Lorrha Water Supply Scheme

Groundwater Source Protection Zones

Prepared by:

Kevin Motherway, Natalya Hunter Williams & Geoff Wright
Geological Survey of Ireland

In collaboration with:

North Tipperary County Council

April 2002

1. Introduction

The objectives of this report are:

- To delineate source protection zones for the Lorrha Water Supply source.
- 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 site is situated approximately in the townland of Annagh, about 1 km southwest of Lorrha village, County Tipperary, and 2 km east of Lough Derg. The site has a well house and a pump house. The water is chlorinated.

3. Summary of Well Details

GSI no.	1719NEW058	1719NEW065
Grid ref. (1:25,000)	19107 20360	191085 203601
Townland	Annagh	Annagh
Owner	North Tipperary County Council	
Well type	Borehole	Piezometer (observation borehole)
Elevation (top of casing)	35.83 m OD	37.31 m OD
Depth	16.9 m	49 m
Diameter	8" (200 mm)	2" (51 mm)
Open/screened interval	Unknown (assumed 13 – 16.9m bgl)	24 – 49 m
Depth-to-rock	Not recorded, from nearby piezometer probably about 12.5 m.	12.5 m
Static water level	33.31 m OD (pumping test, 21/9/00)	33.81 m OD (21/9/2000) 31.96 m OD (2/6/2000)
Drawdown	4.88 m (21/9/2000) 7.47 m (2/6/2000)	2.03 m (21/9/2000)
Daily Abstraction	280 m^3/d (2930 gph)	
Hours of pumping	21 (on demand)	-
Pumping rate	319 m^3/d (assuming 21 hour pumping duration)	-
Pumping test summary	(i) Average abstraction rate: 355 m^3/d (pump output variable 109 – 392 m^3/d)	-
	(ii) Specific capacity 73 m^3/d/m (after 390 minutes pumping)	-
	(iii) Transmissivity: 64 m^2/d (Jacob analysis) 90 m^2/d (Logan approximation)	-

4. Methodology

Desk study

Bedrock geology information was compiled from Brück (1985) and soils were compiled from Teagasc (1993). Basic 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 of investigation comprised site visits and fieldwork in the area. This included a walkover survey in order to investigate further the subsoil and bedrock geology, the hydrogeology, the vulnerability to contamination and the current pollutant loading. Water samples taken were analysed in the State Laboratory. Five auger holes were drilled by the GSI to investigate depths to bedrock, and a piezometer was installed near to the pumping well to monitor water levels. A short pumping test was carried out in September 2000.

Data analysis

The assessment stage utilised analytical equations and hydrogeological mapping to delineate protection zones around the public supply well.

5. Topography and Surface Hydrology

The source lies within the catchment of a small southwest flowing river that flows into Slevoir Bay, on Lough Derg. The river is located 530 m west of the site. Approximately 800 m to the southwest of the source, the ground adjacent to the river is boggy. To the east, well-drained ground rises steeply in a ridge which the Lorrha - Carrigahorig road follows, and then more gently to a local high point of 78 m OD 1.5 km to the east. Topographic relief between the WSS borehole and the river is 1.6 m, and between the borehole and the hill top is about 42 m. Topographic gradients are about 0.03 to the east of the borehole, and about 0.003 to the west.

In the vicinity of the source, the soils are classified as having limestone till parent material by Teagasc (Finch and Gardiner, 1993). GSI augering reveals subsoils composed of clayey tills, sometimes with cobbles, rock fragments or gravels (see Figure 3).

6. Geology

6.1 Bedrock Geology

The bedrock geology of the area comprises sediments of Lower Carboniferous age (c. 330 million years old) which were subsequently faulted. The rock units of the area, shown in Figure 1, are summarised in Table 1, below.

Table 1: The bedrock geology in the vicinity of Lorrha WSS.

Rock Formation	Rock Material	Thickness	Occurrence
Lorrha Calp (CDlr)	Muddy limestone:	400 m	Underlying the source and much of the surrounding area.
Waulsortian Limestone Formation (WA)	Clean limestone: massive, unbedded micrite.	200 - 300 m	Occurs in small subcrops south west and west of Lorrha WSS, and the high ground to the east/southeast. Probably underlies the source at a fairly shallow depth

6.1.1 Geological Structure

Lorrha WSS is bored into the Lorrha Calp Formation (CDlr) on the northern limb of a gently folded anticline. Bedding dip measured in an outcrop 100 m to the east of the site is 3^{o} to the NE. Waulsortian limestones probably underlie the source at a fairly shallow level.

6.2 Subsoils (Quaternary) Geology

Evidence from GSI auger hole drilling indicates that the subsoils in the area are comprised largely of clayey till deposits containing some gravel to cobble sized rock fragments. Soils in the area, mapped by Teagasc (1993) are described as having a limestone till parent material.

Teagasc (1993) assign the soils in this area to the 'Patrickswell Series'. This soil type is characteristically well drained and hence moderately permeable.

6.3 Depth-to-rock

The depth to rock is known at selected localities from a drilling program undertaken for this study by the GSI to ascertain the thickness and type of the subsoils. The locations of the five auger holes are shown on Figure 2, and the logs are summarised in Figure 3. Depths to bedrock range from 1.0 to 12.5 m. Near the borehole it is about 12.5 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 spring 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 prep.)
  County Council analyses of Public supplies (1989 – 2000)
  EC STRIDE Sub-programme Measure 1 (September 1993)

The hydrochemical data are summarised fully in the accompanying report "An assessment of the quality of public, group scheme and private groundwater supplies in North County Tipperary".

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 900 mm. Potential Evaporation (PE) is estimated from a Met Éireann national contoured map as 500 mm/yr. Actual evapotranspiration (AE) is estimated by taking 90% of the potential figure, to allow for soil moisture deficits, as 450 mm/yr. Using these figures, the potential recharge (R – AE) is taken as approximately 469 mm. Runoff is assumed to be 40% of available recharge, i.e. 188 mm. This assumption is based upon an empirical standard (Wright *et al.*, 1983) used in GSI for poorly-moderately permeable clayey till subsoils of the type which dominate the area around the site. However, the value also takes account of the influence of topography on runoff, of variable but thin subsoil thicknesses, and the drainage pattern. These calculations are summarised below:

Average annual rainfall	919 mm
Estimated P.E.	500 mm
Estimated A.E. (90% P.E.)	450 mm
Potential recharge	469 mm

Surface Runoff	188 mm
Recharge	281 mm

7.3 Groundwater levels

Water level data were obtained during well surveys carried out in the area in September 2000. Water levels (non-pumping and recovered) at the site were as follows:

Pumping well	33.31 m aOD
Piezometer	33.81 m aOD
River level (next to the Annagh road)	34.24 m aOD

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 river that drains Friar's Lough. The natural hydraulic gradient between the borehole and the river (to the west) is estimated to be 0.02 (0.2%) on average, with groundwater flow to the west. East of the borehole, where the ground rises quite steeply, the natural hydraulic gradient is estimated to be approximately 2-3% with flow in a westerly direction.

7.5 Hydrochemistry and Water Quality

Field measurements indicated an electrical conductivity of 750 μS/cm and a temperature of 10.7°C. Results of laboratory analyses of water samples are presented in Appendix 1. Data that reflect water quality are shown graphically in Figure 4. The following key points are identified from the data:

- The groundwater samples indicate a calcium-bicarbonate ($Ca - HCO_3$) hydrochemical signature.
- Groundwater hardness is classed as 'very hard' (total hardness 399 mg/l as $CaCO_3$, one sample).
- Nitrate concentrations are low, ranging between 1.79 and 5 mg/l (as NO_3), with an average concentration of 3.7 mg/l (26 samples) over the period June 1989 to November 2000. The GSI threshold of 25 mg/l was no exceeded in the sampling period. The results are representative of background nitrate levels, and no contamination is indicated.
- The single measured chloride concentration range was 18.4 mg/l (August 2000). Chloride is a constituent of organic wastes and (away from coastal areas) levels higher than 25 mg/l may indicate contamination, and above 30 mg/l usually indicate significant contamination. With one sample, no conclusion can be drawn, except to comment that the concentration falls within acceptable limits.
- Bacteriological sampling indicates no faecal contamination of the source on the one time it was sampled (August 2000). Sixteen total coliform measurements recorded zero count, but 15 of these samples were either non-source (i.e. treated) or of indeterminate source.
- A potassium:sodium (K:Na) ratio of 0.1 can be calculated from the available data. Values significantly higher than 0.4 can indicate organic contamination by slurries.
- Although low K:Na ratios do not guarantee non-contamination, low nitrate and acceptable chloride concentrations, together with no bacteria recorded, indicate that the drinking water is not contaminated.
- Iron levels are generally low or below the method detection limit, but in September 1990 an iron concentration of 0.79 mg/l (almost 4 times the MAC) was recorded. Manganese concentrations frequently exceed the EU Drinking Water Directive maximum admissible concentration (MAC) of 0.05 mg/l (11 times out of 17). On the remaining 6 times the source was tested, manganese concentrations were below the method detection limit (MDL) of 0.002 mg/l. Neither metal is detrimental to health at the recorded concentrations but can cause aesthetic problems and deterioration in well performance.

- At Lorrha, fluoride concentrations are close to the EU MAC of 1 mg/l. This is about the concentration in artificially fluoridised waters. However, it is important to know the amount of fluoride in water used by children to which extra fluoride may be added, since excessive fluoride causes tooth enamel mottling and brittleness.
- The concentration of strontium in August 2000 was 0.465 mg/l. There are no guidelines for strontium, but commonly it occurs with metals like barium, which does have a MAC of 0.5 mg/l.

7.6 Aquifer Parameters

To estimate the aquifer parameters of the Lorrha Calp Formation in the vicinity of Lorrha WSS, a 7 hour pumping test was undertaken by the GSI on 20 September 2000. Different methods were used to analyse the data depending upon the quality of the data. For example, the 'Logan approximation' (Logan, 1964) was applied to data from the pumping phase of the test because the pumping rate was highly variable. The Jacob analysis method (Cooper and Jacob, 1946) is used on the recovery data, assuming an average pumping rate of 355 m^3/d.

As shown in Table 2, permeability estimates range between 4.3 and 6.1 m/d. There are various reasons for the apparent differences:

- Borehole and pumping test factors

  The Logan approximation is based on the assumption that the aquifer has reached a 'steady state' (where the pumped water level, for a constant pumping rate, hardly changes with time). Test data show that the water level was still declining at the end of the test when the pump cut out. The Logan-calculated permeability is, therefore, an upper limit estimate.

  To use the Jacob analysis, the pumping rate should be constant. This was not the case during the test due to circumstances beyond the control of the GSI. Therefore, the permeability result from the analysis is an estimate only.

- Aquifer factors

  The pumping test results indicate that the aquifer has some recharge coming from the overlying subsoils. Early and late time data reflect better the properties of the aquifer. The lower permeability estimates come from early and later times in the pumping test.

Table 2: Estimated aquifer parameters for the rock units at Lorrha WSS

Parameter	Data source	Lorrha Calp Formation parameter values*
Permeability m/d	420 minutes pumping test (GSI) • Jacob analysis of recovery • Logan approximation	 4.3 – 5.9 6.1
Porosity	estimated from experience	0.02
Hydraulic gradient	estimated from topography	0.02 east of production boreholes; 0.002 between well and river.

* Note that for the purposes of estimating permeability from pumping test-derived transmissivities, the aquifer thickness is assumed to be 15 m.

For the reasons outlined above, a permeability of 5 m/d, estimated from the recovery data from the GSI pumping test, is assigned to the Lorrha Calp Formation aquifer.

The pumping test, in addition to allowing permeability estimation, revealed extremely good connectivity between the pumping well and the observation well 12 m away. During pumping, the drawdown in the observation well is always about 2.8 m less than that in the pumping well. However,

after the pumps are switched off, the recovery of the drawdown in both wells is almost exactly simultaneous. This level of connection between wells is indicative of a large fracture, although it does not necessarily imply that the fracture network extends significantly beyond the wells.

7.7 Aquifer Category

The Lorrha Calp Formation (CDlr), from which the borehole draws water, is classified as a Locally Important aquifer (**Ll**). The Waulsortian limestone, which underlies the Lorrha Calp, also is classified in North County Tipperary as a 'Locally important aquifer' (**Ll**).

7.8 Conceptual Model

- The Lorrha WSS borehole draws water from the Lorrha Calp Formation with possible support from the Waulsortian limestone, both 'bedrock aquifers which are moderately productive only in local zones' **(Ll)**.
- The permeability in these aquifers depends on the development of faults, fissures and fractures, as indicated by pumping tests and site investigations, in addition to regional experience.
- To the east, the bedrock aquifers are overlain by poorly to moderately permeable till which is mainly less than 3m thick. There are few drains and surface streams up-gradient from the site, indicating the free draining nature of the thin subsoils and the relatively high permeabilities of the bedrock. Low permeability clayey tills cover much of the area between the borehole and the river.
- The groundwater can be considered unconfined over much of the area, and partially confined by the tills to the west.
- Pumping tests also indicate high-connectivity faults, and additionally a small recharge component that probably comes from the tills overlying the west of the source area.
- The groundwater flow in the area broadly reflects topography, flowing generally westwards from the top of the hill towards the river that drains Friar's Lough. The natural hydraulic gradient east of the borehole is estimated to be approximately 2-3% and between the borehole and the river is estimated to be 0.2% on average.
- The degree of communication between the river and the bedrock aquifer is probably variable along the reach from Friar's Lough to downstream of Lorrha WSS. The water level at Friar's Lough is thought to represent the water table elevation, but the degree of river-aquifer interaction at the place where the Annagh road crosses the river may be less than 100%, since the clayey till subsoil is inferred to be on the order of 10m thick at this location.

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 increased water demand due to expansion and 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 at site is 280 m^3/d. To determine the ZOC, this figure is increased by 50% to 420 m^3/d.

Taking the annual recharge to be 281 mm as indicated in Section 7.2, the area required to supply a daily abstraction of 420 m^3/d is calculated to be 0.54 km^2 (54 ha).

The boundaries of the ZOC are illustrated in Figure 1 and are delineated as follows:

Northern boundary: defined by a local groundwater divide, and a small NW-SE trending ridge of 7 m topographic relief.

Eastern/southern/southeastern boundaries: defined by the crest of the ridge and by topography.

Western and southwestern boundaries: 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 = 420 m^3/d, K = 5 m/d, b = 20m, and i = 0.002, then X_L = 334 m.

These boundaries are based largely on topography, our current understanding of groundwater conditions in the area and on the available data.

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 1).

Because of evidence of different hydraulic gradients, the 100-day ToT is estimated separately to the west and east of the borehole:

East: Taking the permeability as 5 m/d, natural hydraulic gradient as 0.02, and Effective Porosity as 0.02, and using the Thiem steady state equation to compute the additional gradient due to pumping (Thiem, 1906 in Driscoll, 1986), the 100 day ToT is estimated as 500 m. This takes in about 30 % of the ZOC east of the borehole.

West: Taking the permeability as 5 m/d, natural hydraulic gradient as 0.002, Effective Porosity as 0.02, transmissivity as 75 m^2/d and the pumping rate above, and using the Thiem steady state equation for confined flow (which accounts for the extra gradient induced by pumping), the 100 day ToT is estimated as 210 m. This takes in about 40 % of the ZOC area in the region between the borehole and the river.

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 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 permeabilities are high (e.g., sands and gravels) or moderate and subsoils are between 3 and 10 m thick, aquifer vulnerability is 'High'. As this is an interim study, a distinction is made only between Extreme and other vulnerability categories.

The groundwater vulnerability in the area is considered to be Extreme for much of the area, especially to the east of the borehole. Between the borehole and the river, groundwater vulnerability is 'High to Low'. Groundwater vulnerability in the vicinity of Lorrha WSS 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 GWPS, in which only the extremely vulnerable areas are delineated, there is a possible total of only four source protection zones (Table 3). 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 Lorrha WSS source (see Figure 6), as shown in Table 3.

Table 3: Matrix of Source Protection Zones

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

11. Land use and Potential Pollution Sources

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

12. Conclusions and Recommendations

- The boreholes at Lorrha extract water from a limestone 'bedrock aquifer which is moderately productive only in local zones' **(Ll)**.
- The area around the supply has 'Extreme' to 'Low-High' vulnerability to contamination.
- 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.
- Fluoride concentrations are close to the EU MAC of 1 mg/l. This is about the concentration in artificially fluoridised waters. However, it is important to monitor the amount of fluoride in water used by children especially, since excessive fluoride causes tooth enamel mottling and bone brittleness.
- Otherwise, the water quality generally is good, except for elevated iron and manganese. However, chemical and bacteriological analyses of raw water (not 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

Brück, P.M. 1985. *The Geology of the Country between Slieve Aughty, the Silvermines-Devilsbit Mountains and Slieve Bloom, Central Ireland*. Department of Geology, University College Cork, Occasional Report Series RS 85/12.

DoELG/EPA/GSI (1999) *Groundwater Protection Schemes*. Department of Environment & Local Government, Environmental Protection Agency & Geological Survey of Ireland, joint publication.

Driscoll, F. (1986) *Groundwater and Wells* (2nd Ed). Johnson Filtration Systems, Minn., USA. 1089pp.

EPA (March 1997 and in preparation) *Nitrates in Groundwater County Tipperary (NR)*. EPA, Regional Inspectorate, Dublin

Finch, T.F. & Gardiner, M.J. (1993) *Soils of Tipperary North Riding*. Soil Survey Bulletin No. 42, National Soil Survey of Ireland, Teagasc, Dublin.

Hunter Williams, N. & Wright, G. (2001) *An assessment of the quality of public, group scheme and private groundwater supplies in North Tipperary County*. Geological Survey of Ireland.

Wright, G.R. *et al.* (1983) *Groundwater Resources of the Republic of Ireland.* Report to the Commission of the European Community.

Figure 1: Bedrock geology in the Lorrha area. Based on Brück (1985).

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

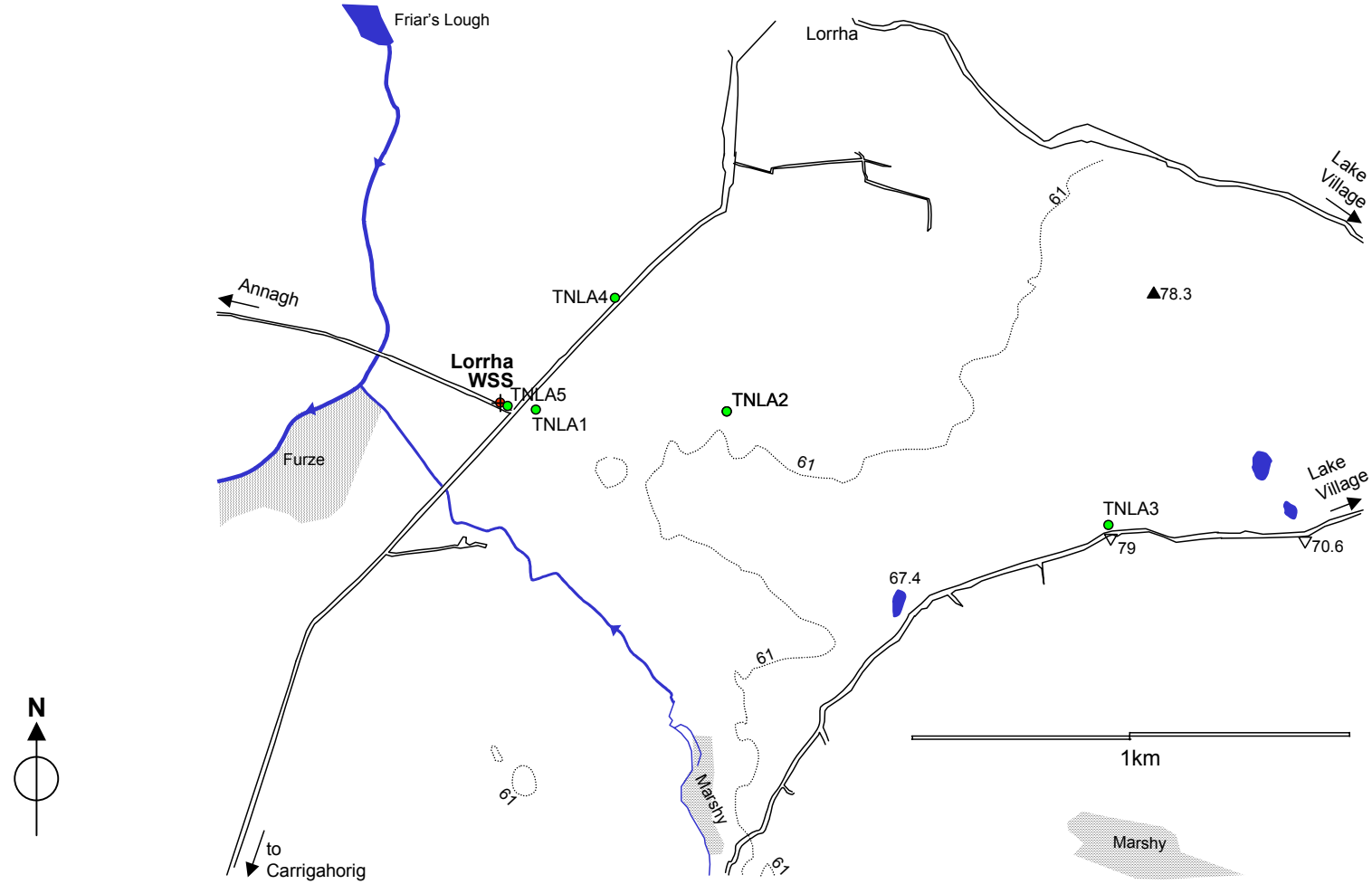
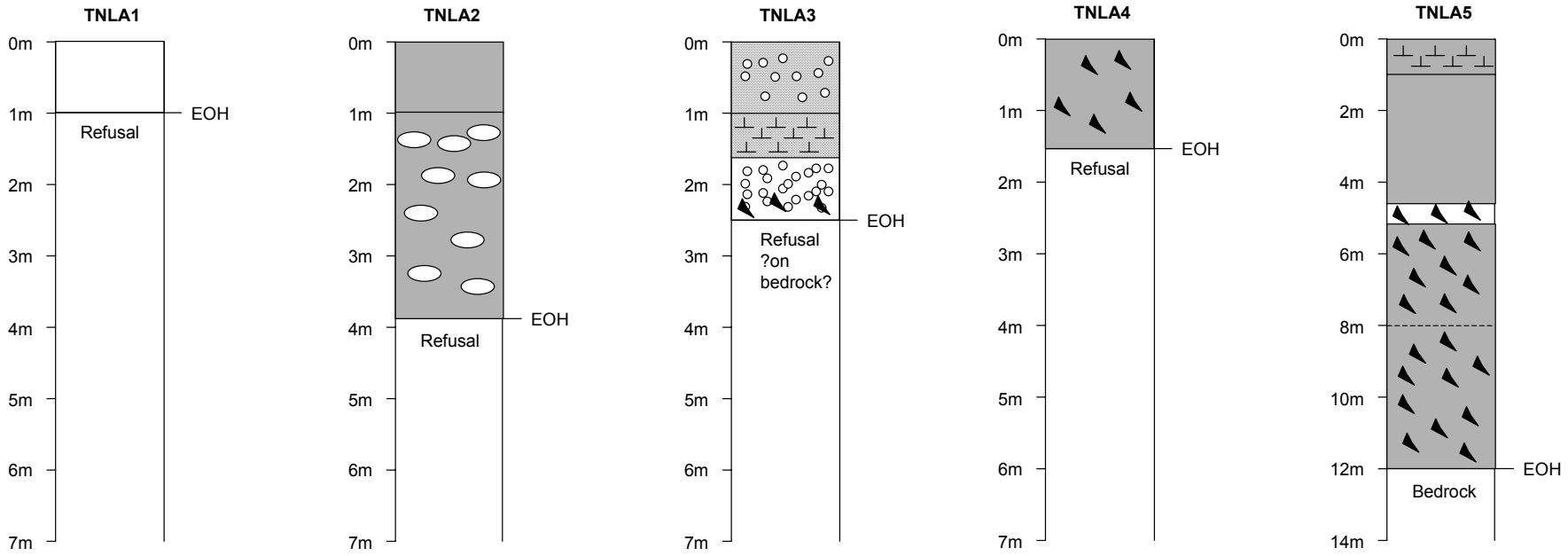


Figure 2: Location map of Lorrha WSS production borehole
Showing auger holes drilled by GSI to determine depth to bedrock in the vicinity (TNLA1 to TNLA5) and other hydrogeological features discussed in the text.



TNLA1 -

1.0m	Refusal at 1m

TNLA2 -

1.0m	Blue Brown Clay
2.0m	Blue Brown Clay with some cobbles
3.0m	Blue Brown Clay with some cobbles
3.9m	Refusal

TNLA3 -

1m	Sandy CLAY with Gravel
1.5m	Fine silty SAND
1.9m	GRAVEL
2.0m	GRAVEL and angular rock fragments
2.4m	Refusal on shaly Bedrock?

TNLA4 -

1.0m	CLAY with broken Limestone fragments
1.5m	REFUSAL

TNLA5 - Corehole (augered first)

1.0m	Grey SILT/CLAY
2.0m	Grey CLAY
4.5m	Broken Rock
5.0m	Clay and Broken Rock
7.5m	Clay and Broken Rock
8.0m	WET CLAY with some Broken Rock
9.0m	WET CLAY with some Broken Rock
12.0m	EOH on Bedrock

Core - Very dolomitised and mineralized (mainly Calcite and dolomite) CALP Limestone. Very poor core recovery (very broken poor quality rock). Frequent Vugs and fractures.

Figure 3: Summary logs and lithological descriptions of auger holes drilled to assess depth to bedrock in the vicinity of Lorrha WSS boreholes. See Figure 2 for the locations of the auger holes.

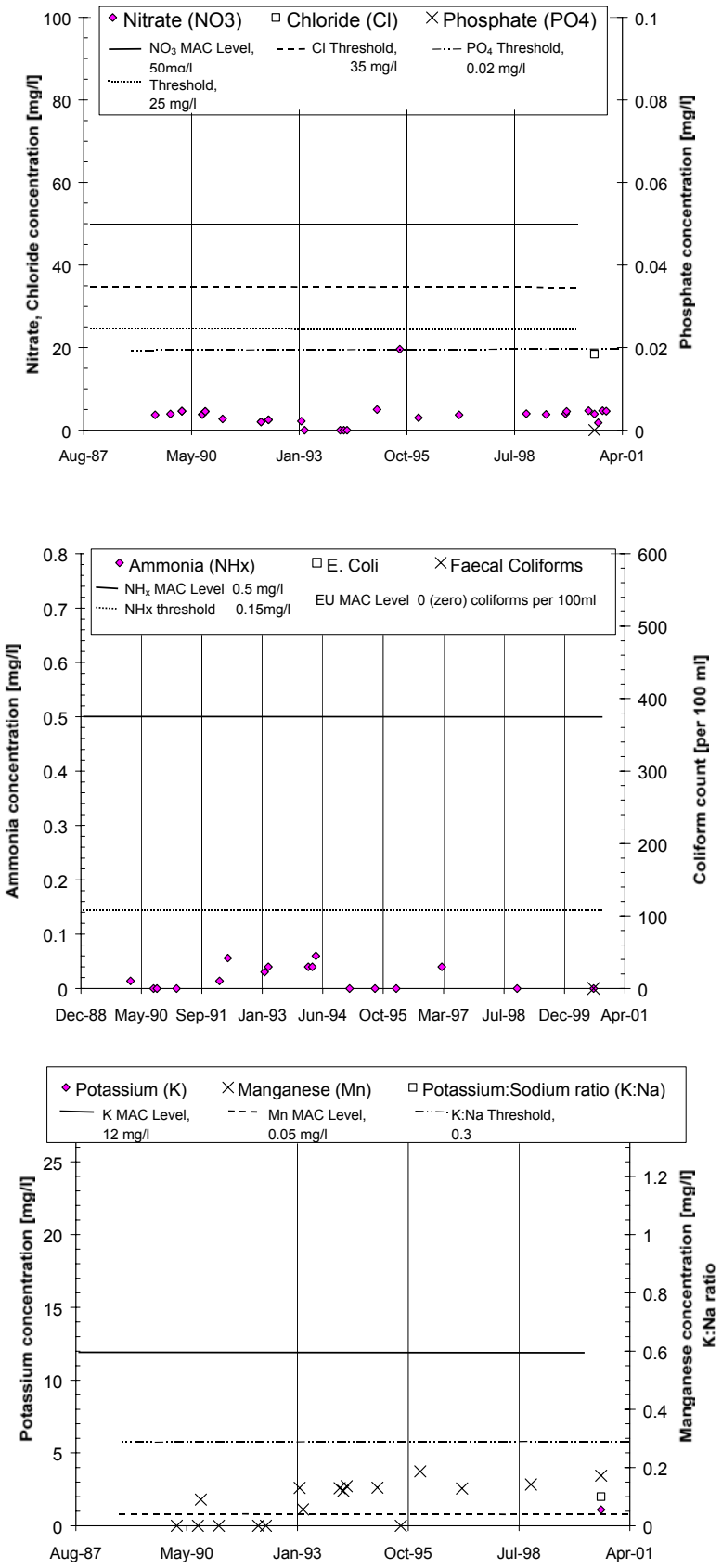
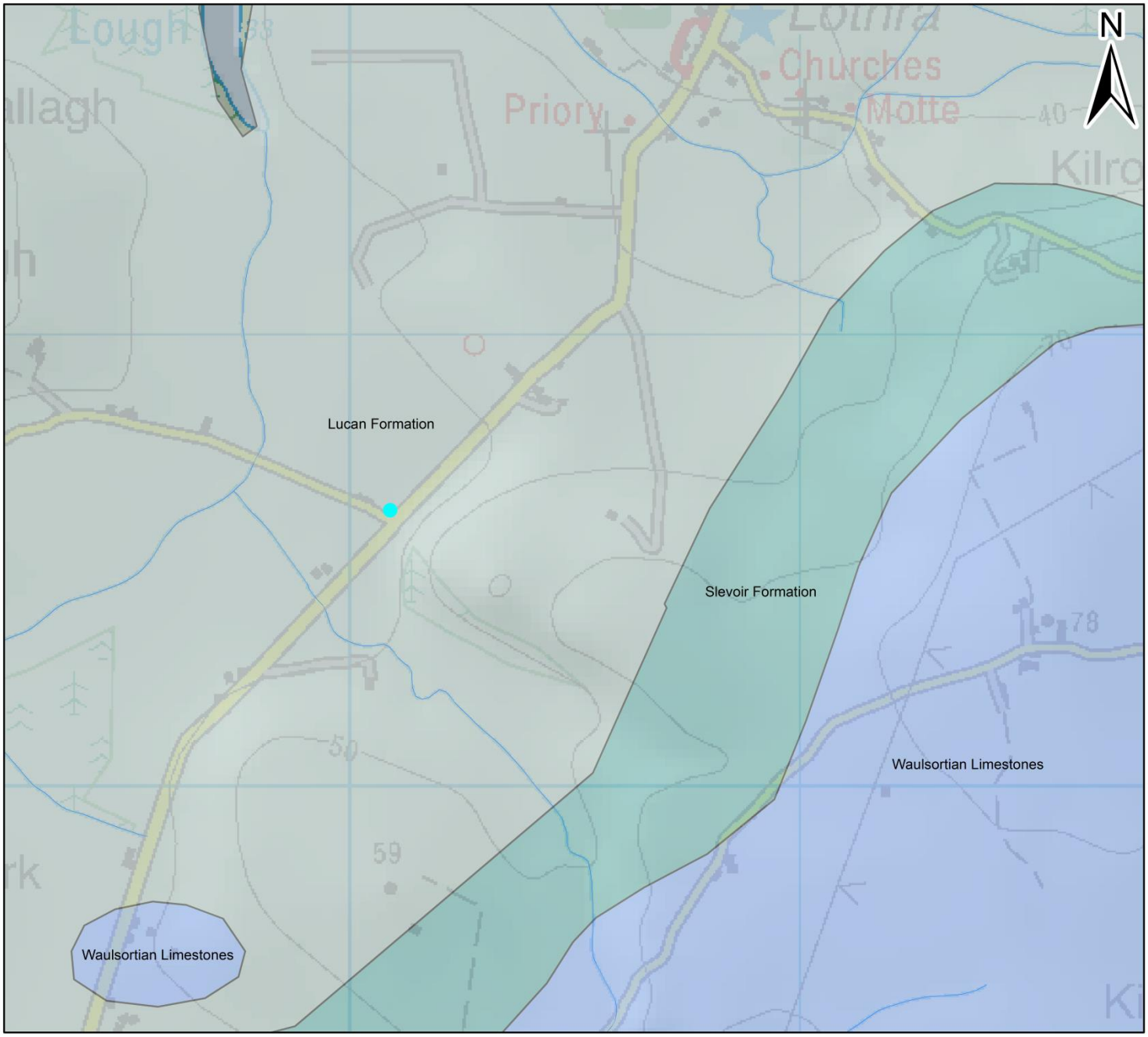


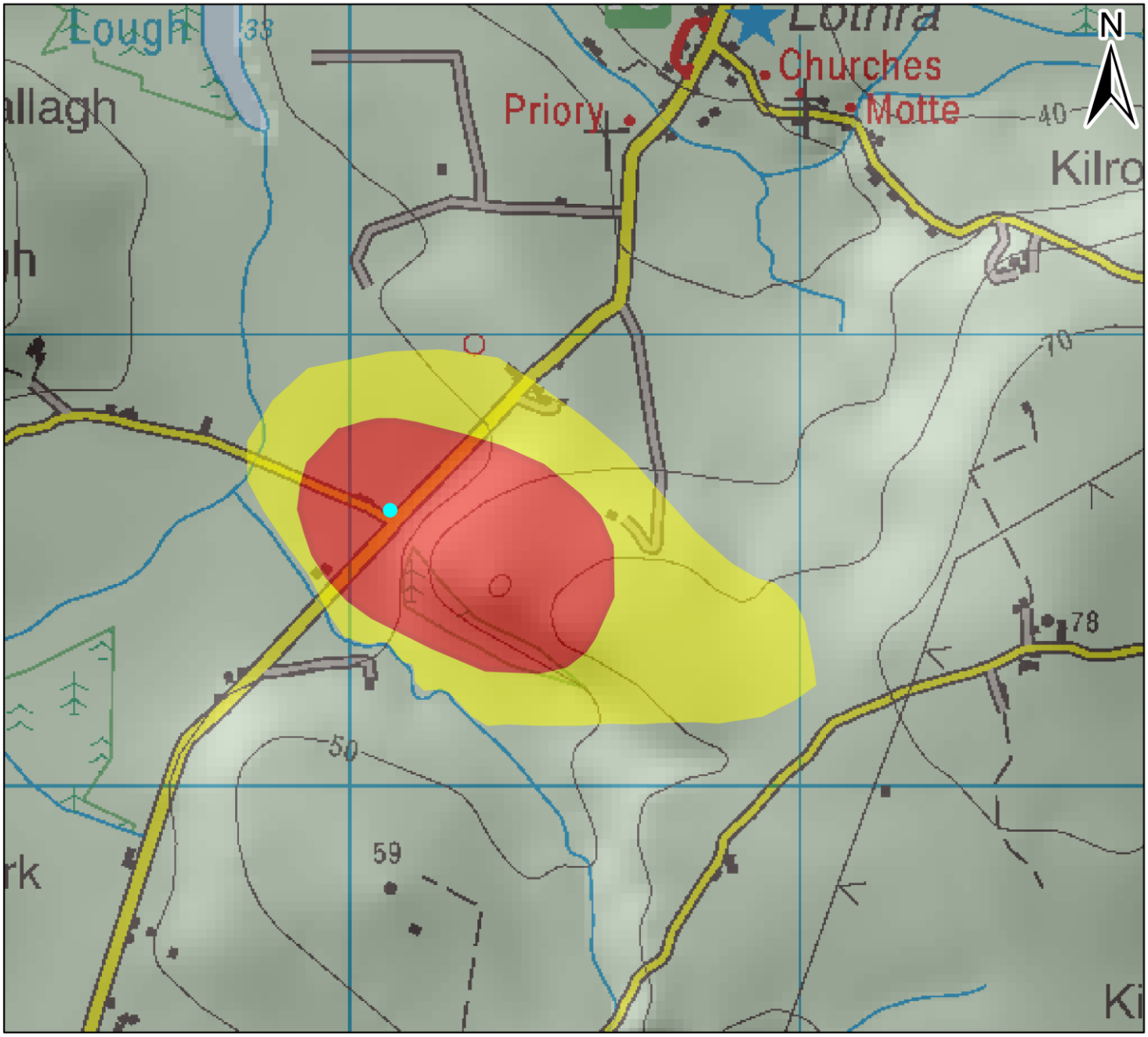
Figure 4: Key indicators of agricultural and domestic groundwater contamination at Lorrha WSS.

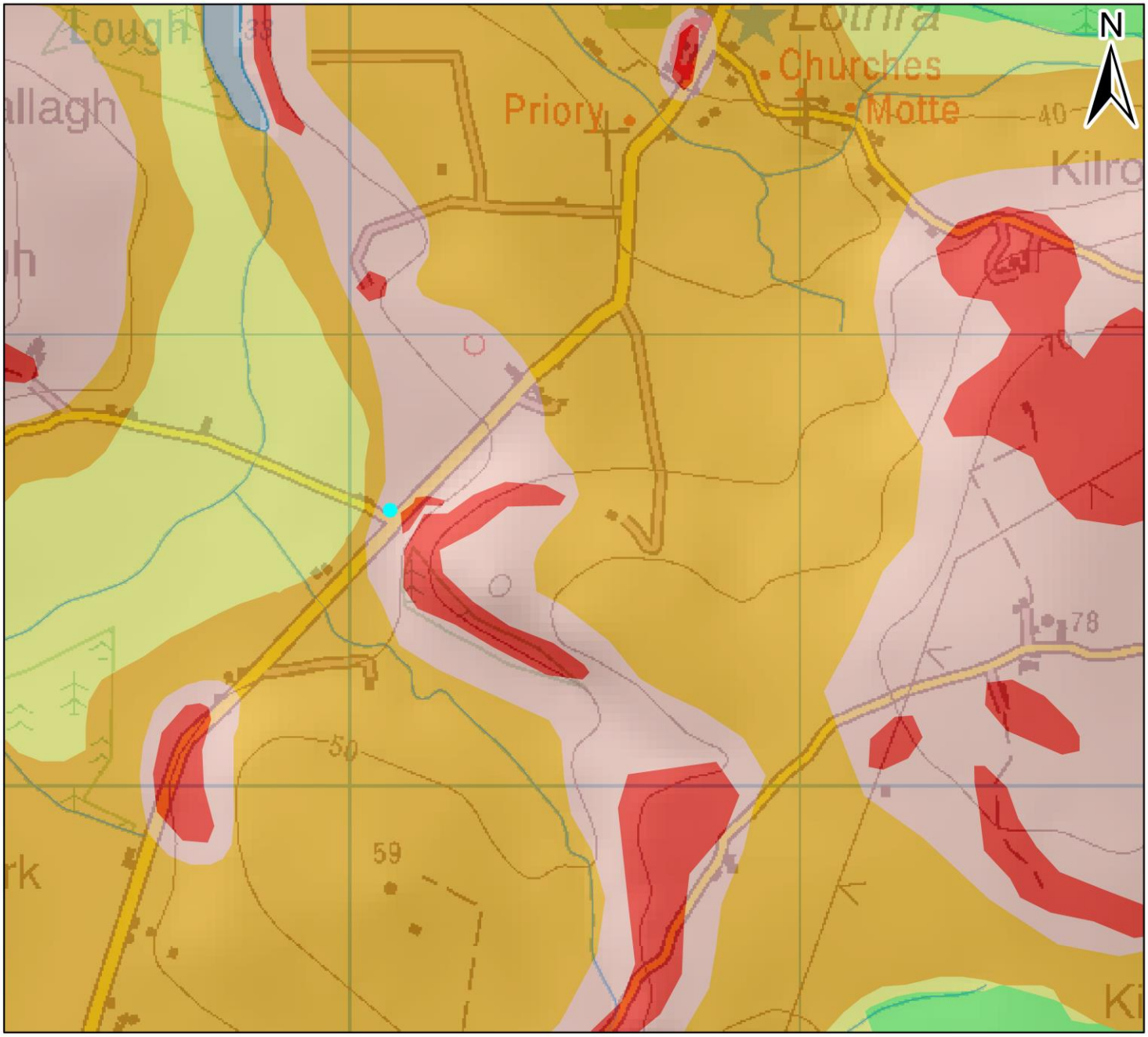
Appendix 1: Laboratory Analyses of Groundwater at Lorrha WSS

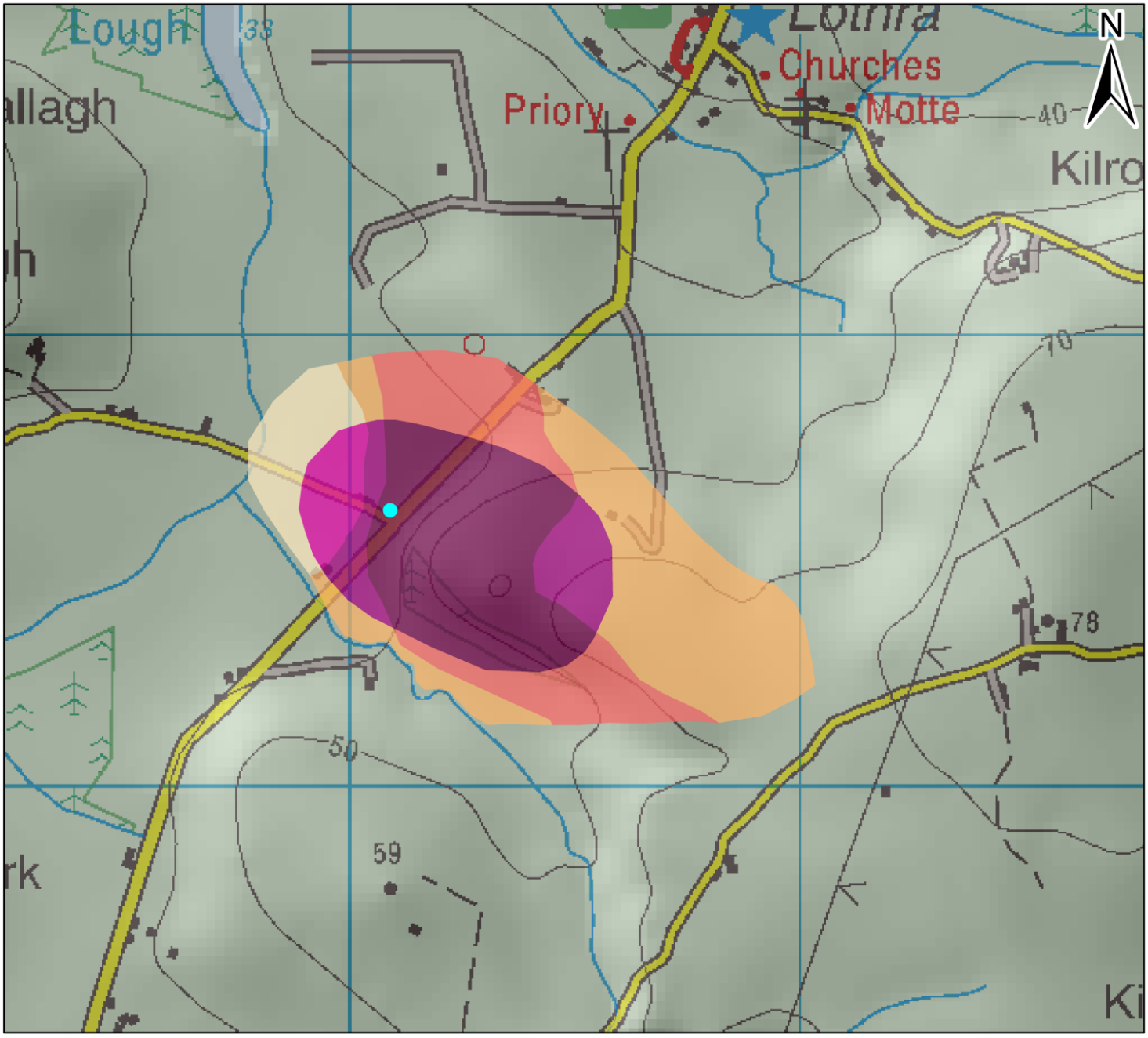
Parameter	Results of Laboratory Analyses																																			
Laboratory	dwr		North Tipperary Co.Co																										dwr	State Lab	dwr							
Sample treatment			-	NS?	-	NS	-	-	-	-	NS	-	NS	NS	NS	NS?	NS	NS	-	-	NS	NS						S								
Date	04/06/89	24/10/89	07/02/90	09/02/90	16/08/90	17/08/90	12/09/90	21/02/91	12/02/92	21/04/92	29/09/92	19/02/93	22/03/93	16/02/94	21/03/94	20/04/94	23/01/95	22/08/95	13/02/96	24/02/97	29/09/98	09/11/98	12/05/99	09/11/99	18/11/99	09/06/00	03/08/00	07/09/00	17/10/00	21/11/00							
EC (µS/cm)			700		753		725	739	736	728		737	761	769	752	759	764	755	797	786		824					845										
pH (lab.)			7.1		7.3		7.2	7.2	7.3	7.5		7.4	7.0	7.3	7.2	7.3	7.2	7.4	7.2	7.1		7.1														
Total Hardness (mg/l $CaCO_3$)																											399									
Total Alkalinity (mg/l $CaCO_3$)																											370									
Calcium (mg/l)																											135									
Magnesium (mg.l)																											14.9									
Chloride (mg/l)																											18.4									
Sulphate (mg/l)																											65.4									
Sodium (mg/l)																											11									
Potassium (mg/l)																											1.1									
K:Na																											0.1									
Nitrate (mg/l NO_3)	3.7	3.9	4.6		3.8		4.5	2.7	2.0	2.5		2.2	<MDL	<MDL	<MDL	<MDL	5.0	4.4	3.0	3.7		4.0		3.8	4.0	4.5	4.7	3.9	1.8	4.7	4.6					
Iron (mg/l)			0.15		**0.79**		0.1	<MDL	<MDL	<MDL		0.05	<MDL	0.15	0.06	0.06	0.07	<MDL	<MDL	0.06		<MDL					0.01									
Manganese (mg/l)			<MDL		<MDL		**0.09**	<MDL	<MDL	<MDL		**0.13**	**0.06**	**0.13**	**0.12**	**0.17**	**0.13**	<MDL	**0.19**	**0.13**		**0.14**					**0.17**									
E/F coli per 100 ml.																											0									
Total *coli* /100ml				0		0		0	0	0	0	0	0	0	0	0	0	0			0	0					0									
Total Ammonia (mg/l NHx)			0.014		<MDL		<MDL	<MDL	0.014	0.056		0.03	0.04	0.04	0.04	0.06	<MDL	<MDL	<MDL	0.04		<MDL					<MDL									
Comments	Manganese and iron probably have natural source. Ammonium concentrations may have natural origin (in shale layers), but should be monitored, along with faecal bacteria. Nitrate concentrations good. Should have on-going monitoring																																			

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


N
Legend
Borehole
Rivers
Geological Units
Lucan Formation
Slevoir Formation
Waulsortian Limestone Formation
Lucan Formation
Slevoir Formation
Waulsortian Limestones
Waulsortian Limestones
0 0.125 0.25 0.5 Km


Lough
allagh
Priory
Churches
Motte
Kilro
40
70
78
50
59
rk
N
Legend
Borehole
Rivers
Source Protection Area
SI- Inner Source Protection Area
SO- Outer Source Protection Area
0 0.125 0.25 0.5 Km


Priory
Churches
Motte
40
78
50
59
N
Legend
Borehole
Rivers
Vulnerability
X- Extreme (rock close/karst)
E- Extreme
H- High
M- Moderate
L- Low
0 0.125 0.25 0.5 Km


Lough
allagh
Priory
Churches
Motte
Kilro
40
70
78
50
59
rk
N
Legend
Borehole
Rivers
Source Protection Zone
SI/E
SI/H
SI/M
SO/E
SO/H
SO/M
0 0.125 0.25 0.5 Km