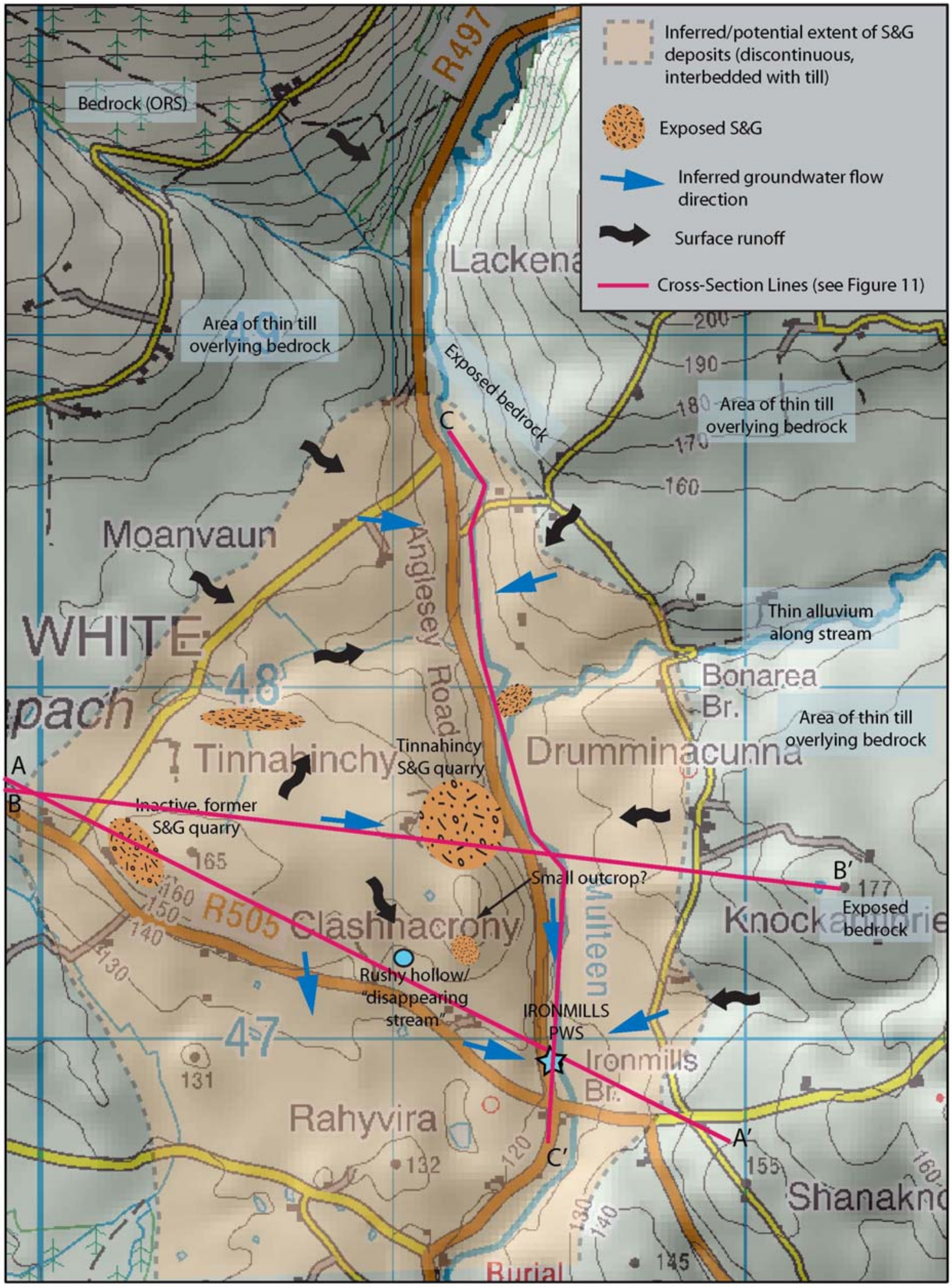


Figure 10: Inferred Extent of the Ironmills S&G Deposits

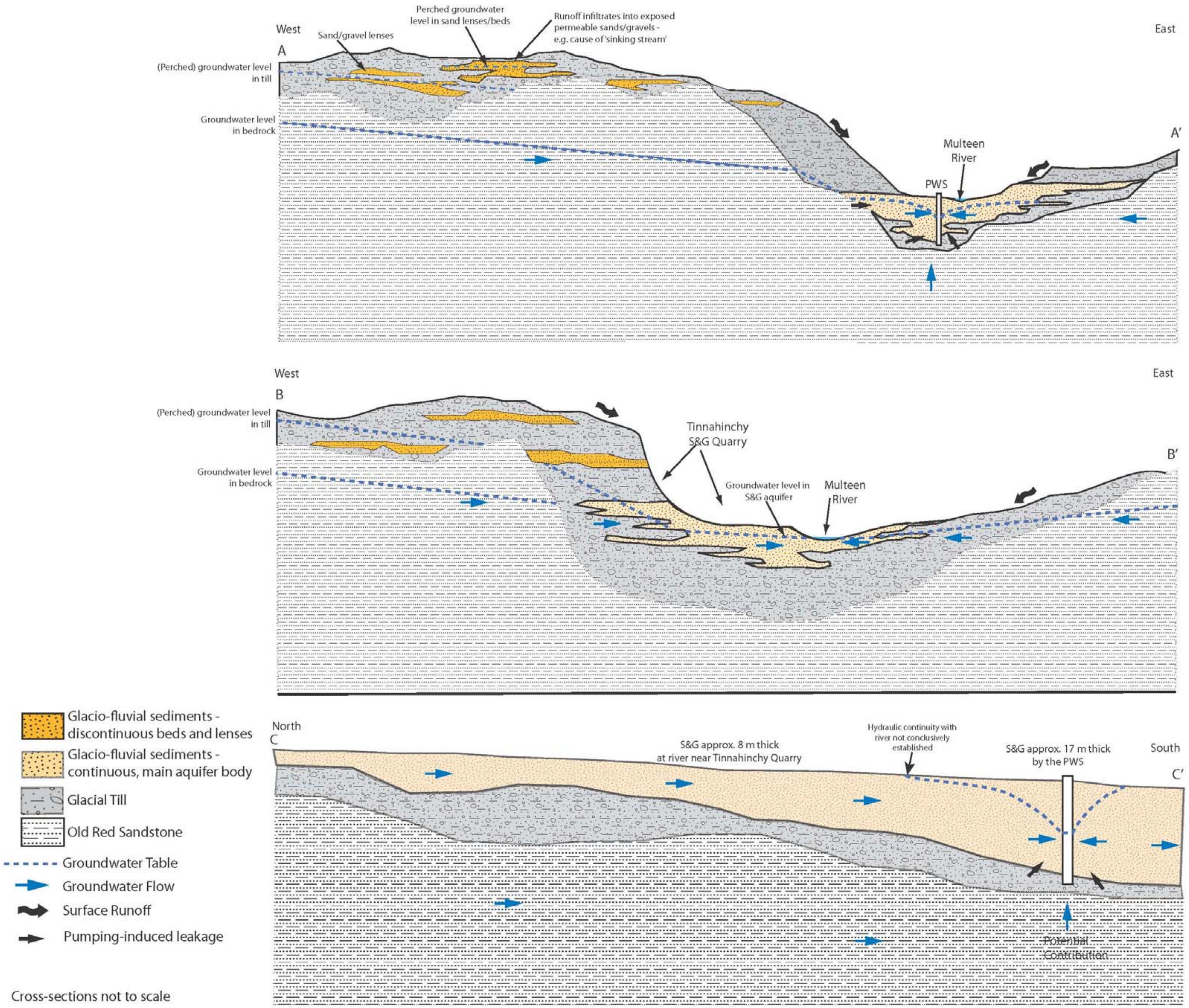


Figure 11: Conceptual Hydrogeological Cross-Sections

The till is heterogeneous, containing lenses and discontinuous beds of higher-permeability sediments. Such features give rise to small groundwater seeps at higher elevations, *i.e*. above the water table of the main S&G aquifer. Surface runoff and shallow groundwater seeps both give rise to small drainages (rainfall-dependent streams) that contribute small quantities of water to: a) the Multeen River; b) shallow rushy hollows and peat (where water ponds and partly infiltrates); and c) in one case, to a 'sinking stream' (see **Appendix A**), presumably where the stream flows across coarser sediments.

The S&G aquifer is unconfined and geometrically constrained as described above. The lateral boundaries of the S&G deposits are evident in existing drawdown data that have been collated from test pumping of BH1 and BH2. Test pumping data exhibit an apparent 'barrier effect' whereby drawdown increases faster than would be predicted under the assumptions of the Theis equation (which assumes radial flow in a homogenous aquifer of infinite extent).

Groundwater flow along the river valley to the north of the PWS appears to converge on the river. On account of the apparent greater thickness and extent of the S&G deposits on the western margin of the river valley, the ZOC of the PWS may be 'skewed' in this direction. However, it has been shown that abstracted water is also contributed from east of the river whereby measured water levels decreased in a shallow dug well approximately 200 m from the PWS (Keegan, 1993).

Whether or not the Ironmills PWS draws on river water during pumping operations has not been conclusively established, and there is conflicting information available on the possible hydraulic interaction between the aquifer and the river at the PWS location and further upstream:

- Available records of static water levels within BH1 and BH2 appear to be lower than the stream bed elevation at the PWS, although such water levels may not be truly indicative of 'static' conditions, but rather represent water levels that are still recovering following a pumping cycle.

- Streamflow measurements indicate that the Multeen River may be both a losing and gaining river depending on location – notably losing near its confluence with the Glasheenyreagha stream, and gaining in a downstream direction towards the PWS.

- Water quality data from the river and the PWS indicate distinct contrasts between data ranges of pH, DO, colour, alkalinity, hardness, EC, nitrate and chloride, as indicated by mean values in **Table 4**. Although the contrasts are perhaps less apparent than what would be expected between a fast flowing river and a S&G aquifer, measurable differences are noted.

- Keegan (1993) had suggested the abstraction might not draw on river water on the basis of 'stable' measurements of temperature and EC over a 36 hour test pumping period.

- Field measurements of pH and EC from the Multeen River in October 2011, November 2011 and March 2012 (see **Appendix G**) indicate a higher stream EC during low flow conditions compared to higher flow conditions, suggesting a higher groundwater influence on river water quality at lower stream flow rates.

Existing data are, therefore, inconclusive. In order to establish conclusively the hydraulic interaction between the PWS abstraction and the river, detailed and longer-term piezometry is needed. Given the flow measurements of the Multeen River in March 2012 and the high permeability of the S&G aquifer, it is reasonable to assume that some natural interaction between the S&G aquifer and river water is taking place along sections of the river valley. The proportion of river water being abstracted from the PWS would in all cases be very small. As mentioned in Section 4, the average daily abstraction of 1,638 m^3/d represents only 6% of the estimated Q_{95} flow of the river, and this particular relationship assumes that 100% of the abstracted water is sourced from the river, which is unrealistic.

Table 4: Summary of EPA Water Quality Data

	Location	Ironmills Bridge			Morpeth Bridge (7 km d/s from Ironmills)			Raw Groundwater PWS		
	Dates	2001-2006			2007-2010			2007-2010		
	Unit	n=32			n=15			n=16		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
pH	--	**8.2**	7.5	9.1	**8.1**	7.8	8.6	**7.4**	7.1	8.5
Temperature	ºC	**11.4**	7.0	18.4	**10.9**	5.8	17.4	**11.6**	10.2	13.7
Dissolved Oxygen	mg/l O_2	**11.4**	10.0	13.2	**11.8**	9.4	14.0	**3.8**	0.6	6.1
Dissolved Oxygen	%Sat	**104.3**	93.0	121.0	**106.5**	97.0	127.0	**34.5**	5.7	54.9
Colour	Hazen	**30.5**	5.0	125.0	**21.1**	5.0	40.0	**4.6**	2.8	7.0
Alkalinity	mg/l $CaCO_3$	**77**	31	109	**113**	80	169	**248**	214	320
Hardness	mg/l $CaCO_3$	**nd**	nd	nd	**129**	104	148	**255**	211	282
Electrical Conductivity	µS/cm	**209**	126	279	**282**	202	409	**510**	372	735
Molybdate Reactive Phosphorus	mg/l P	**0.021**	0.006	0.057	**0.031**	0.007	0.083	**0.017**	0.003	0.032
Ammonia	mg/l N	**0.031**	0.004	0.143	**0.014**	0.003	0.025	**0.028**	<0.007	0.110
Nitrate	mg/l N	**1.4**	0.9	2.0	**2.5**	1.8	4.0	**3.0**	2.6	4.2
Chloride	mg/l Cl	**13.5**	11.0	17.0	**13.7**	12.0	15.0	**17.3**	11.6	35.0

As the established permeability of the S&G aquifer is very high, it is concluded that the S&G aquifer provides a readily available source of groundwater to the PWS, with possible, minor (but as yet not quantified) recharge and contribution from the river.

9.2 ZOC boundaries

The ZOC for the PWS is estimated using a water balance approach, by considering the recharge area needed to supply a volume of water equivalent to the abstraction rate. When delineating ZOCs, the GSI generally recommends that actual abstraction rates be increased by 50% to be conservative in the mapping. The 50% increase is intended to allow for variations in abstractions (e.g. increases in demand) and for the expansion of the ZOC during dry weather periods. The size and shape of the ZOC is controlled by (a) the total discharge, (b) the groundwater flow direction and gradient, (c) aquifer permeability and (d) groundwater recharge.

Using an abstraction rate of 2,457 m^3/d (equivalent to the average daily abstraction rate in 2011 of 1,638 m^3/d plus 50%) and a bulk annual average recharge rate of 600 mm/yr (see Section 9.3), the total area required to supply this quantity is 1.52 km^2. This assumes no contribution from the river, which is conservative. Guided by this total area, the Uniform Flow Equation (UFE) (Todd, 1980) was applied to determine the shaping of the ZOC, as follows:

A. Width of upgradient boundary:

$$Y_L = Q / (2 * T * i)$$

where,

Y_L is the half-width of the upgradient boundary;
Q is the daily pumping rate (m^3/d);
T is Transmissivity (m^2/d); and

i is the non-pumping hydraulic gradient (m/m).

For the estimated transmissivity of 850 m^2/d and a gradient of 0.01, Y_L is 52 m.

B. The maximum downgradient distance (X_L) that the borehole can pump water from under prevailing hydraulic gradients:

$$x_L = Q / (2\pi * T * i)$$

where Q, T and i have the same definitions as above.

For the estimated transmissivity of 850 m^2/d and a gradient of 0.01, X_L would be 17 m.

These calculations would suggest that the ZOC should be very long (15 km) and very narrow (100 m) in an upgradient direction along the river valley to provide the area needed (1.52 km^2). However, these dimensions are not considered realistic for several reasons: a) the S&G deposits do not extend 15 km to the north; b) the S&G aquifer is neither homogenous nor of constant thickness away from the PWS (which is assumed by the Uniform Flow Equation); c) there is an apparent natural gradient towards the river from the east and west; and d) Keegan (1993) reported an 8 cm drop in water levels in a dug well approximately 200 m east of the PWS (*i.e.* it responded to pumping) when BH2 pumped at a rate of approximately 2,500 m^3/d. Guided by these considerations, and further guided by the notion that bedrock contributes a small (undefined) percentage of flux into the S&G deposits (particularly from the inferred bedrock high area to the west of the river), the delineated ZOC is presented in **Figure 12**.

The **southern** (downgradient) boundary is carried sufficiently far south so that the ZOC encompasses the dug well that responded to test pumping in 1992 (Keegan, 1993) at a pumping rate nearly identical to that defined above for ZOC delineation purposes. The **eastern and western** boundaries are influenced by the interpreted geology and groundwater flow lines towards the river and PWS. The **northern** boundary is defined by the known extent of the S&G deposits along the river in a northerly direction. The delineated ZOC encompasses the Tinnahinchy S&G pit where recharge is possibly enhanced by percolation from settling ponds. It also encompasses several small rushy hollows to the west of the PWS and southwest of the quarry where surface runoff ponds and further infiltrates into the underlying till and S&G deposits.

The groundwater regime in the study area is complicated by its glacial history and resulting subsurface heterogeneity. The lateral ZOC boundaries presented in **Figure 12** are undoubtedly simplifications of the actual ZOC, as the lateral boundaries will in reality be dictated by the geometry of the S&G deposits which: a) are not uniform; and b) are expected to grade into lower-permeability sediments at the valley margins. Nonetheless, the delineated ZOC is considered to capture the broader characteristics of the S&G aquifer. Although contributions from the Multeen River to the PWS may be small, the delineated ZOC also includes the river, roughly from the position along the river valley in the north where the S&G deposits are inferred to begin. The Multeen River catchment area outside of the interpreted position of the S&G deposits is not included in the ZOC. Adjacent and underlying tills can be expected to contribute some water from leakage during pumping conditions.

9.3 Recharge and water balance

The term 'recharge' refers to the amount of water that replenishes the groundwater flow system. The recharge rate is generally estimated on an annual basis, and consists of input (*i.e.* annual effective 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 important in source protection delineation, as it will dictate the size of the ZOC to the source (and therefore the Outer Source Protection Area). At Ironmills, the main parameters involved in recharge rate estimation are:

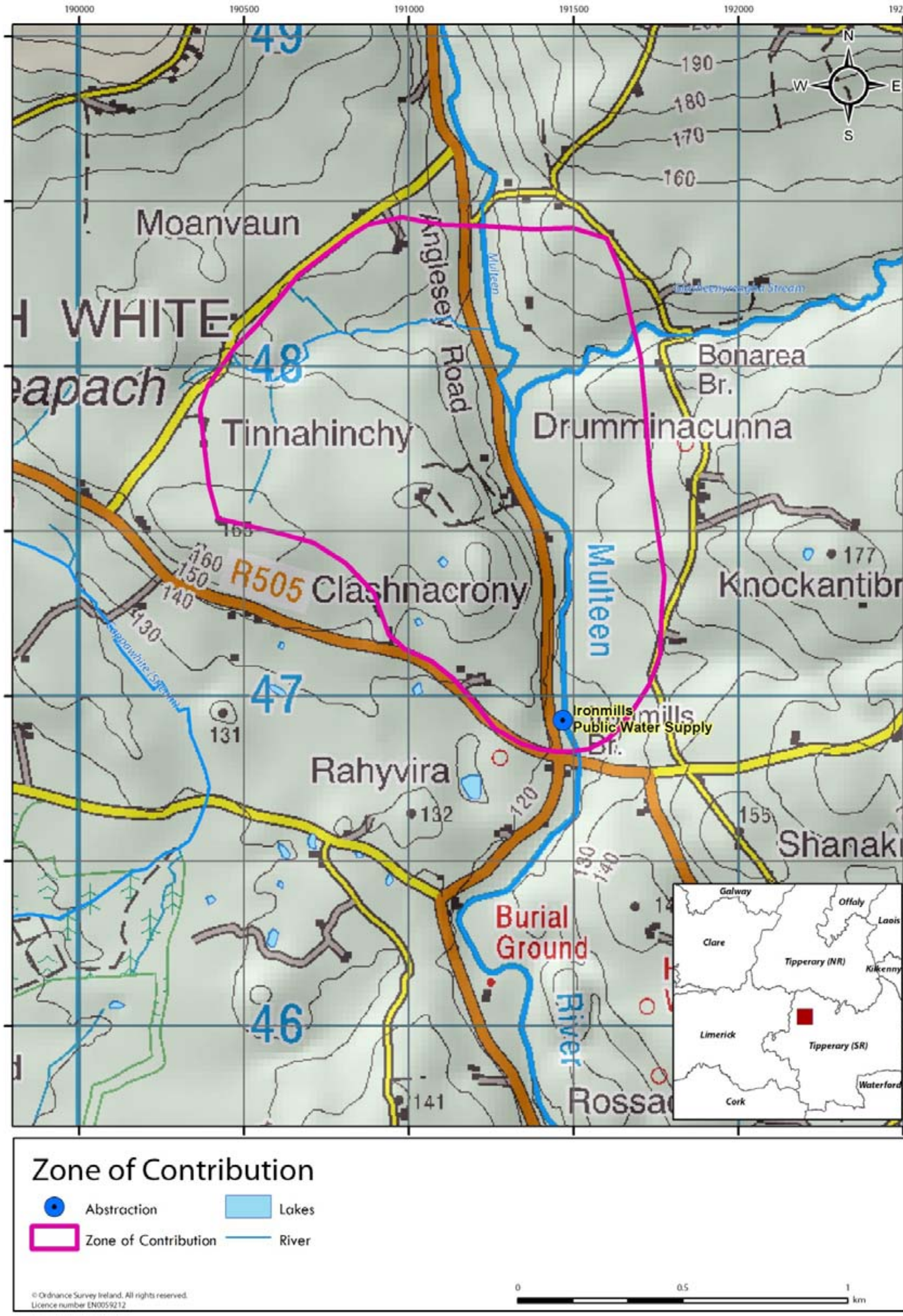


Figure 12: Estimated Zone of Contribution for the Ironmills PWS

annual rainfall; annual evapotranspiration; and a representative recharge coefficient (Rc) which is estimated using Guidance Document GW5 (Groundwater Working Group 2005). The Rc that is proposed for a S&G aquifer in a 'high' groundwater vulnerability setting, and overlain by well-draining soil ranges from 60–100% with an inner range of 80–90%. As noted previously, there are areas within and adjacent to the Tinnahinchy quarry where vulnerability should be considered as 'extreme', where an even higher Rc would apply, but proportionally across the study area, the footprint is proportionately small. A bulk value of Rc of 85% is proposed, in which case the average annual recharge calculation is summarised as follows:

Average annual rainfall (R)	1,200 mm
Estimated P.E.	520 mm
Estimated A.E. (95% of P.E.)	494 mm
Effective rainfall	706 mm
Potential recharge	706 mm
Bulk recharge coefficient	85%
Recharge	600 mm

With a recharge of 600 mm/yr and an abstraction rate of 2,457 m^3/day, the area required to supply the water to the PWS is approximately 1.5 km^2.

10 Source protection zones

The Source Protection Zones (SPZs) are a landuse planning tool which enables an objective, geoscientific assessment of the risk to groundwater to be made. The zones are based on an amalgamation of source protection areas 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 Source Protection Area (SI) and the Outer Source Protection Area (SO).

The SI is mainly the area defined by the horizontal 100-day time of travel from any point below the water table to the source (DoELG/EPA/GSI, 1999). The 100-day horizontal time of travel to the source is calculated from the velocity of groundwater flow in the aquifer using hydraulic properties as described in Section 8.4. The SI describes the horizontal flow to the source and is independent of the vertical aquifer recharge component which is described by the groundwater vulnerability. From Section 8.4, the groundwater velocity is inferred to be on the order of 2 m/d and hence the 100-day time of travel distance is 200 m. The Inner Protection Area, representing approximately 6% of the ZOC, is illustrated in **Figure 13**.

Resulting groundwater Source Protection Zones for the abstraction rate of 2,457 m^3/d are shown in **Figure 14** and are based on an overlay of the source protection areas on the groundwater vulnerability. Resulting SPZs cover these areas: SI/H (6%); SO/E (2%); and SO/H (92%). The extreme vulnerability SPZ has been assigned within the footprint of the Tinnahinchy pit floor, where S&G has been excavated to within 3 m of the groundwater table. Further piezometry is needed along the Multeen River to establish, conclusively, if an 'extreme' vulnerability assignment should be factored in along the river, in which case an 'extreme' SPZ buffer would be applied along the river course. At this time, there is insufficient evidence that the river and the underlying aquifer are in direct connection, hence the buffer is not included in this report.

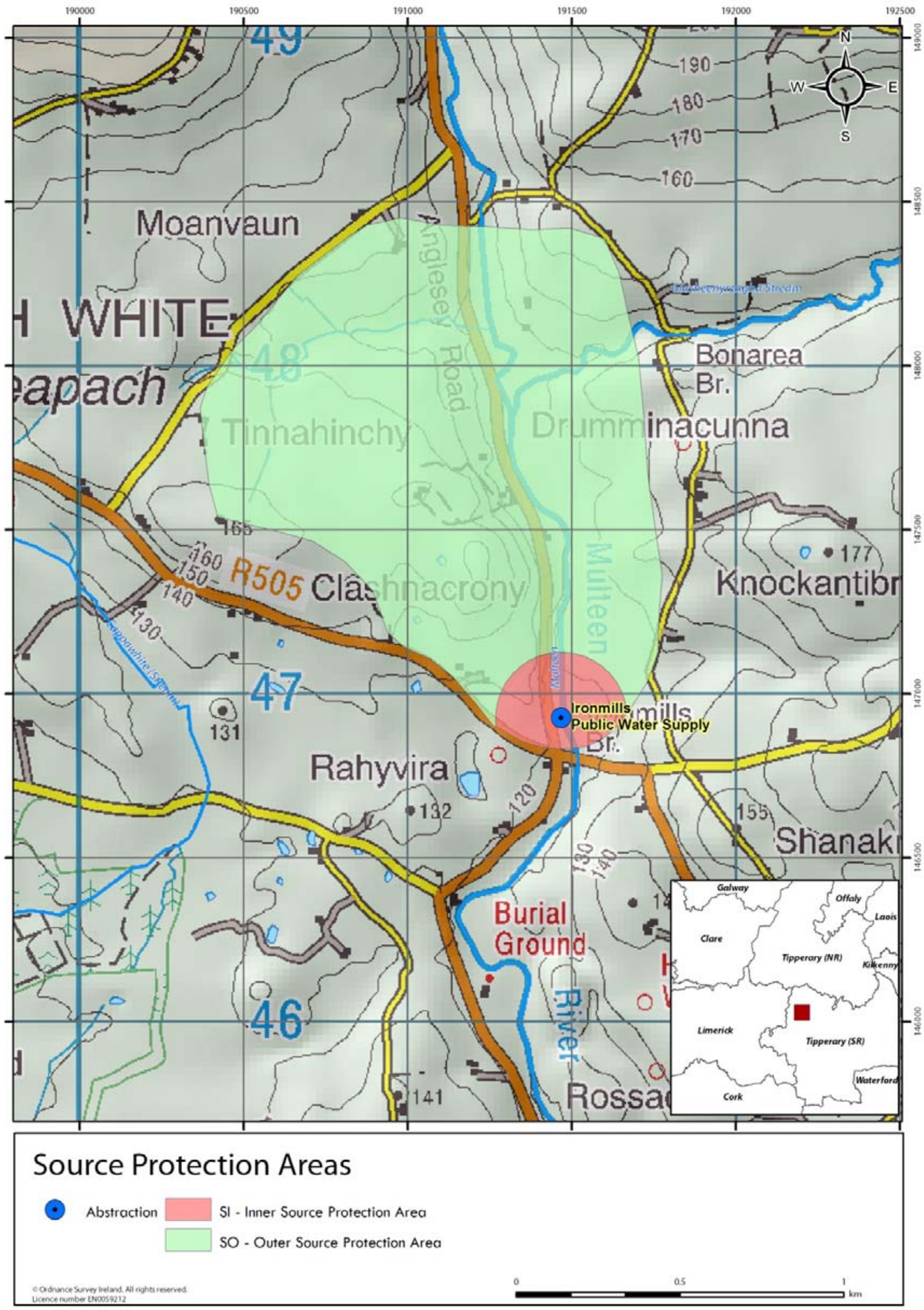


Figure 13: Inner and Outer Source Protection Areas for Ironmills PWS

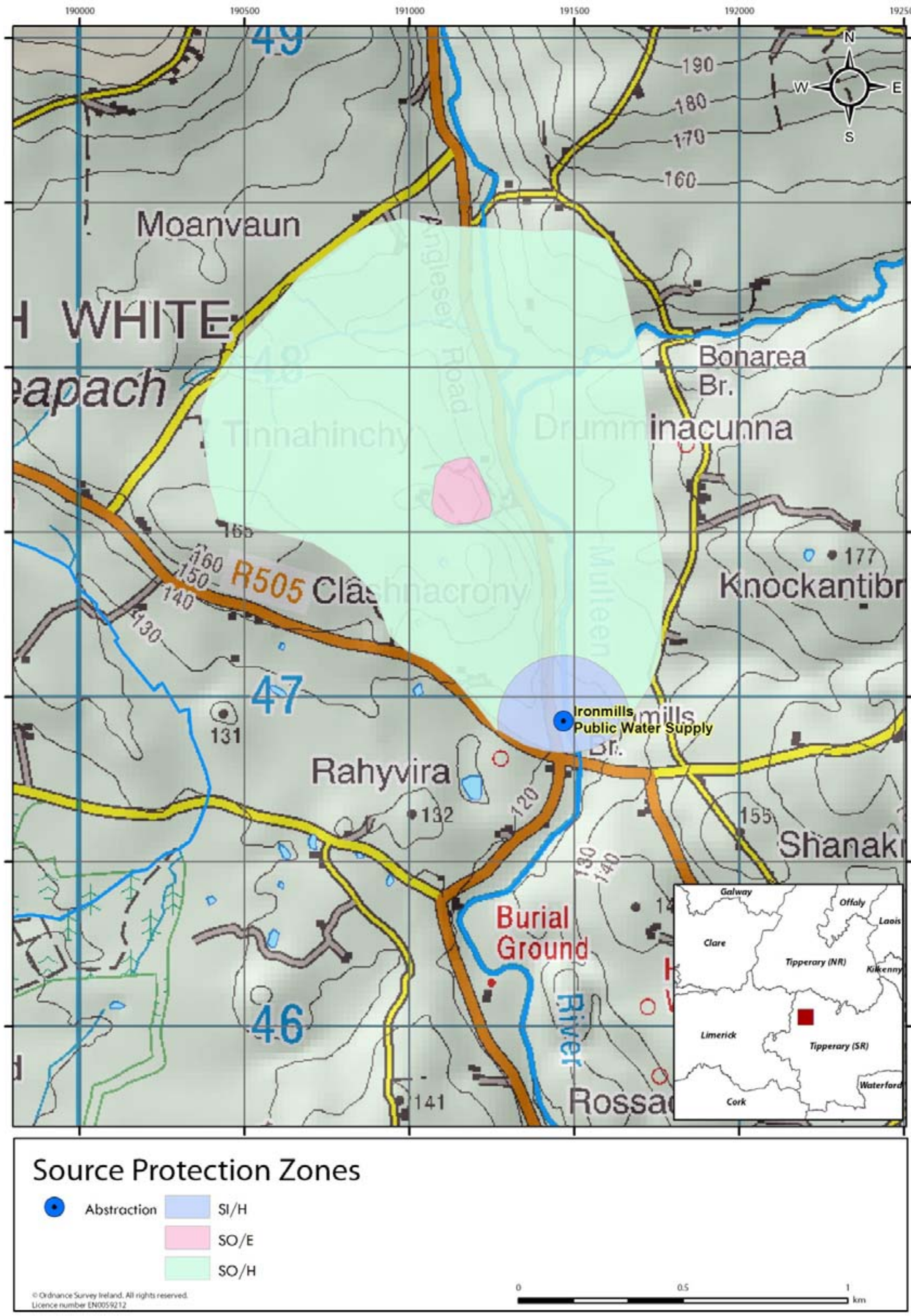


Figure 14: Source Protection Zones for Ironmills PWS

11 Potential pollution sources

Land use within the Multeen River valley is predominantly agricultural grassland. The main potential pollution sources in the ZOC of the PWS are considered to be landspreading of organic and inorganic fertilisers, farmyard slurry storage areas and farmyard washings. There are an estimated 8 houses and 3 farmyards within the ZOC. The nearest farmyard to the PWS that is within the ZOC is approximately 600 m to the north. The area is served by mains water supply, but is not sewered, and wastewater disposal occurs *via* on-site wastewater treatment systems (usually septic tanks). Potential impacts on groundwater quality from septic tanks and farmyards are typically elevated concentrations of ammonia, nitrates, phosphate, chloride, potassium, BOD, COD, TOC, pesticides, faecal bacteria, viruses and cryptosporidium. Private home heating fuel tanks are located within the ZOC. The main potential contaminants from this source are hydrocarbons.

A scrappage yard used for dismantling old plant equipment is located approximately 500 m up-gradient of the wells, and located within the flow path to the ZOC of the PWS. During a recent site inspection, staff from South Tipperary County Council (STCC, 2010) noted improper storage of spent oil and chemical containers.

The Tinnahinchy S&G pit is located within the ZOC and only 700 m to the north of the PWS. As the S&G aquifer is exposed and the pit floor is close to (within 3 m of) the groundwater table, groundwater vulnerability should be considered as 'extreme' within the quarry footprint.

Finally, the PWS boreholes are situated within a below-ground concrete chamber. For this reason, there is a risk that surface water ingress into the wells from surface runoff can occur. The primary substances of concern from this pathway would be microbial pathogens.

Concentrations of key water quality indicators at the source to date are generally very good. However, as presented in Section 8.3, there is an indication that nitrate and chloride are present in groundwater at concentrations that are considered higher than "natural background".

12 Conclusions

The Ironmills PWS abstracts groundwater from a S&G aquifer of an extent that has been interpreted but has yet to be fully established. A conservatively large ZOC covering an area of 1.5 km^2 for the source has been delineated based on 150% of the 2011 average abstraction rate of 1,638 m^3/d, assuming that all of the water abstracted is sourced from the S&G aquifer. The PWS may be hydraulically connected to the Multeen River, but this has not yet been conclusively demonstrated. Without detailed piezometry at and near the PWS, the potential proportion of the abstracted water that would originate from the river cannot be calculated with any degree of certainty. If water is abstracted from the river, the delineated ZOC boundaries would have to be adjusted (reduced) to account for that proportion of river water abstracted.

The S&G nature of the aquifer provides natural protection against pollution and impact to groundwater quality, by allowing for attenuation of pollutants in both subsoils and the groundwater environment. Groundwater also moves at slow rates, up to 4 metres per day, so point-source pollution incidents (such as spillages) within the ZOC can be addressed in time without necessarily posing an immediate risk to the PWS. There are suggestions, however, that groundwater quality is slowly being impacted from diffuse, presumably, agricultural activities within the catchment, as indicated by slightly elevated nitrate and chloride concentrations at the PWS above concentrations that would be considered 'natural background'.

The three-dimensional geometry of the S&G deposits along the Multeen River valley is largely undefined. As recognised by the GSI (2001), site investigations in the general area of South Tipperary may prove 'other gravel deposits to be aquifers' beyond what has been currently mapped. Additional evidence is emerging from the work presented in this report that the S&G deposits at Ironmills may constitute an 'aquifer' in the formal sense of GSI mapping (*i.e*. having a sufficiently saturated area greater than 1 km^2).

13 Recommendations

Specific recommendations are:

1. Explore the geometry and continuity of the S&G deposits associated with the PWS, to assess whether or not the deposits can or should be classified as a formal aquifer according to GSI criteria. There are numerous S&G exposures along the Multeen River valley in a southerly direction. The designation of a 'new' aquifer may result in a new groundwater body being established within the Southeastern River Basin District, if it is sufficiently large (*i.e.* meeting GSI criteria).

2. The groundwater vulnerability mapping, which presently designates the entire S&G study area as 'high', should be updated on the basis of any new exploration work that might be carried out as recommended above. There are indications from current information that the vulnerability may be different from that currently mapped. For example, there are indications of shallow groundwater tables that would alter designations to 'extreme', *e.g.* within and near the active Tinnahinchy S&G pit and inactive pit at Glassdrum.

3. The delineated ZOC is considered to be conservatively large. It is assumed that all of the water abstracted is sourced from the S&G aquifer, but there is uncertainty as to whether or not the PWS also draws on river water directly. If the PWS draws on river water directly, then the ZOC is too large, by a factor that is proportional to the fraction of water pumped from the river. To conclusively demonstrate this, additional hydrogeological field work should be carried out as follows:

   - Continuous (metered) monitoring of field pH, temperature and electrical conductivity from the untreated water at the PWS;
   - Continuous monitoring of water levels in BH1 and BH2 – this is presently not possible as there is insufficient space to lower water level metres and pressure transducers without removing the submersible pumps and making new arrangements for monitoring purposes. This should be arranged; and
   - Drilling and construction of three shallow (<5 m deep) 50 mm diameter piezometers adjacent to the river and on the east side of the river. These should be equipped with data loggers over an extended (one year) period to examine changes in water levels with pumping operations, hydrometeorological conditions and river flows.

4. Care should be taken at the location used for dismantling old plant equipment to minimise the risk of contamination of groundwater, as recommended by South Tipperary County Council (STCC, 2010).

5. Activities at the Tinnahinchy S&G pit should be periodically inspected by STCC. Weekly water level measurements and semi-annual water quality monitoring should be conducted at the down-gradient end of the site. This well should be screened within the same S&G deposits that form part of the aquifer at Ironmills, and is located between the pit and the Multeen River.

6. Finally, minor improvement works at the source might usefully include upgrade of the wellhead protection at BH1 and BH2, whereby a drain should be installed at the base of the concrete chamber to lower the risk of ponding of water within the chamber.

14 References

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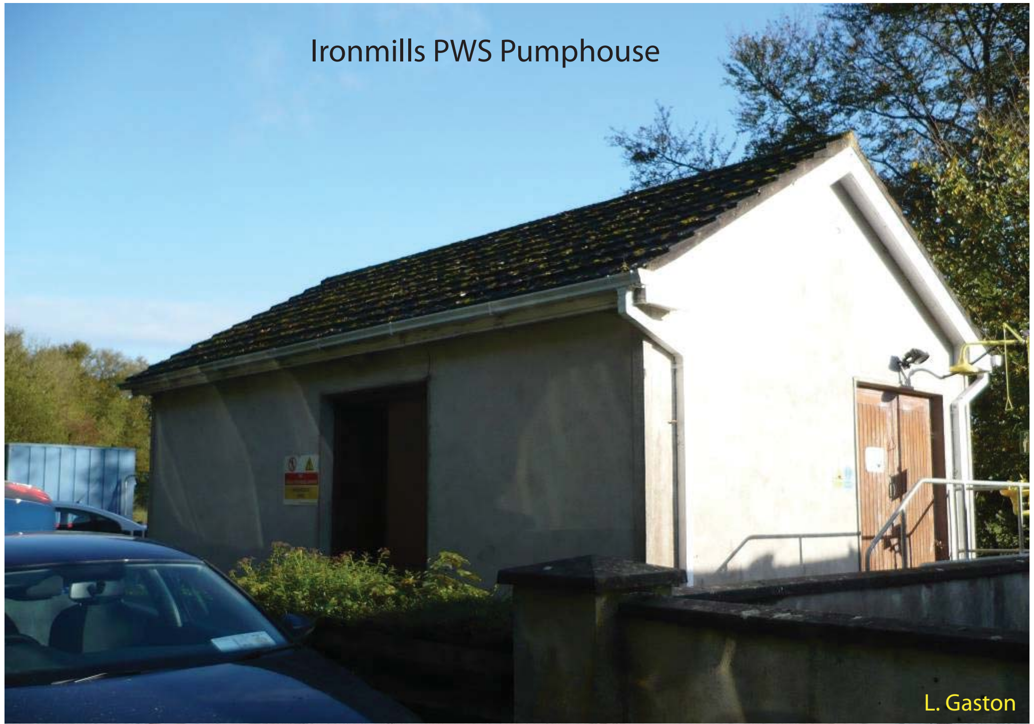
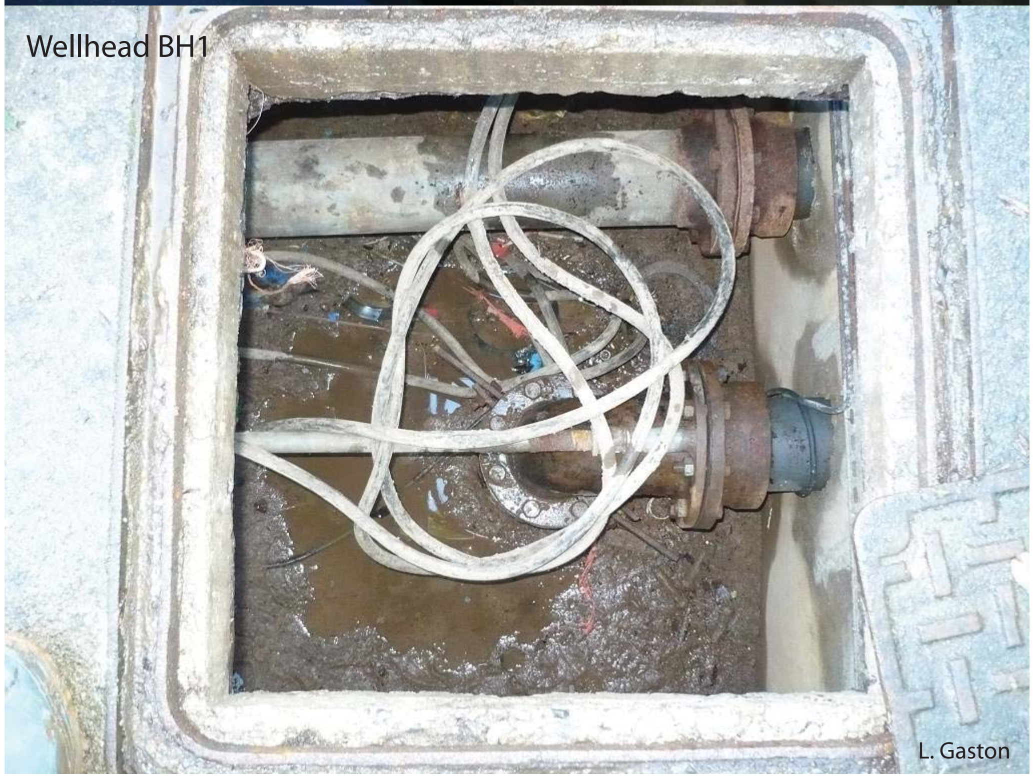
APPENDIX A

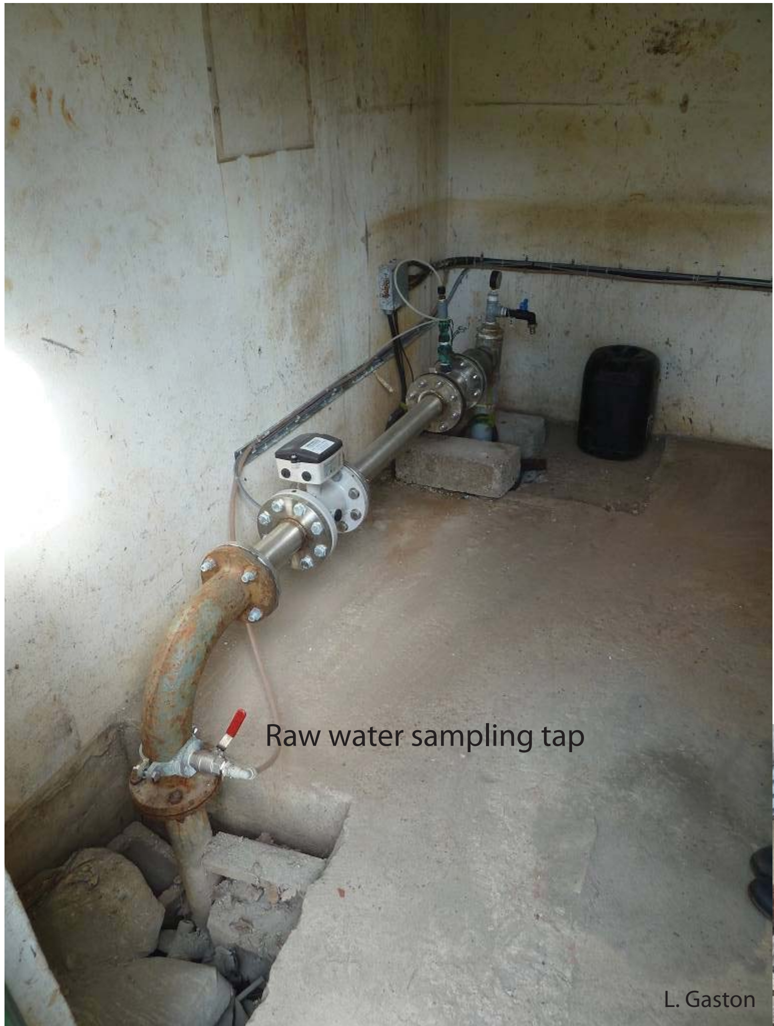
Photographs


Ironmills PWS Pumphouse
L. Gaston


Concrete Chamber
Housing Wells BH1 and BH2
L. Gaston


Wellhead BH1
L. Gaston


Wellhead BH2
L. Gaston


Raw water sampling tap
L. Gaston


Wellhead BH1
L. Gaston


Wellhead BH2
L. Gaston

View east across Tinnahinchy Quarry

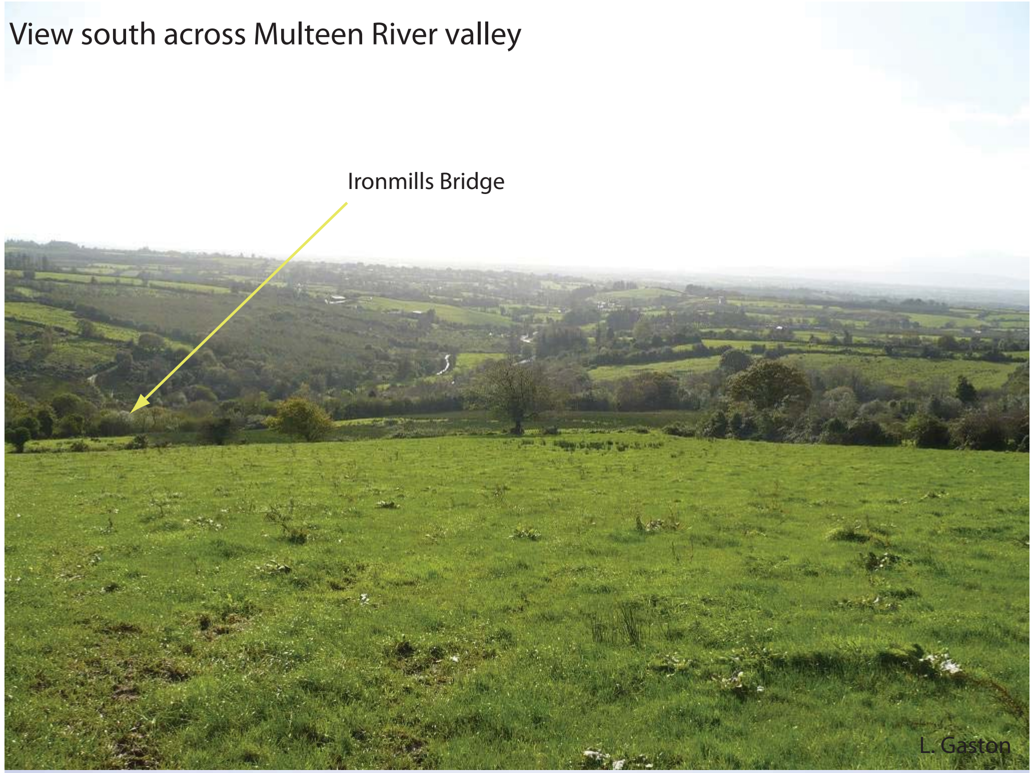
View south across Tinnahinchy Quarry

View north across Tinnahinchy Quarry

View northeast across Tinnahinchy Quarry

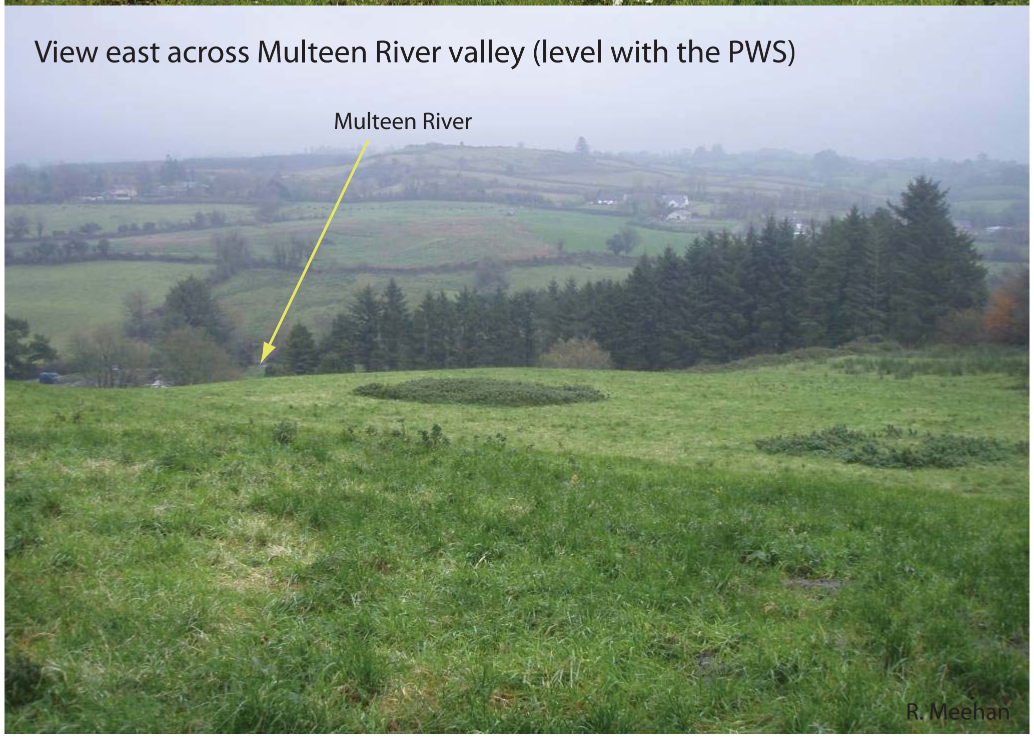
Sand and gravel deposits exposed at Tinnahinchy Quarry

View east across Multeen River valley (north of Tinnahinchy)

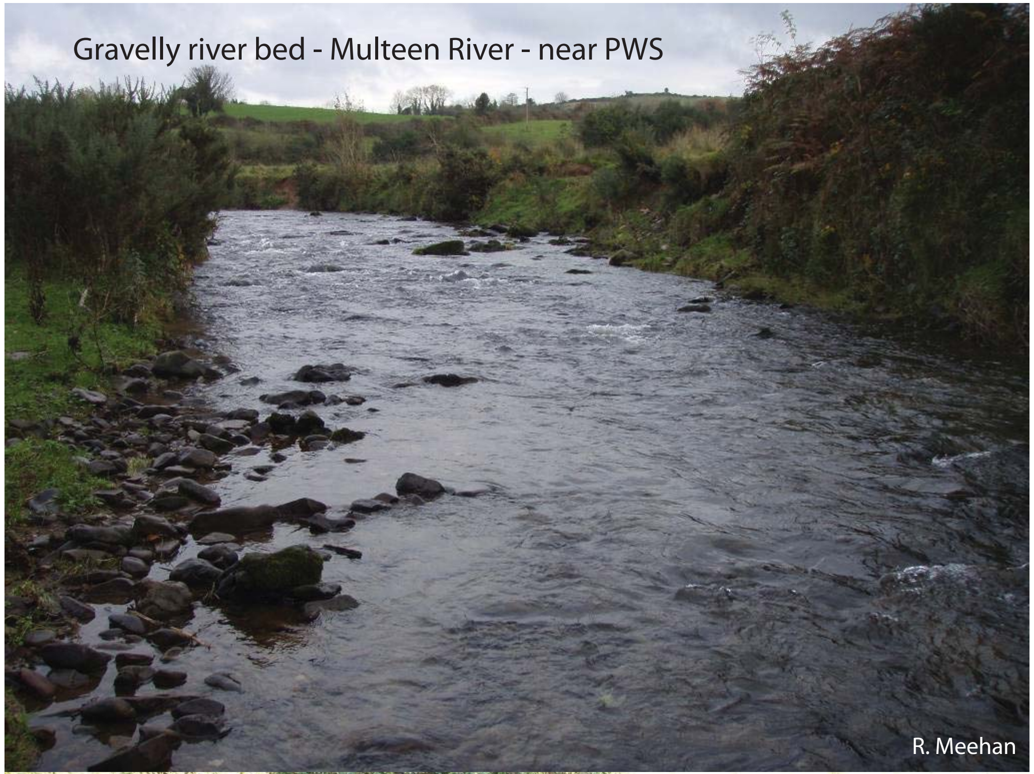


View south across Multeen River valley

View north across Multeen River valley (towards Hollyford)



View east across Multeen River valley (level with the PWS)


Gravelly river bed - Multeen River - near PWS
R. Meehan


Multeen River floodplain near PWS
R. Meehan


Multeen River - "mean" flow conditions near PWS
L. Gaston


Multeen River - sediment transport during rainstorm
L. Gaston


'Sinking stream" (into gravels)
Kettle-holes?
R. Meehan


'Sinking stream" (into gravels)
R. Meehan


'Sinking stream" (into gravels)
R. Meehan


Small internal drainage with rushes
R. Meehan

Disused gravel pit at Glassdrum

Face in disused gravel pit at Glassdrum

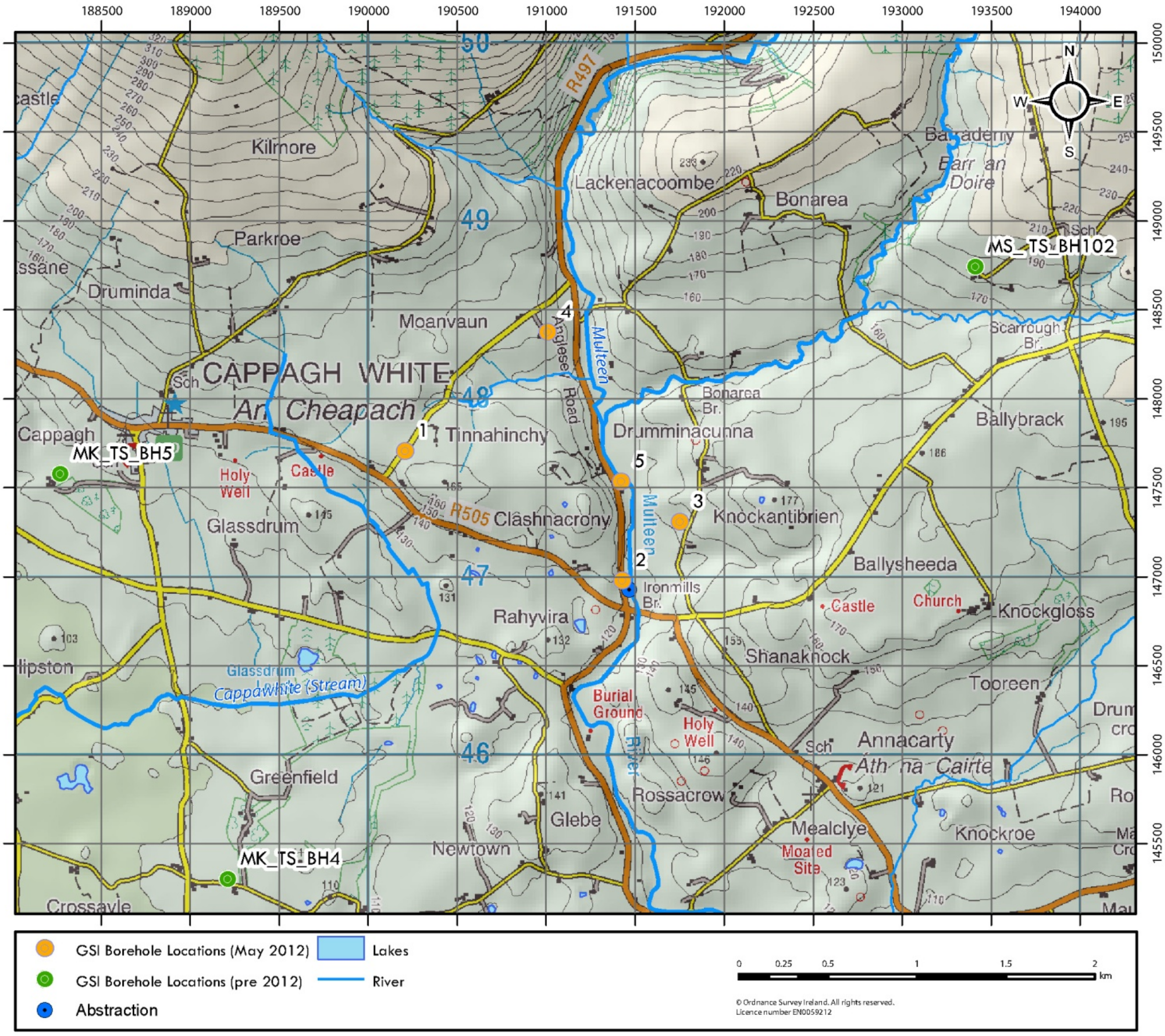
Groundwater "lake" in disused gravel pit

APPENDIX B

Results of Drilling at Ironmills, May 2012

(Geological Survey of Ireland)

GSI Drilling at Ironmills, May 2012



GSI Drilling Locations

Drilling Log Summary (May 2012)

Location	Borehole Number	Depth to Bedrock (m)	X-coord	Y-coord	Depth interval (m bgs)	Description
West of old Quarry	**1**	15.5	190207	147706	0-12 12-15.5 15.5	Firm dark brown very silty fine sandy clay with pebbles A blue/grey silty stoney clay (possibly decomposed bedrock) auger limit - end
Beside Source	**2**	>18	191428	146979	0-4 4-6 6-18 18	Dark brown silt with pebbles (till?) Red/brown very silty sand (water saturated) Hard becoming dense brown stoney tills auger limit - end
East of River	**3**	>26	191751	147310	0-8 8-9.5 9.5-26 26	Moderately dense dark brown very silty sandy clays with pebbles and occasional layers of pure silty sand Dense clays as above Firm dark brown silty tills with occasional pebble layers auger limit - end
North - hill	**4**	>24	191009	148378	0-11 11-14 14-24 24	Medium dense brown silty sandy clays with layers of large/ medium/ fine clayey gravels Moderately dense firm brown coarse sand Firm becoming quite dense brown silty tills auger limit - end
River beside quarry	**5**	>13	191422	147536	0-4 4-5 5-10 13	Silty brown sandy gravels Coarse silty sandy brown tills (water saturated) Unusually hard to dense brown tills auger limit - end

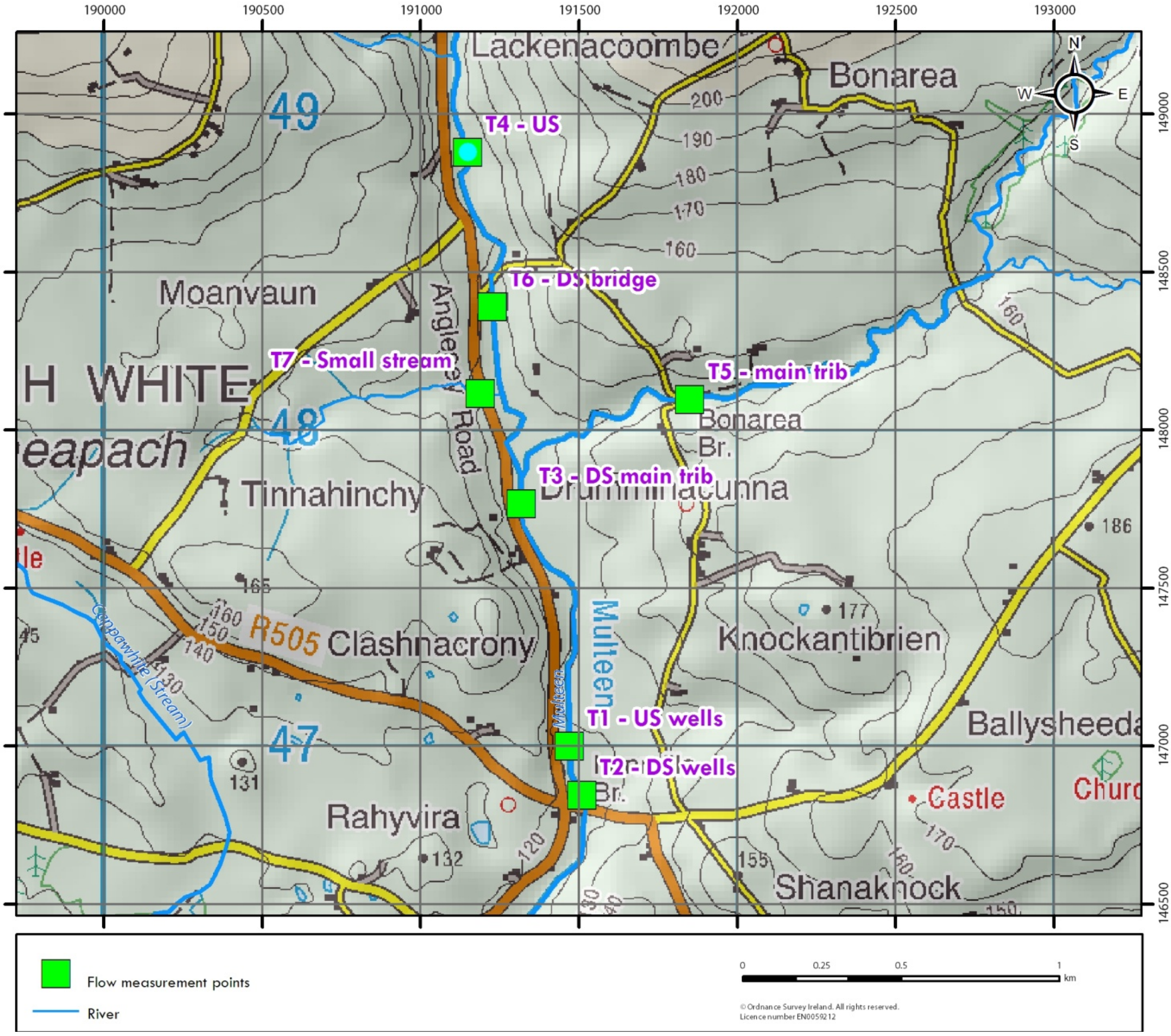
Drilling Log Summary (pre-2012)

Borehole Number	Depth to Bedrock metres	X-coord	Y-coord	Depth interval in metres	Description
MK_TS_BH4	7	189211	145299	0-7	very sandy SILT/CLAY with gravels (PS 17% clay, 44% fines, 43% sand, 13% gravels)
MK_TS_BH5	5	188270	147580	0-5	sandy CLAY with gravels
MS_ TS_BH102	>10	193410	148744	0-5 5-10	silty gravelly SAND silty SAND

APPENDIX C

Surface Water Flow Measurements

Surface water flow measurements at Ironmills, 2011/2012

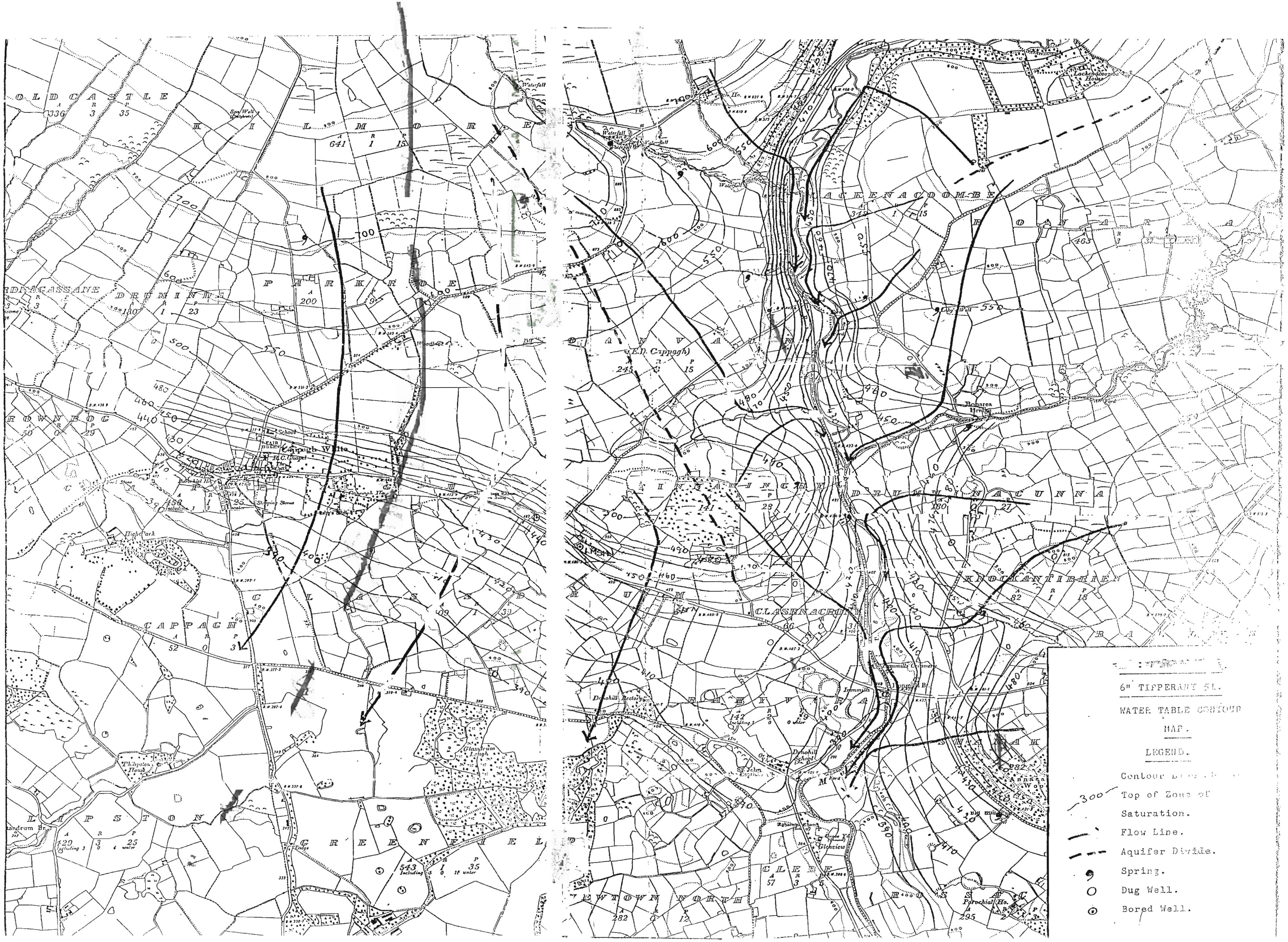


Flow Measurements

Location Description		Easting	Northing	Flow (l/s) 16/11/2011	Flow (l/s) 28/03/2012	EC)µS/cm) 16/11/2011	EC)µS/cm) 28/03/2012
T4 - US	Main River	191149	148879	796	286	192	209
T6 - DS bridge	Main River	191185	148392	-	346	193	209
T3 - DS main tributary	Main River	191319	147767	827	358	202	225
T1 - US wells	Main River	191445	146994	894	349	207	241
T2 - DS wells	Main River	191511	146844	792	422	204	237
T5 - Main tributary	Tributaries	191851	148097	131	90	208	254
T7 - Small tributary	Tributaries	191189	148115	18	3	307	392

APPENDIX D

Groundwater Contour Map



6" TIPPERARY 51.
WATER TABLE CONTOUR MAP.
LEGEND.
Contour
300
Top of Zone of Saturation.
Flow Line.
Aquifer Divide.
Spring.
Dug Well.
Bored Well.
CAPPAGH
DRUMINNA
PARKROE
OLDCASTLE
CLASHNACROW
KNOCKANTIBRIEN

APPENDIX E

Test Pumping Results – Keegan 1993

Groundwater Vulnerability & Protection in County Tipperary (South Riding). Ireland
M. Keegan MSc. 1993. Sligo RTC.

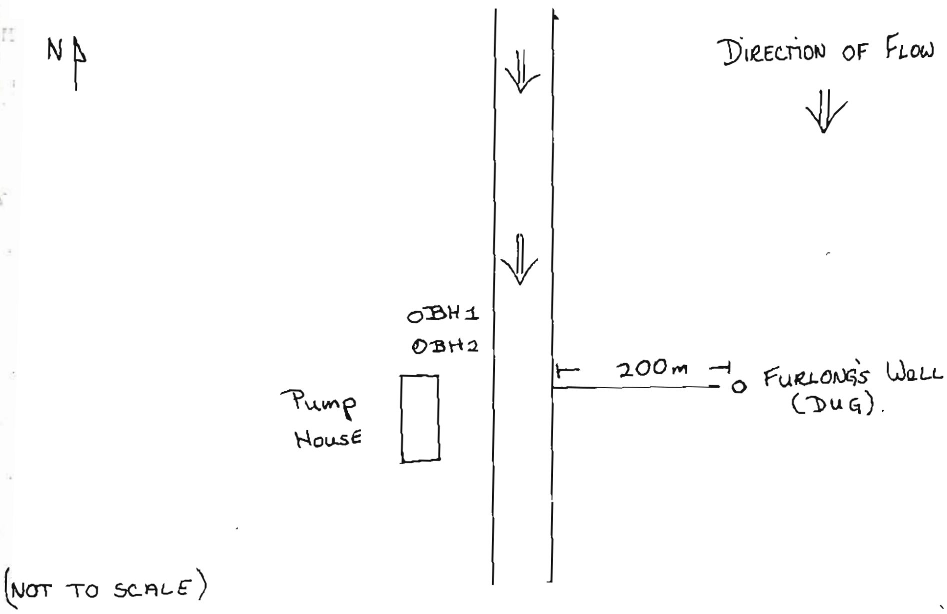
APPENDIX B.6

RESULTS OF A PUMPING TEST AT IRONMILLS, CAPPAGHWHITE,
CO. TIPPERARY

RESULTS OF PUMP TEST AT IRONMILLS, CAPPAWHITE, CO. TIPPERARY.

A thirty six hours pump test was carried out on a Co Co borehole # 2 (BH 2) at Ironmills. The monitoring of this test was carried out by M. Keegan and K. Forde on request of Tipperary SR Co Co -Sanitary Section.

BH 2 commenced pumping at 8:00hrs on the 17/08/92, and continued pumping at a constant rate of 28,000gph until 20:00hrs on the 18/08/92. During this time the pumping well BH 2 and the observation well BH 1 were monitored by M.Keegan and K. Forde (GSI). A nearby (approx. 200m) shallow dug well (Furlong's) was monitored by Tipperary SR Co Co.



The analysis of the pump test data has been undertaken by M. Keegan GSI/Sligo RTC. The raw data plus the semi-log time drawdown for both BH 1 and BH 2 follow.

The transmissivities of the pumping well BH 2 and the observation well BH 1 decreases with time.

BH 2	T = 1862m^2/d
	T = 859.3m^2/d
BH 1	T = 1471.6m^2/d
	T = 980m^2/d

The graphs (observation and pumped) show that the transmissivity is decreasing with time until it reaches a "barrier" ie: an area of less permeable material with time.

If the river was a source of recharge to the borehole the graph would quickly level out or even increase. This is not so, the cone of influence may spread futher than originally thought.

The water level in the well (Furlong's) drop from Wednesday 7:30 hrs to Thursday 20:00 hrs by 8 cms .

The temperature and the conductivity of both the pumped borehole and the adjacent river were measured , this was undertaken to examine if they are in hydraulic continuity. There was a slight increase in the conductivity and the temperature of the borehole during the pump test.

Temperature	**Conductivity**
10 - 10.5 °C	5 - 5.2 *u*S

The increase is insignificant at this scale and therefore suggests that the borehole does not receive recharge from the river. This implies that the borehole and the river are not in hydraulic continuity.

This agrees with the information from the pump test. The extent of the cone of influence is not known because there is insufficent water levels from Furlong's well during the pump test.

The information to hand implies that there was a decrease of 0.08m in water level in Furlong's well during the thirty-six hour pump test of Borehole 2 at Ironmills.

...dwater Division,
...gical Survey
...land

AQUIFER TESTS
WATER LEVEL
MEASUREMENTS

Page...1...

...ole name. IRONHILLS ...... No. 1 ...

... T1 .... 6" sheet No. 51 .....

... 18/8/92 ....

...her ... Fair ....

Drawdown [✓] Recovery [ ]

Pumping well [ ] Observation well [✓]

Distance from pumping well ...... 2 m ...... m

Test conducted by ... MK + KF ......

...	Elapsed time Mins/ Hours	Days	Mins	Water level M	Draw-down M	Meter reading	Q	Remarks (i.e. pump behaviour, water temp, water quality etc)
0	0	0·0		4·205				
	½ min	3·47 x 10^{-4}						
01	1	6·95		5·16	0·955			
	1½	1·04 x 10^{-3}						
2	2	1·39		5·325	1·12			
2½	2½	1·74		5·375	1·17			
3	3	2·08		5·41	1·205			
3½	3½	2·43		5·44	1·235			
4	4	2·78		5·465	1·245			
4½	4½	3·13		5·485	1·28			
05	5	3·47		5·505	1·3			
06	6	4·17		5·52	1·315			
07	7	4·86		5·55	1·345			
8	8	5·56		5·565	1·36			
9	9	6·25		5·58	1·375			
10	10	6·94		5·59	1·385			
	13	8·33						
14	14	9·72		5·62	1·415			
16	16	1·11 x 10^{-2}		5·645	1·44			
	18	1·25						
20	20	1·39		5·67	1·465			
	22	1·53						
24	24	1·67		5·70	1·495			
26	26	1·81		5·71	1·505			
	28	1·94						
30	30	2·08.		5·725	1·52			
	35	2·43						
40	40	2·78		5·75	1·545			
	45	3·13						
50	50	3·47		5·78	1·575			
	55	3·82						
00	1 hour	4·17	60	5·81	1·605			
15	1¼	5·21	75	5·855	1·65			
30	1½	6·25	90	5·88	1·675			
45	1¾	7·29	105	5·905	1·7			
00	2	8·83	120	5·93	1·725			

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...logical Survey
...reland

AQUIFER TESTS
WATER LEVEL
MEASUREMENTS

page 2

...hole name IRONHILLS ...... No. 1 ...... County ... . 6" sheet no. 51 ...

Elapsed time	Days	MINS	Water level	Drawdown	Meter reading	Q	Remarks (i.e. pump behaviour, water temp, water quality etc)
Mins/ Hours			M	M			
~~2½~~	—	156	5.965	1.745 ⊛ change to river			10.11 → 5.42
3	1.25	180	5.985	1.78			10.17 → 5.975
3½	1.46	210	6.07	1.865			10.45 → 5.97
4	1.67	240	6.09	1.885			changed pump to
5	2.08	300	6.13	1.925			river.
6	2.5	360	6.18	1.975			11.13 → 6.06
7	2.92	420	6.2	1.995			11.24 → 6.06
8	3.33	480	6.23 ⊛	2.025			changing pumping rate
9	3.75	540		change	back to		when switch to river.
10	4.17	600			reservoir.		2115
12	5.0	720	6.96	2.155		720 mins	⊛ 21.00 → 6.32 change over
14	5.83	840					to river.
16	6.67	960					
18	7.5	1080					Pump to
21	8.75	1260					Reservoir
24	1.0 x 10^0	1446	6.54	2.335			⊛ 9.00 → 6.545 2.347
~~27~~ 28	~~1.125~~	1680	5.6.	* 1.395 pump off for 2			mins 1560 10.00 → 6.58 2.375
30	1.25	1800					29 1380 13.40 → 6.61 2.405
36	1.5	2160	6.7	2.1495			30 1832 14.32 → 6.25 2.045
42	1.75						31 1885 15.25 → 6.63 2.425
48	2.0						33 2032 17.52 → 6.66 2.45
54	2.25						35 2105 19.05 → 6.67 2.465 (mins)
60	2.5						
66	2.75						
72	3.0						Pump turned off by
	3.5						workman for 2 mins
	4.0						- recovery of at
	4.5						least 1m
	5.0						
	6.0						
	7.0						
	8.0						
	9.0						
	10.0						

...her remarks River level Wed 11am 0.665 down from peg
" 8.05pm 0.683 " " "
Thurs 9am 0.685 " " "

...elong's Well Tues 7.30am 03.95m
Wed 10am 3.99, 7.55pm - 4.03
Thurs 9am 4.03

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Ireland

AQUIFER TESTS
WATER LEVEL
MEASUREMENTS

Page 1

rehole name FRONMILLS No. 2 | Drawdown [✓] | Recovery [ ]

nty TT 6" sheet No. 51 | Pumping well [✓] | Observation well [ ]

te 18/8/92 | Distance from pumping well 0 m

ather Fine | Test conducted by MC + KF

Time GMT/BST	Elapsed time Mins/Hours	Days	Mins	Water level M	Draw-down M	Meter reading	Q	Remarks (i.e. pump behaviour, water temp, water quality etc)
00.	0	0.0		4.225				
	½ min	3.47 x 10⁻⁴						
	1	6.95						
	1½	1.04 x 10⁻³						
	2	1.39						
	2½	1.74						
	3	2.08						
	3½	2.43						
	4	2.78	—					
	4½	3.13						
	5	3.47						
	6	4.17						
	7	4.86						
	8	5.56						
	9	6.25						
	10	6.94						
:12	12	~~8.33~~	12	6.65	2.425			
	14	9.72						
	16	1.11 x 10⁻²						
	18	1.25	18	6.70	2.475			
	20	1.39						
	22	1.53	22	6.77	2.545			
	24	1.67						
	26	1.81						
	28	1.94	28	6.70.	2.475			difficult to get
	30	2.08.						accurate readings
	35	2.43	35	6.79	2.565			because noise
	40	2.78						was continuous
	45	3.13	45	6.805	2.58.			
	50	3.47						
	55	3.82	55	6.81	2.585			
9.05	~~1 hour~~	~~4.17~~	65	6.86	2.635			
9.20	~~1¼~~	~~5.21~~	80	6.90	2.675			
9.35	~~1½~~	~~6.25~~	95	6.91	2.685			
9.50	~~1¾~~	~~7.29~~	110	6.94	2.715			
10.55	~~[illegible]~~	~~[illegible]~~	170	[illegible]	[illegible]			

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of Ireland

AQUIFER TESTS
WATER LEVEL
MEASUREMENTS

page..2..

Pumping.

Borehole name..IRONHILLS.......... No....2..... County....T.L............. 6" sheet no..51....

Time	Elapsed time	Days		Water level	Draw-down	Meter reading	Q	Remarks (i.e. pump behaviour, water temp, water quality etc)
GMT/ BST	Mins/ Hours			M	M			
10.58	~~2½~~	—	178	6.98	2.755			
11.05	~~3~~	1.25 +5	185	7.11	2.885			Change pumping
11.35	3½	1.46 +5	215	7.12	2.895			rate to steady 28,000
12.05	4	1.67 +5	245	7.16	2.935			11.25 → 7.2 2.975
13.05	5	2.08 +5	305	7.21	2.985			
14.05	6	2.5 +5	365					
15.05	7	2.92 +5	425	7.25	3.025			
16.05	8	3.33 +5	485	7.28	3.055			
	9	3.75 +5						
	10	4.17+5						DRAWDOWN
20.25	12	5.0 +5	745	7.26.	3.035			21.00 → 7.20. 2.975.
	14	5.83						(750)
	16	6.67						
	18	7.5						
	21	8.75	—					
8.10	24	1.0 x 10^0	1450	7.57	3.335		(1505)	9.05 → 7.565. 3.34
	27	1.125					(1562)	10.02 → 7.59 3.365
14.05	30	1.25	1810				(1835)	14.25 → 7.73? 3.505
20.05	36	1.5	2165	7.72	3.495		(1885)	15.25 → 7.73 Difficult to read
	42	1.75					(2036)	17.56 → 7.74 3.515
	48	2.0					(2104)	19.04 → 7.75. 3.525.
	54	2.25						
	60	2.5						
	66	2.75						
	72	3.0						
		3.5						
		4.0						
		4.5						
		5.0						
		6.0						
		7.0						
		8.0						
		9.0						
		10.0						

Other remarks

Temperature and Conductivity

[illegible]HT	Temp °C	Conductivity µS x10^3	Borehole	River	Comments
			Placed into Borehole		
[illegible].45	10.5	5.2	✓		
[illegible].00.	10.5	5.2	✓		
[illegible].55.	10.5°	5.2	✓		
11.25	10.5°	5.2.	✓		
			Placed into River.		
[illegible]3.50.	13.8°	2.18		✓	
14.22.	14°	2.18		✓	
15.24	12.75°	2.6.		✓	
15.47	14.97°	2.6		✓	
16.52.	13°	2.63		✓	

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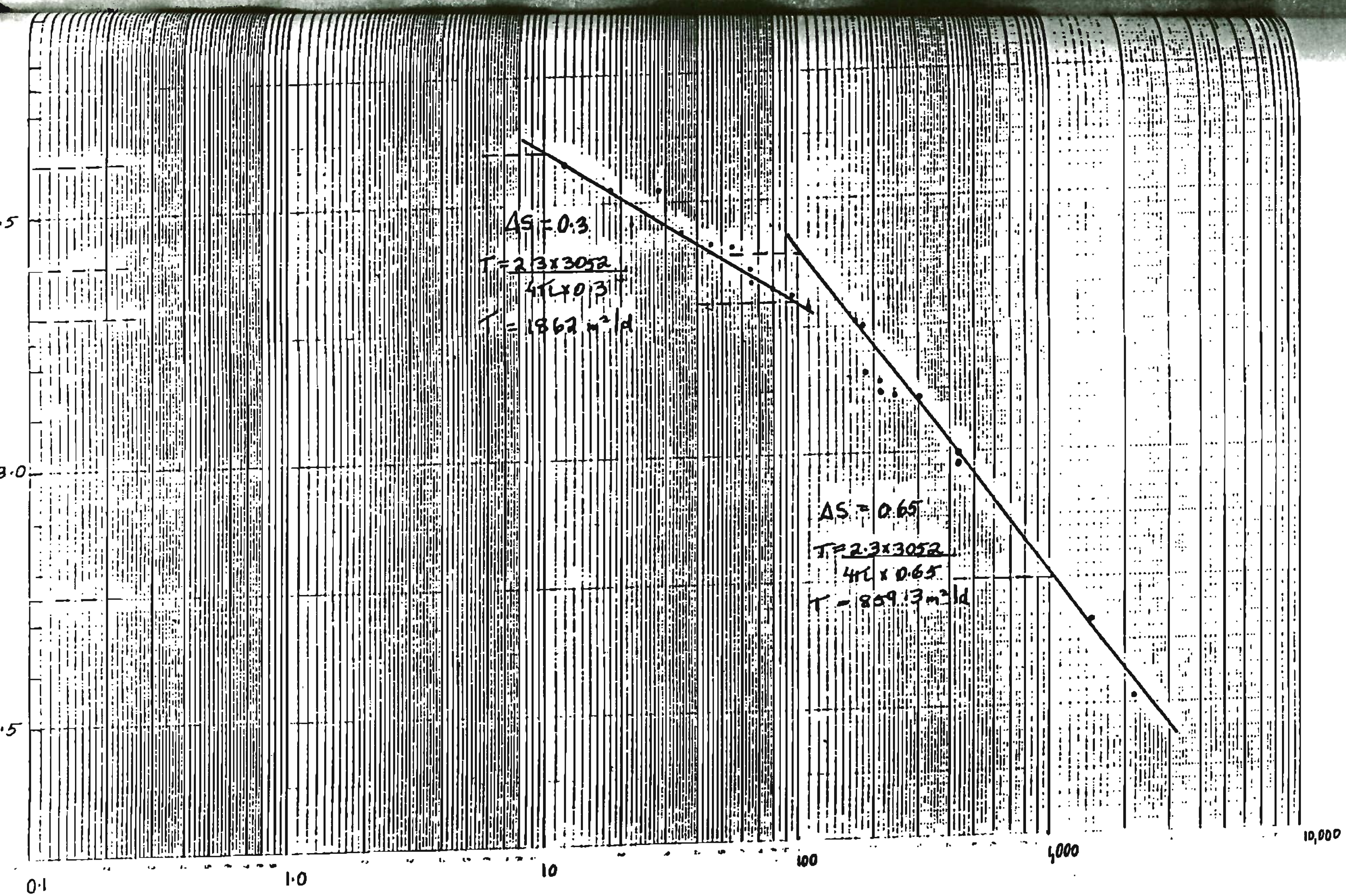
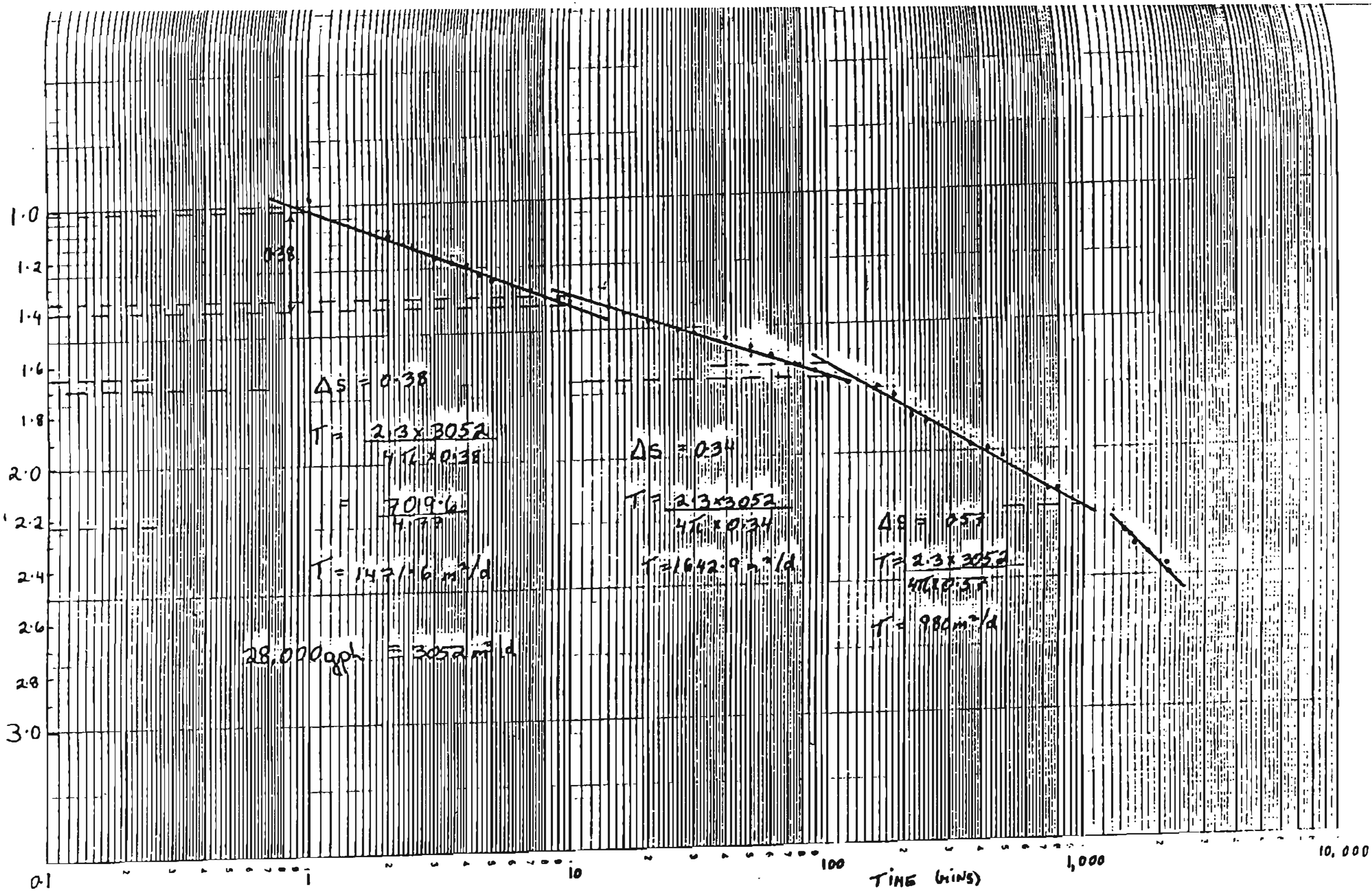
PERIODIC WELL
MEASUREMENTS

Temperature + Conductivity Measurements

GMT	Temp °C	Conductivity $\times 10^2 \mu S$	Borehole	River	
	10°	5 μS	✓		
11.05	10°	5.00	✓		
11.10	10.5°	5.05	✓		
11.27	10.3°	5.07	✓		
			Placed into river at 11.40		
11.45	11.2°	2.1		✓	30m upstr from BH2
11.55	11.4°	2.1		✓	
12.15	11.6	2.1		✓	
12.35	12.0	2.1		✓	
12.45	12.2.	2.1		✓	
			Placed in Borehole at 12.50		
13.03	10.2°	5.09	✓		
13.30	10.2°	5.09	✓		
13.45	10.2°	5.09	✓		
14.00	10.2°	5.09	✓		
			Placed into River at 14.0		
14.45	13.2°	2.1		✓	
			Placed into Borehole 15.3		



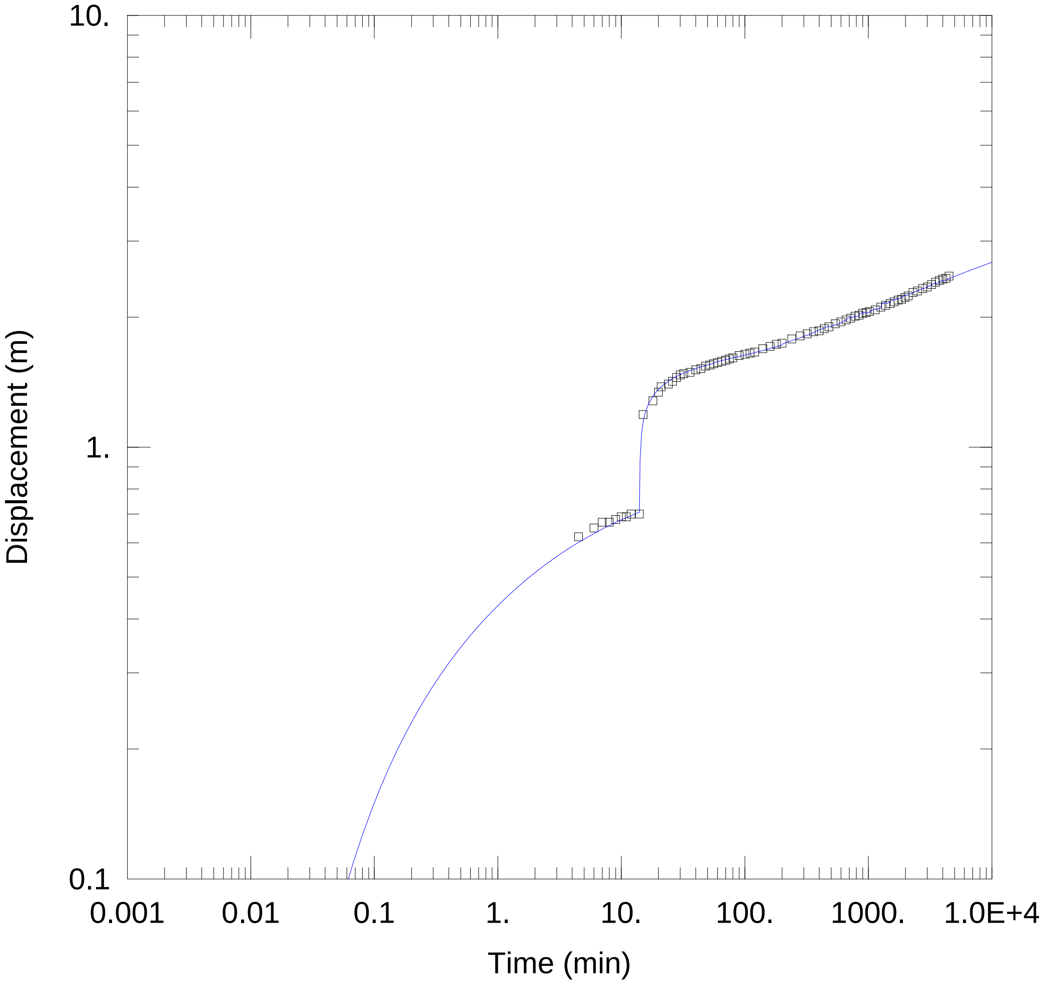
ΔS = 0.3
T = 2.3 x 3052 / 4π x 0.3
T = 1862 m²/d
ΔS = 0.65
T = 2.3 x 3052 / 4π x 0.65
T = 859.13 m²/d
0.1
1.0
10
100
1,000
10,000
.5
3.0
.5



1·0
1·2
1·4
1·6
1·8
2·0
2·2
2·4
2·6
2·8
3·0
0·38
Δs = 0·38
T = 2·3 x 3052 / 4π x 0·38
= 7019·6 / 4·77
T = 1471·6 m²/d
28,000gph = 3052m³/d
Δs = 0·34
T = 2·3x3052 / 4π x 0·34
T = 1642·9 m²/d
T = 2·3 x 3052
T = 980m²/d
0·1
1
10
100
1,000
10,000
TIME (MINS)

APPENDIX F

Test Pumping Results – South Tipperary County Council



WELL TEST ANALYSIS

Data Set: C:\...\Ironmills 1987.aqt
Date: 10/10/12 Time: 21:43:32

PROJECT INFORMATION

Company: CDM Smith
Client: EPA
Location: Ireland
Test Well: BH2
Test Date: 1987

AQUIFER DATA

Saturated Thickness: 17. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BH2	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ BH1	2	0

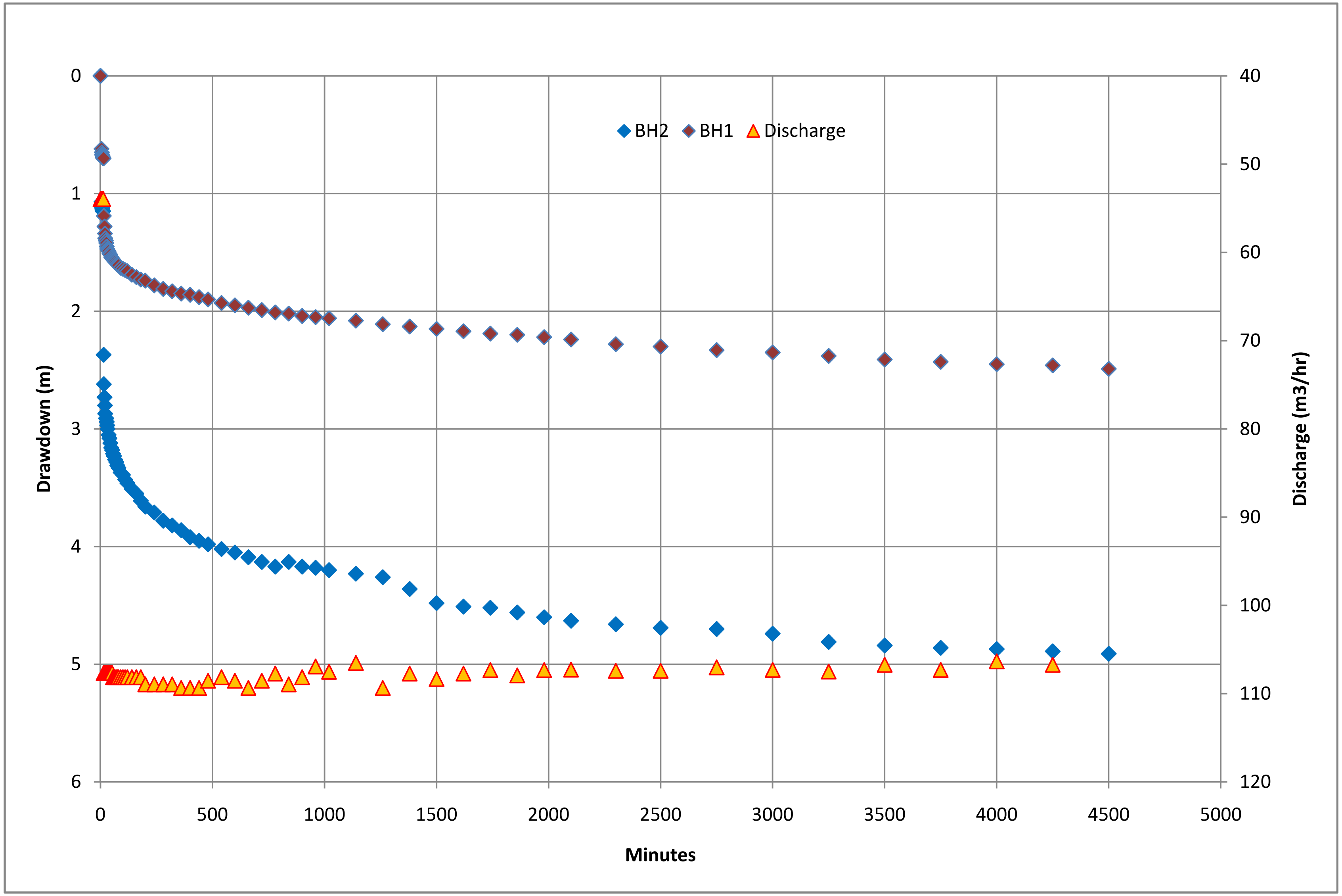
SOLUTION

Aquifer Model: Unconfined

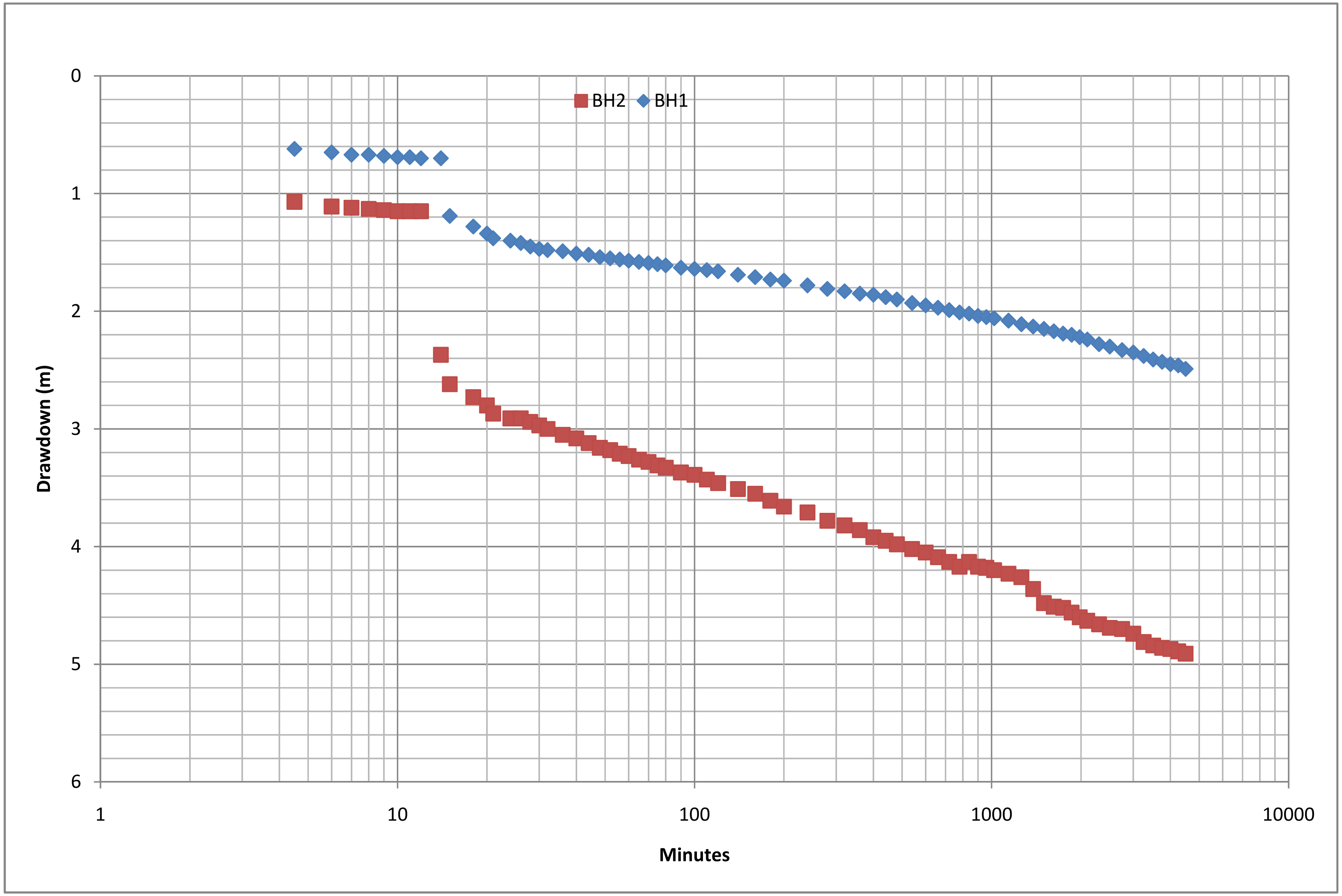
Solution Method: Neuman

T = 714. m^2/day
Sy = 0.2207

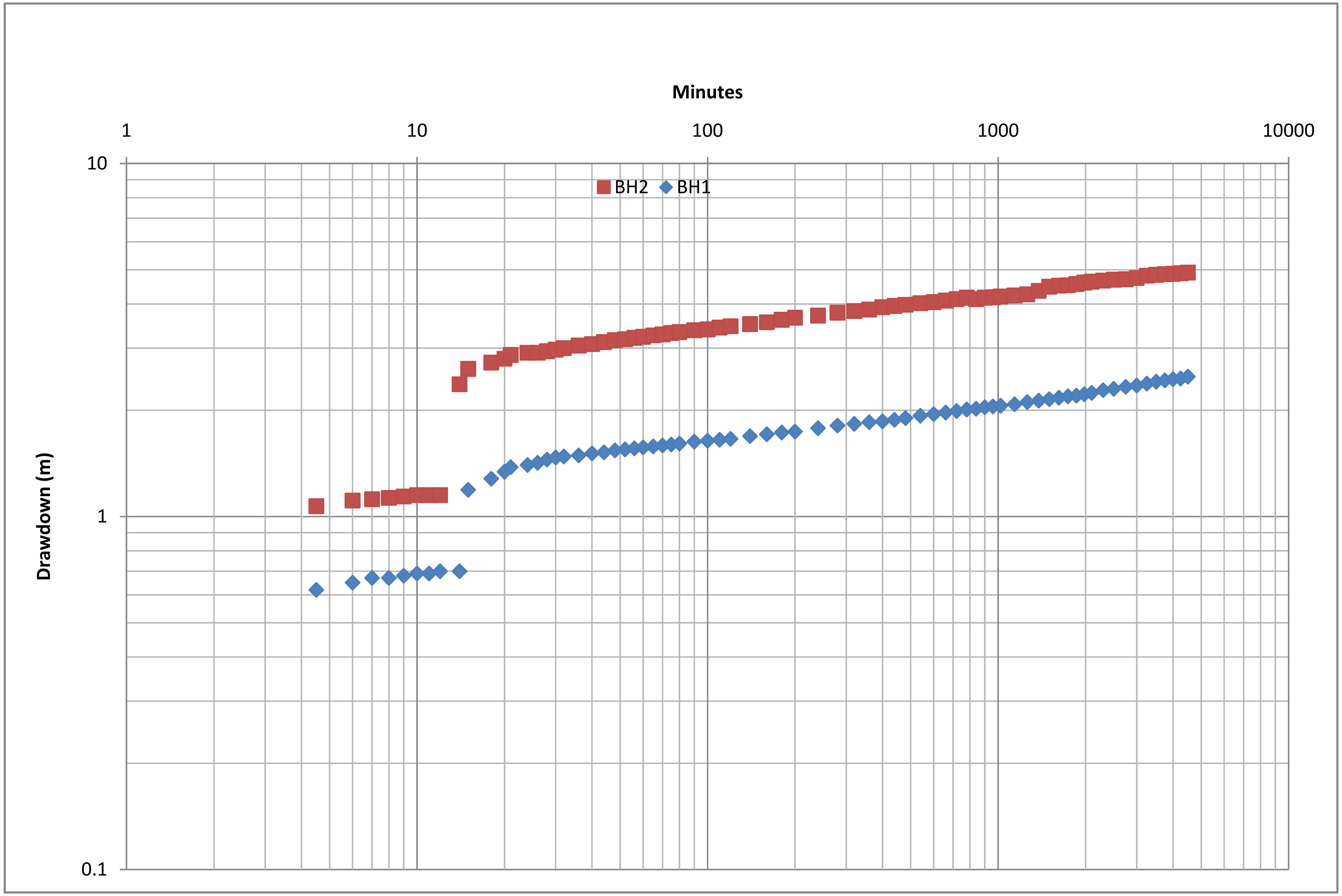
S = 0.01186
ß = 0.001407



BH2
BH1
Discharge
Drawdown (m)
Discharge (m3/hr)
Minutes
0
1
2
3
4
5
6
40
50
60
70
80
90
100
110
120
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000



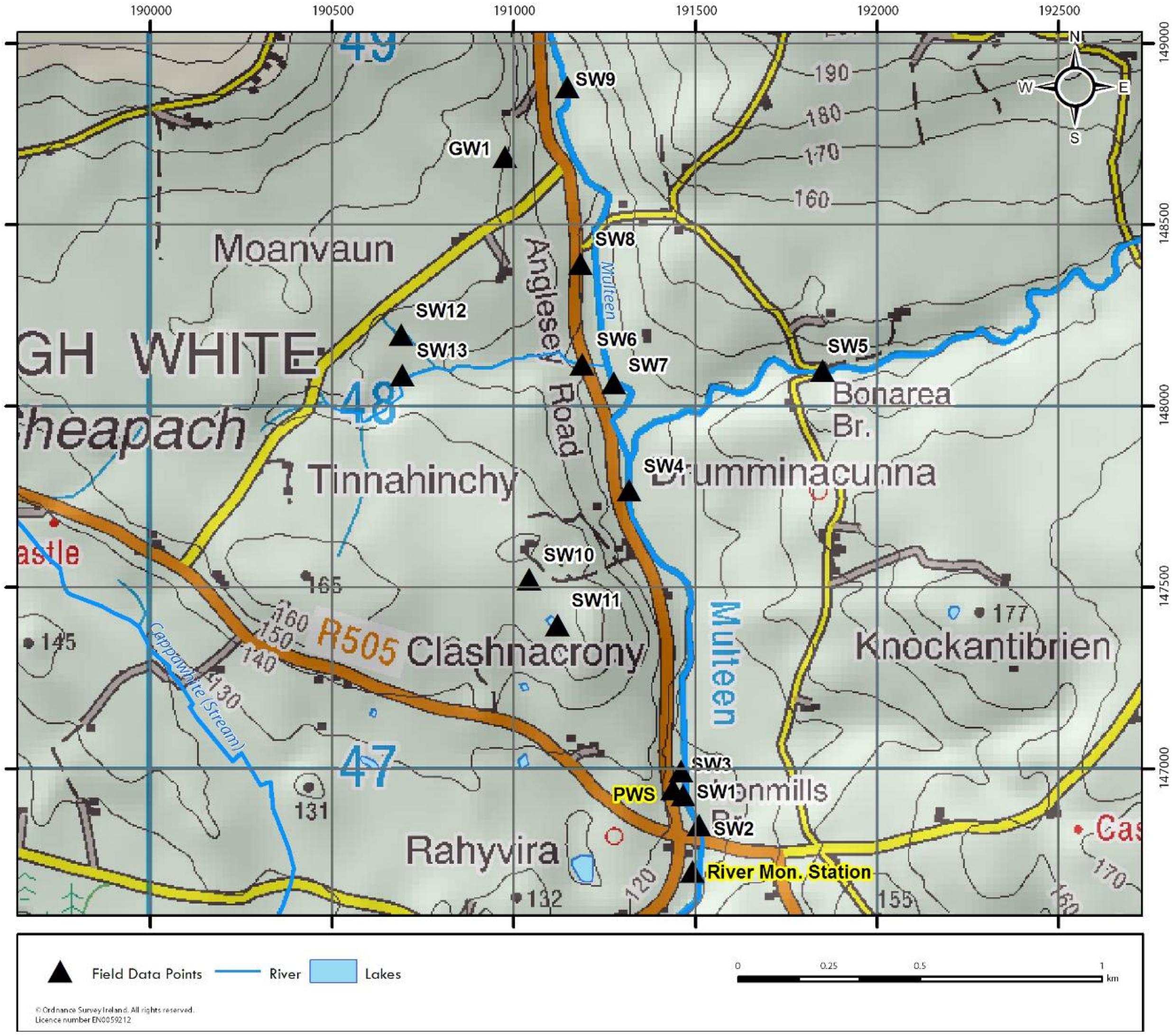
BH2
BH1
Drawdown (m)
0
1
2
3
4
5
6
1
10
100
1000
10000
Minutes



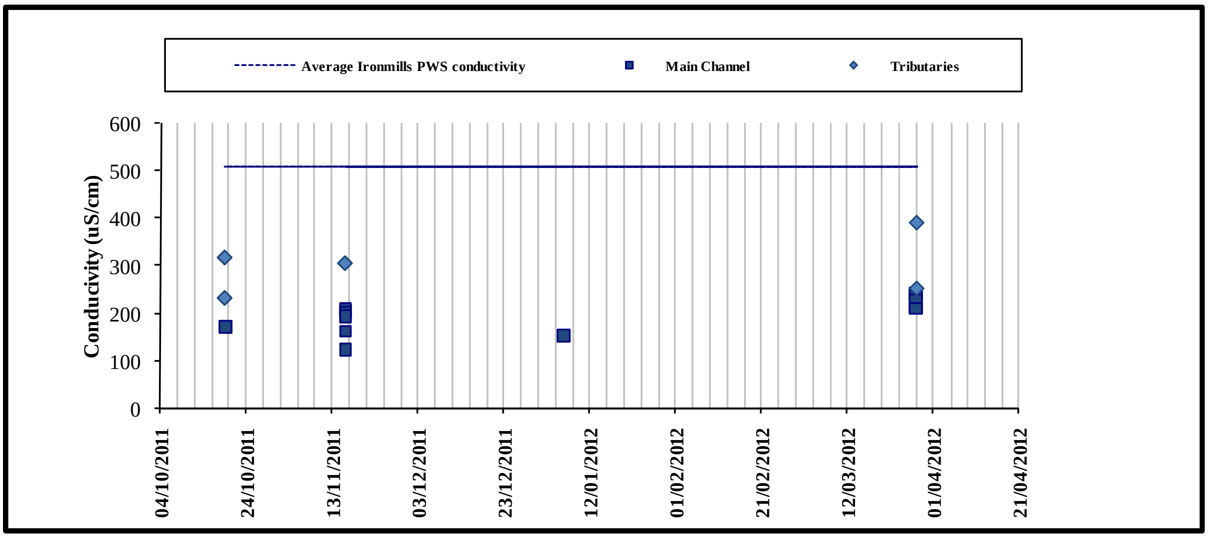
Minutes
1
10
100
1000
10000
10
1
0.1
Drawdown (m)
BH2
BH1

APPENDIX G

Water Quality – Field Measurements



Surface Water Measurement Locations – pH, EC



Field Electrical Conductivity - Surface Water

Groundwater and Surface Water Quality

	Location	Date	pH		Conductivity (µS/cm)		Data source
PWS	**On site**	2007-2010	Ave 7.4	Range: 7.1-8.5	Ave 510	Range: 372-735	EPA Monitoring
River Mon. Station	**Multeen River at Ironmills Bridge**	2001-2006	Ave 8.2	Range: 7.5-9.1	Ave 210	Range: 126-279	LA Monitoring
Surface Water	**SW1**	06/01/2012	7.57		152		Field Monitoring
	SW2	16/11/2011	7.82		204		
		28/03/2012	8.27		237		
	SW3	16/11/2011	7.84		207		
		28/03/2012	8.14		241		
	SW4	16/11/2011	7.81		202		
		28/03/2012	8.29		225		
	SW5	19/10/2011	-		170		
		16/11/2011	7.9		208		
		28/03/2012	8.45		254		
	SW6	16/11/2011	7.9		307		
		28/03/2012	8.32		392		
	SW7	16/11/2011	7.9		202		
	SW8	16/11/2011	7.7		193		
		28/03/2012	8.32		209		
	SW9	16/11/2011	7.8		192		
		28/03/2012	8.32		209		
	SW10	16/11/2011	6.2		162		
	SW11	16/11/2011	6.8		123		
	SW12	19/10/2011	-		234		
	SW13	19/10/2011	-		319		
Boreholes/ Wells	**PWS**	06/01/2012	7.1		497		
	GW1	19/10/2011	-		310		