Two-Mile-Borris Water Supply Scheme

Groundwater Source Protection Zones

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1. Introduction

The objectives of this report are:

- To delineate source protection zones for the Two-Mile-Borris Water Supply sources.
- To outline the principal hydrogeological characteristics of the area.
- To assist North Tipperary County Council in protecting the water supplies from contamination.

2. Location and Site Description

The water source is a borehole in the townland of Borris, at a T-junction in the middle of Two-Mile-Borris village, some 7 km east of Thurles. There is a pump house. The borehole is pumped on demand; there is no storage.

The water is chlorinated.

3. Summary of Well Details

GSI no.	2015SEW199
Grid ref. (1:25,000)	21962 15793
Townland	Borris
Owner	North Tipperary County Council
Well type	Borehole
Elevation (top of casing)	approximately 121.24 m OD
Depth and screening	28.7 m, open interval unknown (presumed 5 – 28.7 mbgl)
Diameter	8" (200 mm)
Depth-to-rock	unknown, but is less than 3m very close to the borehole, both east and west
Recovered water level	approximately 113.87 m OD (7.37 m bgl)
Drawdown	1.2m (PWL about 8.57 m bgl at a pumping rate of 280 m^3/d)
Hours pumped per day	13 to 14
Daily Abstraction	120 m^3/d (26,400gal/d)
Abstraction rate	218 m3/d (2000 gal/hr)
Pumping test summary	(i) Average abstraction rate: 268 m^3/d ("constant" rate test, 13 July 2001) (ii) Specific capacity: 233 m^3/d/m (after 240 minutes pumping) (ii) Transmissivity: 283 m^2/d (Logan approximation) 338 m^2/d (Jacob analysis)

4. Methodology

Desk study

Bedrock geology information was compiled from the GSI Geology 1:100,000 Sheet 18 (Archer *et al*, 1996) and subsoils were compiled from. Basic public supply well details were obtained from GSI records and County Council personnel; such details include borehole depth, elevation, abstraction rate, and pumping test details.

Site visits and fieldwork

The second stage comprised site visits and fieldwork in the area. This included a walkover survey in order to further investigate the subsoil and bedrock geology, the hydrogeology, the vulnerability to contamination and potential hazards. Water samples were taken for analysis in the State Laboratory. Four continuous-flight auger holes were bored to ascertain the depth to bedrock in the area. A pumping test was conducted on 13/7/2001. The duration of pumping (4 hours 55 minutes) was limited by the pump cutting out.

Data analysis

The assessment stage utilised analytical equations and hydrogeological mapping, supported by a simple computer model, to delineate protection zones around the public supply well.

5. Topography and Surface Hydrology

The source lies within the catchment of the Black River, which is located about 350 m west of the site. The river flows roughly northwards to join the Drish River about 1700 m north of Two-Mile-Borris. The Drish then flows west to join the Suir just south of Thurles.

6. Geology

6.1 Bedrock Geology

The bedrock geology of the area comprises sediments of Carboniferous age (about 350 million years old) which were subsequently faulted. The rock units of the area, which are shown in Figure 1, are summarised below.

Table 1: The bedrock geology in the vicinity of Two-Mile-Borris WSS

Rock Formation	Rock Material	Thickness	Occurrence
Durrow (DW)	Fossiliferous coarse limestone with shales, oolites, and some fine grained limestone	c. 200m	To the west of Two-Mile-Borris
Aghmacart (AG)	Very dark grey fine grained muddy limestones, some dark grey shales	c. 200m	At the borehole and to the east of Two-Mile-Borris
Crosspatrick (CS)	Pale grey fossiliferous coarse grained limestone with much chert and some grey shale	Up to 60m	c. 1km east of Two-Mile-Borris

6.1.1 Geological Structure

The site lies on the southeastern side of a syncline (V-shaped fold) which runs SW-NE between Two-Mile-Borris and Thurles. The rocks dip northwest at a fairly low angle (up to 15^{o}). At its closest point, the northeast-southwest trending boundary between the Durrow (DW) and Aghmacart (AG) Formations is about 250m to the northwest. Similarly, the boundary between the Aghmacart (AG) and Crosspatrick (CS) formations is approximately 750 m southeast. The nearest mapped fault to the site is about 1.2 km south east, and trends northeast-southwest (Figure 1).

6.2 Subsoils (Quaternary) Geology

The subsoils in the vicinity of the source and its zone of contribution are comprised of glacial deposits, with some possible fluvioglacial deposition, and some post-glacial peats. The soil compositions are influenced by the underlying limestone rock type. The characteristics of each category are described briefly below.

6.2.1 Limestone Till

Auger-hole drilling by the GSI determined the glacially-deposited subsoils in the vicinity of Two-Mile-Borris WSS to be gravelly and silt/clay (Figure 2). Teagasc (1993) assign the topsoils in this area to the 'Patrickswell Series'. This soil type is characteristically well drained and hence moderately permeable.

6.2.2 Sands & Gravels

Auger hole drilling by the GSI determined sand and gravel as comprising the subsoil cover in the vicinity of two of the four auger holes (TNTW1 and TNTW3, see Figure 3), 190 m west and 380 m northeast of the source (Figure 2). It is likely that some of the sands and gravels were deposited by fluvioglacial processes. These deposits are moderately to highly permeable.

6.2.3 Peat

Peat deposits are mapped by Teagasc (1993) as occupying a small area around the Black River about 600 m north of the borehole; peaty soil was observed in auger hole TNTW2 (Figure 2 and Figure 3). Teagasc (1993) assess that the peat has a fen origin, which implies a high water table. Peat deposits would usually be considered as having low permeability.

6.3 Depth-to-rock

The depth to rock is known at selected localities from a drilling programme undertaken for this study by the GSI to ascertain the thickness and type of the subsoils. The locations of the four auger holes are shown on Figure 2, and the logs are summarised in Figure 3. Measured depths to bedrock range from 2.2 to 5.3 m.

7. Hydrogeology

7.1 Data availability

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

- Hydrogeology

  Data such as flows, and water levels in the public supply and local boreholes were gained from Co. Co. personnel, and collected by the GSI as part of this study.

- Hydrochemistry/water quality

  GSI targeted sampling (August 2000)

  EPA (March 1997 and in press)

  County Council analyses of Public supplies (1990 – 1999)

7.2 Rainfall and Recharge

Rainfall data for the area were obtained from Met Éireann. The mean annual rainfall (R) for the area (1961-90) was 946 mm. Potential Evaporation (PE) is estimated from a Met Éireann national contoured map as 506 mm/yr. Actual evapotranspiration (AE) is estimated by taking 90% of the potential figure, to allow for soil moisture deficits, as 455 mm/yr. Using these figures, the potential recharge (R - AE) is taken as approximately 491 mm. Runoff is assumed to be 20% of available recharge, i.e. 172 mm. This assumption is an empirical standard used in GSI for very thin subsoil/outcrop areas and permeable, sand & gravel subsoils of the type which dominate the area around the site. In deriving this value, we also take into consideration the roads and building development, and the presence of lower permeability subsoils in the vicinity. These calculations are summarised below:

Average annual rainfall	946 mm

Estimated P.E.	506 mm
Estimated A.E. (90% P.E.)	455 mm
Potential recharge	491 mm
Surface Runoff	98 mm
Recharge	393 mm

7.3 Groundwater levels

Water level data were obtained during well surveys carried out in the area in July 2001. The non-pumping water level at the public supply borehole was about 113.87 m OD; the water level in a hand pump about 110 m along the road to the west was 116.07 m OD. A private supply to Murphy's pub comes from a borehole about 50 m to the southwest of the Two-Mile-Borris source. It was not possible to obtain a true static water level reading in this borehole (as the borehole is pumped on demand). However, a water level of 115.65 m OD recorded early in the morning on 13 July 2001 is probably representative of the static water level at this location.

7.4 Groundwater Flow Directions and Gradients

The water table in the area is assumed to broadly reflect topography with groundwater flowing toward and discharging into the Black River, in a general west-northwesterly direction. The natural hydraulic gradient in the area is assumed to be a very subdued reflection of the topography, and is estimated from groundwater level data and surface hydrological features to average 0.0025.

7.5 Hydrochemistry and Water Quality

Field measurements indicated an electrical conductivity of 740 μS/cm and a temperature of 10.8^{o}C. Results of laboratory analysis of water samples are presented in Appendix 1.

The following key points have been identified from the data:

- The groundwater samples indicate a Calcium - Bicarbonate (Ca - HCO_3) hydrochemical signature.
- The groundwater is 'excessively hard' (total hardness 375 mg/l as $CaCO_3$).
- Nitrate concentrations range between 16.1 and 53.5 mg/l (as NO_3), with an average concentration of 33.4 mg/l (9 samples) over the period January 1989 to August 2000. As far as is measured, nitrate levels have breached the EU MAC (maximum admissible concentration) once, and exceeded the GSI threshold seven times.
- A single chloride measurement recorded a concentration of 26.6 mg/l. Chloride is a constituent of organic wastes and (away from coastal areas) levels higher than 25 mg/l may indicate contamination, and higher than 30 mg/l usually indicate significant contamination. The chloride level, in consideration with other parameters, indicates that groundwater contamination has taken place.
- Significant faecal contamination of the source in the period January 1990 to August 2000 has been detected by bacteriological sampling once (of 3 samples). In the same period, general coliforms were detected on five occasions (out of 9 samples).
- One potassium:sodium (K:Na) ratio of 0.25 can be calculated from the available data. The K:Na ratio is used to help indicate (along with other parameters) if water has been contaminated and a ratio of >0.4 may indicate contamination. To provide sufficient data to assess the source, it should be measured routinely in the future.
- Iron concentrations were below the method detection limit (MDL) of 0.05 mg/l in seven out of eight samples taken. Manganese concentrations were below the MDL of 0.02 mg/l in all six samples.

The borehole has a history of occasional contamination after heavy rainfall. Nitrate levels give cause for concern but have come down from an unacceptable level in 1990-1991 to a more acceptable level at present.

7.6 Aquifer Parameters

To estimate the aquifer parameters of the Aghmacart Formation (AG) in the vicinity of Two-Mile-Borris WSS, a constant rate pumping test was conducted by GSI on 13/7/2001. Pumping for 295 minutes at an average rate of 268 m^3/d was followed by water level recovery monitoring for 110 minutes.

Two different analysis methods were applied to the data. The 'Logan approximation' (Logan, 1964) requires only one overall pumping water level plus the pumping rate. The Jacob analysis method (Cooper & Jacob, 1946) is used to analyse the variation of water level with time in the pumping well during water level recovery. Because the pump rate was highly variable during the test, the aquifer storage and transmissivity could not be calculated from the pumping phase of the test.

As can be seen from the values listed in Table 2, estimated permeabilities range between 14 and 16.9 m/d. The pumping test results indicate that the permeability around the borehole may be higher than this, and also that a low permeability boundary is intercepted by the cone of depression.

A permeability of 15 m/d, estimated from the test in the public supply borehole, is assigned to the Aghmacart Formation aquifer. Effective fracture porosity, estimated from regional experience, is 0.02 (2%).

Table 2: Estimated aquifer parameters for the rock units at Two-Mile-Borris WSS

Parameter	Data source	Aghmacart Formation parameter values
Permeability *	405 minutes pumping test Pumping well (GSI)	
	• Jacob analysis of recovery	16.9 m/d
	• Logan approximation	14 m/d
Porosity	Estimated from regional experience	0.02
Hydraulic gradient		0.0025 (0.25%)

*An aquifer thickness of 20 m is assumed to compute permeability from estimated transmissivities.

7.7 Aquifer Category

Overall in North Tipperary, the Aghmacart Formation, which is understood to be the aquifer beneath the site, is classified as a 'bedrock aquifer which is moderately productive only in local zones' **(Ll)**. However, it is clear from the well performances at Two-Mile-Borris that the yields and aquifer properties are good in this location.

7.8 Conceptual Model

The Two-Mile-Borris WSS borehole draws water from the Aghmacart Formation, a limestone 'bedrock aquifer which is moderately productive only in local zones' **(Ll)**.

The permeability in the aquifer depends on the development of faults, fissures and fractures, as indicated by pumping tests and site investigations, in addition to regional experience.

The GSI pumping test indicates that the permeability is high. It also identifies a low permeability region or other barrier to flow. An artificial flow barrier could arise from building foundations/cellars in the vicinity. It is not possible to determine in which direction this barrier lies.

The water level in the handpump 130 m to the west of the borehole was monitored during the pumping test. The water level remained unchanged, indicating that the cone of depression did not reach this location because of either (a) a flow barrier between it and the pumping borehole, and/or (b) that the downstream limit of the cone of depression does not extend this far. From analytical and numerical modelling (Section 8.2), it seems that the cone of depression does not naturally extend as far as the handpump.

The bedrock aquifer is overlain by low-moderately permeable till that is less than 3m thick in the immediate vicinity of the public supply well. The borehole is situated in the middle of a developed area, which is paved and built up. The groundwater level is about 7.5 m below ground level, suggesting that the aquifer is unconfined over much of the area.

The presence of boggy land in the area to the northwest of the site around the river indicates that the water table is very close to ground level in this vicinity.

The groundwater flow in the area broadly reflects topography, flowing west-northwestward towards the Black River. The natural hydraulic gradient is about 0.0025 (0.25%).

8. Delineation of Source Protection Areas

8.1 Introduction

Two source protection areas are delineated:

- Inner Protection Area (SI), designed to give protection from microbial pollution.
- Outer Protection Area (SO), encompassing the remainder of the zone of contribution (ZOC) of the well.

8.2 Outer Protection Area

The Outer Protection Area (SO) is bounded by the complete catchment area to the source, i.e. the zone of contribution (ZOC), which is delineated 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 rock permeability and (d) the recharge in the area. The ZOC is delineated as follows:

i) An estimate of the area size is obtained by using the average recharge and the abstraction rate.

ii) To allow for errors in the estimation of groundwater flow direction and to allow for an increase in the ZOC in dry weather, a safety margin is incorporated by assuming a higher abstraction rate than the current rate.

Average daily abstraction from the site is 120 m^3/d, at a pumping rate of 218 m^3/d. The pumping rate is used as a daily rate for the following reasons:

- to allow for increased water demand due to expansion.
- to allow for an increase in the ZOC during dry weather.

Taking the recharge to be 393 mm as indicated in Section 7.2, the area required to supply a pumping rate of 218 m^3/d is calculated to be 0.2 km^2 (20 ha). This compares with an area of 0.25 km^2 (25 ha) defined analytically, numerically and on the basis of topography and surface drainage patterns, as described below.

The boundaries of the ZOC are illustrated in Figure 5 and are delineated as follows:

Northwestern boundary: defined by the 'null point', i.e. the downstream limit of the cone of depression under pumping conditions. This can be estimated by:

$$X_L = Q/(2\pi K.b.i.)$$ where

Q = pumping rate, K = permeability, b = aquifer thickness and i = hydraulic gradient.

If Q = 218 m^3/d, K = 15 m/d, b = 20m, and i = 0.0025, then $\mathbf{X_L = 46\ m}$.

Northeast/Southwest Boundaries: these boundaries are defined using the corresponding equation to determine the lateral limits of the water entering the well:

$Y_L = \pm Q/(2K.b.i.)$ where the symbols are as above.

If Q = 218 m^3/d, K = 15 m/d, b = 20m, and i = 0.0025, then $\mathbf{Y_L = \pm 145\ m}$.

The lateral (Y_L) boundaries are modified to take account of the influence of topography on groundwater flow directions (i.e., groundwater divides).

Southeastern Boundary: is defined by the upstream limit of influence of the pumping well and by local topography (groundwater divide).

These boundaries are based largely on topography, our current understanding of groundwater conditions in the area and on the available data. The boundaries defined by the analytical equations above are in good agreement with a computer simulation of the aquifer.

8.3 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100 day time of travel (TOT) from a point below the water table to the source, and is delineated to protect from potentially contaminating activities which may have an immediate influence on water quality at the source, in particular from microbial contamination (Figure 5). The 100-day ToT is estimated as follows:

Taking the permeability as 15 m/d, Hydraulic Gradient as 0.0025, and Effective Porosity as 0.02, the groundwater flow velocity is estimated as 1.875 m/day (15 x 0.0025/0.02), so the 100-day travel time distance is approximately 188 metres.

The Inner Protection Zone has an area of 0.05 km^2 (5 ha). All of the ZOC downstream of the borehole falls within the Inner Protection Zone. Upstream (east and south) of the borehole, approximately 16 % of the ZOC falls within the Inner Protection Zone (SI).

9. Groundwater Vulnerability

Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities. It depends on the thickness, type and permeability of the subsoils. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes (GWPS) document (DoELG/EPA/GSI, 1999).

Areas of rock outcrop and where rock is less than 3m from the surface are rated ‘Extreme’ vulnerability. Where subsoil thickness is between 3 and 10 m thick, aquifer vulnerability ranges between ‘High’ and ‘Moderate’, depending upon the subsoil permeability. No ‘Low’ vulnerability areas are believed to exist.

The groundwater in the areas is considered to be ‘Extremely’ vulnerable over much of the site, with ‘High to Moderate’ vulnerability further away from the well. Vulnerability of groundwater in the area is shown in Figure 5.

10. Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the two elements of land surface zoning (source protection areas and vulnerability categories), i.e. by superimposing the vulnerability map on the source protection area map. Since this is an Interim Groundwater Protection Scheme, in which only the extremely vulnerable areas are delineated, there are a total of only four possible source

protection zones (see the matrix in the table below). Each zone is represented by a code e.g. **SO/E**, which represents an Outer Source Protection area where the groundwater is extremely vulnerable to contamination. There are four groundwater protection zones present around the Two-Mile-Borris source, as shown in Figure 7 and in the matrix below.

Table 3: Matrix of Source Protection Zones

VULNERABILITY RATING	SOURCE PROTECTION	
	Inner	***Outer***
Extreme (E)	SI/E	SO/E
High to Moderate (H-M)	SI/H-M	SO/H-M

11. Land Use and Potential Pollution Sources

The site is at the centre of Two-Mile-Borris village, which lies on the road linking the main Dublin-Cork road (N) with Thurles. Hence possible spillages along this road may constitute the principal hazard to the quality of the water source. Additionally, leaking drains, both storm drains and sewage drains could pose a threat to the aquifer.

There is a petrol pump on the main road about 150 m away from pump house. In addition to risks of spillages whilst filling the subsurface petrol tanks, if the petrol tanks were to rupture a significant potential threat would be posed to the groundwater source.

Otherwise, agriculture is the principal activity in the area. Other hazards include farmyards, septic tank systems, application of fertilisers (organic and inorganic) and pesticides. No detailed assessment of hazards was carried out as part of this study.

12. Conclusions and Recommendations

- The site at Two-Mile-Borris comprises a single borehole, about 30 m deep.
- The area around the supply has 'Extreme' to 'High to Moderate' vulnerability to contamination.
- Contamination of the source has occurred – nitrate and faecal coliform concentrations are both at levels that cause concern.
- The inner and outer 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.
- In addition, chemical and bacteriological analyses of raw water (rather than treated water) should be carried out on a regular basis (every 3 - 6 months)
- Guidelines should be drawn up for dealing with spillages along the roads in the area.

13. References

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Figure 1: Bedrock geology in the Two-Mile-Borris area. Based on Archer *et al.* (1996).

Fig 2 – site map,

Fig 3 – driller logs

Fig 4 - chemistry

Fig 5 – ZOC and TOT map

Fig 6 - vulnerability map

Fig 7 – source PZ

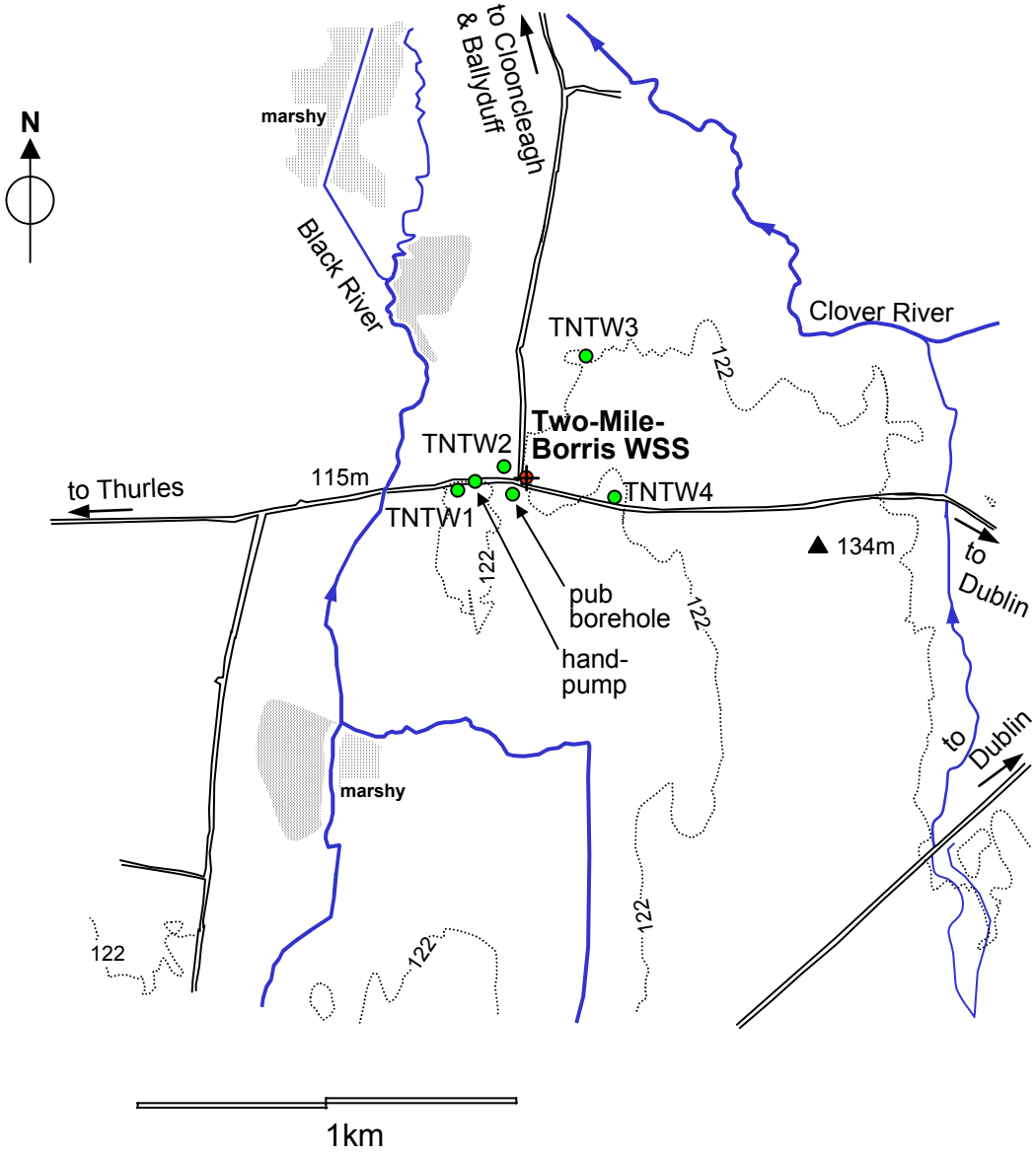

Figure 2: Location map of Two-Mile-Borris WSS borehole.
Showing auger holes drilled by GSI to determine depth to bedrock in the vicinity (TNTW1 to TNTW4) and other hydrogeological features discussed in the text.

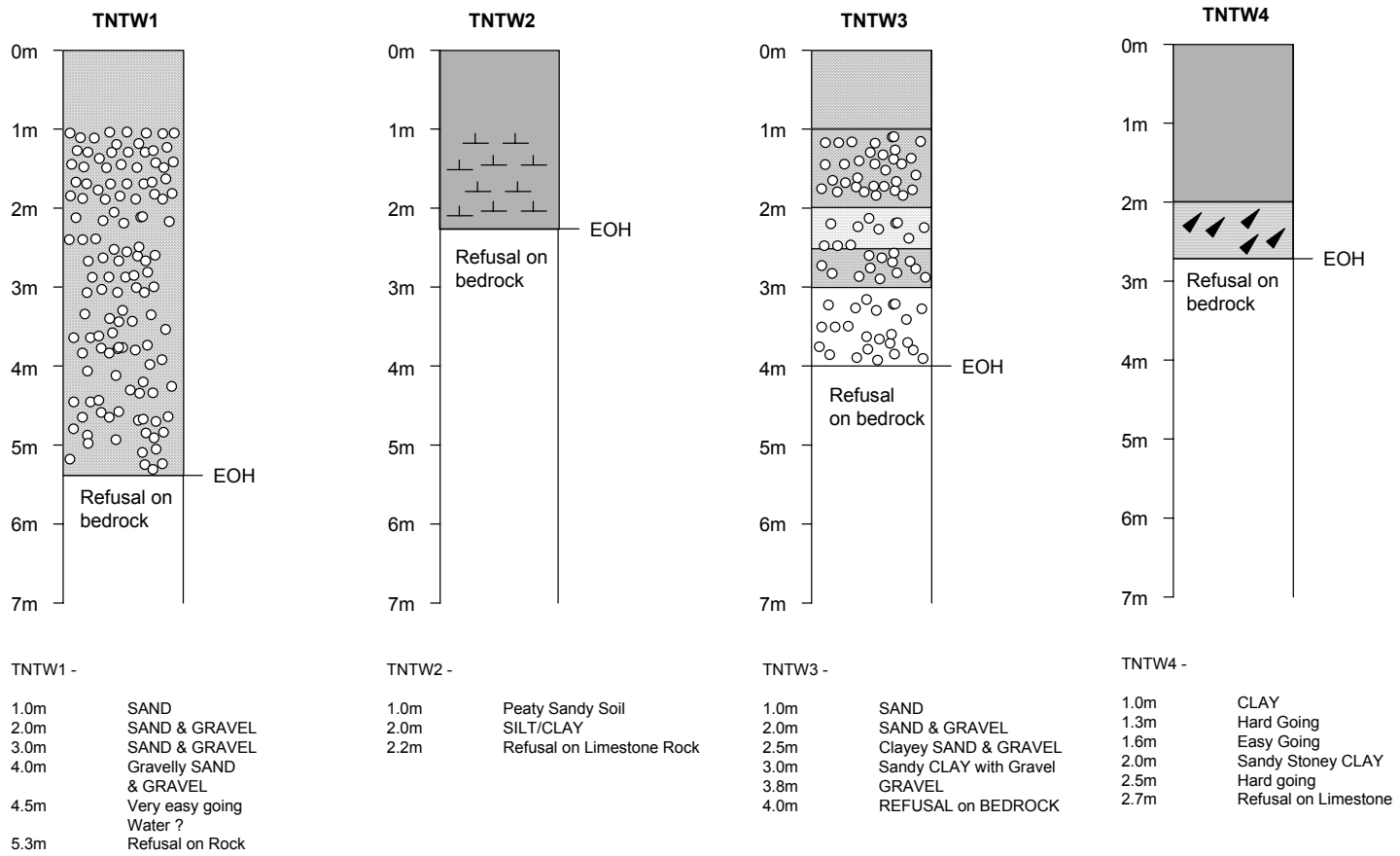

Figure 3: Summary logs and lithological descriptions of auger holes drilled to assess depth to bedrock near Two-Mile-Borris WSS boreholes. See Figure 2 for the locations of the augered holes.

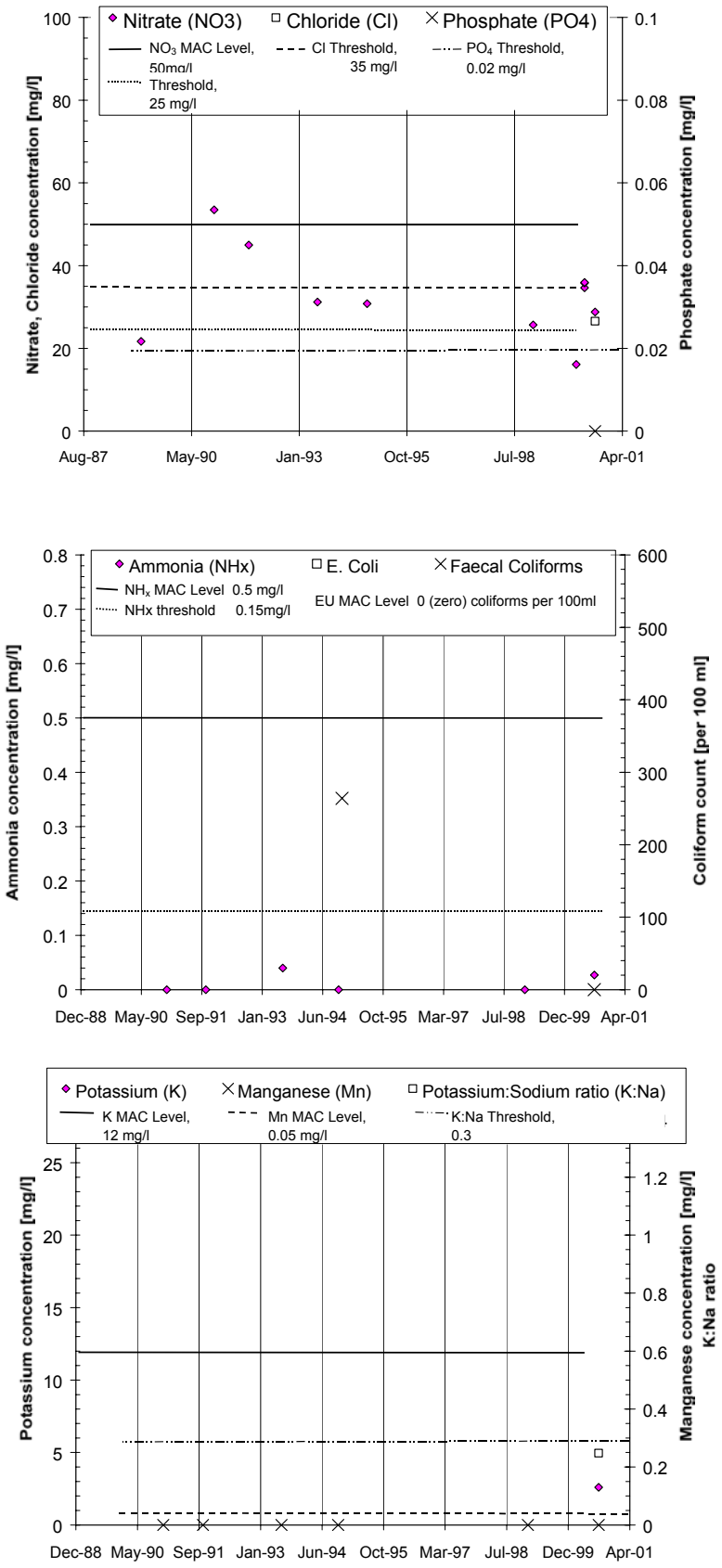

Figure 4: Key indicators of agricultural and domestic groundwater contamination at Two-Mile-Borris WSS

Appendix 1: Laboratory Analyses of Groundwater at Two-Mile-Borris WSS

Parameter	**Results of Laboratory Analyses**															
Laboratory	dwr	North Tipperary Co. Co												dwr		State Lab
Sample treatment		NS?	S	-	NS?	NS?	NS	NS?	-	-	NS?	NS	-			S
Date	24/01/89	05/01/90	27/11/90	03/12/90	06/12/90	21/10/91	05/11/92	02/07/93	20/07/93	24/10/94	02/11/94	22/11/94	12/01/99	15/02/00	03/05/00	09/08/00
EC (µS/cm)				791		796			927	789			1006			709
pH (lab.)				7.3		7.6			7.04	7.2			7.1			
Total Hardness (mg/l $CaCO_3$)																374.7
Total Alkalinity (mg/l $CaCO_3$)																356
Calcium (mg/l)																112.4
Magnesium (mg/l)																22.5
Chloride (mg/l)																26.6
Sulphate (mg/l)																15.7
Sodium (mg/l)																10.5
Potassium (mg/l)																2.6
K:Na																0.25
Nitrate (mg/l NO_3)	21.7			**53.5**		**45.0**			*31.2*	*30.8*			*25.7*	16.1	*35.9*	*28.8*
Iron (mg/l)				0.05		<MDL			<MDL	<MDL			<MDL			<MDL
Manganese (mg/l)				<MDL		<MDL			<MDL	<MDL			<MDL			<MDL
E/F coli per 100 ml.						0						**264**				0
Total coli /100ml		0	6		0	8	18	0			2	280				0
Total Ammonia (mg/l NHx)				<MDL		<MDL			0.04	<MDL			<MDL			0.03
Comments	The borehole has a history of occasional contamination after heavy rainfall. Nitrate levels give cause for concern but appear to be decreasing slightly. Monitoring of water quality parameters should continue.															

Note: **Bold type denotes E.U. MAC exceedances.** *Italic type denotes GSI threshold exceedances* 'NS'/ 'S' denotes Non-source (treated) or Source (raw) water samples