Establishment of Groundwater Zones of Contribution

Cappagh Group Water Scheme

Priest's Field Well

January 2015

Prepared by:

Richard Langford,

Parkmore Environmental Services Ltd.,
and
Geological Survey of Ireland, Groundwater Programme
(Monica Lee, Caoimhe Hickey and Taly Hunter Williams)

And with assistance from:

Craggs/Barrigone GWS

The National Federation of Group Water Schemes







Acknowledgements:

Joe Gallagher (NFGWS)

Tony Prendiville (Cappagh GWS)

Caroline Tomlin (Cappagh GWS)

Additional contributions from:

Hydro-Environmental Services, GIS Mapping

Document control information

Revision	Date	Author	Checked	Approved
A	29/10/2014	Richard Langford	CH	29/10/2014
B	20/1/2015	Richard Langford		
	18/03/2015	Richard Langford		

Project description

Since the 1980's, the Geological Survey of Ireland (GSI) has undertaken a considerable amount of work developing Groundwater Protection Schemes throughout the country. Groundwater Source Protection Zones are the surface and subsurface areas surrounding a groundwater source, i.e. a well, wellfield or spring, in which water and contaminants may enter groundwater and move towards the source. Knowledge of where the water is coming from is critical when trying to interpret water quality data at the groundwater source. The 'Zone of Contribution' 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.

This report has been prepared for Cappagh Group Water Scheme as part of the Rural Water Programme funding initiative of grants towards specific source protection works on Group Water Schemes (DECLG Circular L5/13 and Explanatory Memorandum).

The report has been prepared in the format developed during an earlier pilot project "Establishment of Zones of Contribution" which was undertaken by the Geological Survey of Ireland (GSI), in collaboration with the National Federation of Group Water Schemes (NFGWS), and with support from the National Rural Water Services Committee (NRWSC).

The methodology undertaken by the GSI included: liaising with the GWS and NFGWS to facilitate data collection, a desk study, a site visit to inspect the supply, the local area, and to record groundwater level(s). The data was then analysed and interpreted in order to delineate the ZOC.

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

The report and maps are hosted on the GSI website (www.gsi.ie).

TABLE OF CONTENTS

1. Overview: Groundwater, groundwater protection and groundwater supplies 1

2. Location, Site Description, Well Head Protection and Summary of Groundwater Well Details 2

3. Physical Characteristics and Hydrogeological Considerations 6

3.1 Hydrochemistry and water quality 8

4. Zone of Contribution 9

4.1 Conceptual model 9
4.2 Boundaries 11
4.3 Recharge and water balance 11

5. Conclusions 12

6. Recommendations 13

7. References 14

TABLES

Table 1. Supply Details 4

Table 2. Physical Characteristics of the Area of Interest 6

Table 3. Raw Water Quality, 2003/2004 8

Table 4. Treated Water Quality from Distribution Network, 2008 to 2011 8

DIAGRAMS

Diagram 1. Rural landscape highlighting interaction between surface water and groundwater and potential land use hazards. 2

Diagram 2. Schematic Plan of the GWS Enclosure 3

Diagram 3. Schematic Cross Section and Conceptual Model 10

FIGURES

Figure 1: Location Map (OSi Discovery Series Map. 1:50,000 Scale) 21

Figure 2: Topography and Drainage 22

Figure 3: Subsoil Map 23

Figure 4. Groundwater Vulnerability Map 24

Figure 5. Rock Unit Group Map 25

Figure 6. Aquifer Map 26

Figure 7. ZOC Boundaries 27

APPENDICES

Appendix 1: Cappagh Group Scheme Abstraction Rates 28

Appendix 2: Trial Well Log 30

Appendix 3: Pumping Test Data.....32

Appendix 4: Geophysical Survey 41

Appendix 5: Groundwater Vulnerability 57

Appendix 6: Groundwater Body Description.....60

Appendix 7: Groundwater Recharge 65

Appendix 8: Water Quality Data 67

Appendix 9: Zone of Contribution Calculations 82

Appendix 10: Raw Water Quality Suite of Analysis 83

1. Overview: Groundwater, groundwater protection and groundwater supplies

Groundwater is an important natural resource in Ireland. It originates from rainfall that soaks into the ground. If the ground is permeable, the rainfall will filter down until it reaches the main body of groundwater, which is usually within either the bedrock, or a sand/gravel deposit. If the bedrock or sand/gravel deposit can hold enough groundwater and allow enough flow to supply a useful abstraction, it is referred to as an aquifer.

In Irish bedrock aquifers, groundwater predominantly flows through interconnected fractures, fissures, joints and bedding planes, which can be envisaged as a 'pipe network', of various sizes, with varying degrees of interconnectivity. For example in a poor aquifer the "pipe network" will be small, and the flux or flow of water will be restricted. However, in a regionally important karst aquifer the "pipe network" can be large, and the flux or flow of water can be significant. The speed of flow through these networks will be proportional to the freedom of flow within the "pipe network" and this can be relatively slow to relatively fast. However, all groundwater flow gravitates towards points of lower elevation and delivers groundwater, and a large proportion of the contaminants present in the groundwater, to its destination *e.g.* to boreholes, springs, wetlands, lakes, rivers or the sea.

In sand/gravel aquifers, the groundwater flows in the interconnected pore spaces between the sand/gravel grains. Generally, this is equivalent to a filter system that may physically filter out contaminants to varying degrees, depending on the nature of the spaces and grains. It also slows down the speed of flow giving more time for pathogens to die off before they reach their destination *e.g.* borehole, spring, river and sea.

Further filtration of contaminants may occur where the aquifers are protected by overlying soil and subsoil; thick, impermeable clay soil and subsoil provide good protection while thin, very permeable gravel will provide limited protection. Therefore, variations in subsoil type and thickness are important when characterising the 'vulnerability' of groundwater to contamination.

The karst limestone aquifers provide significant and important groundwater supplies in Ireland. Karst landscapes develop in rocks that are readily dissolved by water *e.g.* limestone (composed of calcium carbonate). Consequently, conduit, fissure and cave systems develop underground[1]. Groundwater typically travels very fast in karst aquifers, which has a significant impact on the water quality; neither filtration nor pathogen die-off are associated with these aquifers.

The interaction between abstraction and geology is shown in **Diagram 1**. In this scenario, a borehole is pumping groundwater from the bedrock aquifer. As the water is abstracted through the well, the original water table (a), is drawn down to level (b), where it induces a drawdown curve of the natural water table (c). The shape of this curve depends on the properties of the aquifer, for example, if the borehole is intersecting an aquifer with few fractures that are poorly interconnected, the groundwater from that system will soon be exhausted, and therefore the pumping will have to pull from deeper depths to maintain supply, which results in the steep, deep drawdown curve. Alternatively, if the borehole is intersecting an aquifer with a large number of well connected groundwater-filled fractures, the abstraction will be met by pulling water from farther away, at a shallower depth, resulting in a shallow, wide drawdown curve.

By knowing the rate of abstraction (output), how much rainfall there is (input), and by assessing the geological elements outlined above (nature of the bedrock fractures or sand/gravel deposit; how permeable the soil and subsoil are) to determine what happens in between input and output, the catchment area, or 'Zone of Contribution' (ZOC), to any groundwater water supply can be determined.

The Cappagh GWS is supplied with 150.5 m^3/day of groundwater from three boreholes (Rosemount Well and two boreholes at the Priest's Field Compound), which mainly draws water from a regionally important karst conduit bedrock aquifer, and partially from a locally important aquifer.

[1] Geological Survey of Ireland, 2000.

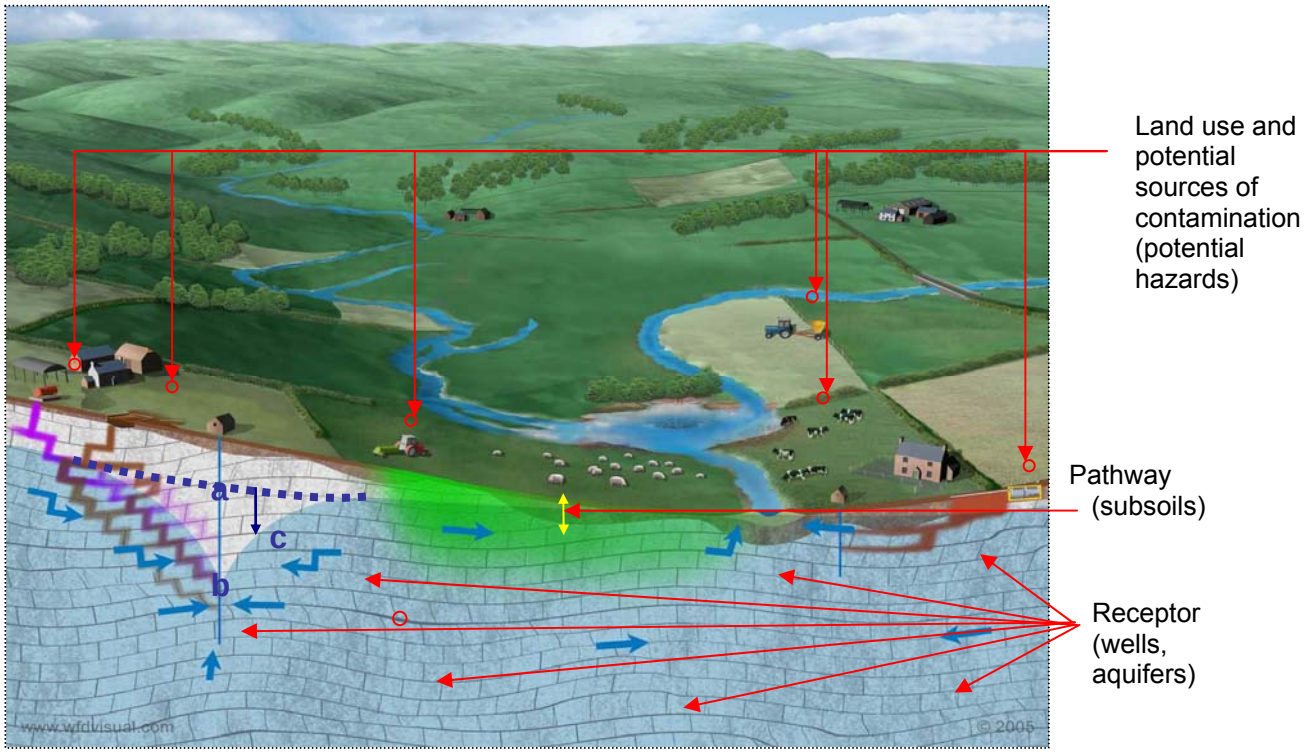


Diagram 1. Rural Landscape Highlighting Interaction between Surface Water, Groundwater and Potential Land Use Hazards.

2. Location, Site Description, Well Head Protection and Summary of Groundwater Well Details

The Cappagh Group Water Scheme (GWS) is supplied from three boreholes. The "Rosemount" borehole is located at Rosemount, Ballingrane, Rathkeale. The "Priest's Field" boreholes are located in Callow, Askeaton, Co. Limerick, two kilometres northeast of the Rosemount borehole. This report focuses on the Priest's Field Wells.

The Cappagh GWS is managed by EPS as part of the Design Build Operate (DBO) scheme. The scheme supplies 300 connections, including 209 domestic water supply connections, and the average abstraction is 150.5 m^3/day[2]. On average, between January 2013 and August 2014, 99.35 m^3/day was abstracted from the Priest's Field wells, with the remaining 51.15 m^3/day being abstracted from the Rosemount well (**Appendix 1**). Water is pumped from the Priest's Field wells during the night to a reservoir, which is located approximately 171 meters east of the well field, and has a capacity of approximately 450 m^3. The two Priest's Field wells are pumped on alternate nights. The water abstracted from the Rosemount borehole is pumped directly to the water distribution network following UV treatment and chlorination. In general, water quality from the Priest's Field sources is consistently better than from the Rosemount borehole, therefore the GWS tried to reduce to volume of water being abstracted from the Rosemount borehole during 2013 and 2014. It is understood that because of reduced pressure in parts of the distribution network, the proportion of water abstracted from the Rosemount supply has been increased from an average of 38 m^3/day between January 2013 and May 2014, to an average of 104 m^3/day since May 2014.

The Priest's Field infrastructure is located within a securely fenced compound (**Diagram 2**). The two abstraction wells (BH1 and BH2), a trial well, and a pump house are located within the compound (Photo 1). Well head protection on the site is good. Both well head openings are capped so no debris or animals/rodents can fall into the well head openings. BH 1 is located within the pump house, and BH2 is located within a secure concrete chamber (Photo's 2, 3 and 4).

[2] EPS, Abstraction Rates, January 2013 to August 2014

Groundwater is passed through a UV treatment system to treat coliforms and is chlorinated prior to entering the reservoir. The treatment works are located in the pump house.

Borehole 1 (BH1) was drilled to a depth of 37.5 m in the early 1960's. No borehole logs are available for BH1. A trial well was drilled by was drilled by Patrick Briody and Sons Ltd. in January 2004. The borehole log is presented in **Appendix 2**. A 72 hour pumping test was completed by Seamus Kelly and Sons in February 2004, and has been collated and analysed as part of this report (**Appendix 3**). Following the results of trial well drilling and testing, a production well (BH2) was installed on the site, and is expected to be 110 m deep. There is no borehole log available for the production well at the stage of writing the report Neither the GWS, EPS, or T.J. O'Connor's has a copy of the borehole log, and the well driller is not known **Table 1** provides a summary of the Priest Field Boreholes with currently known information.

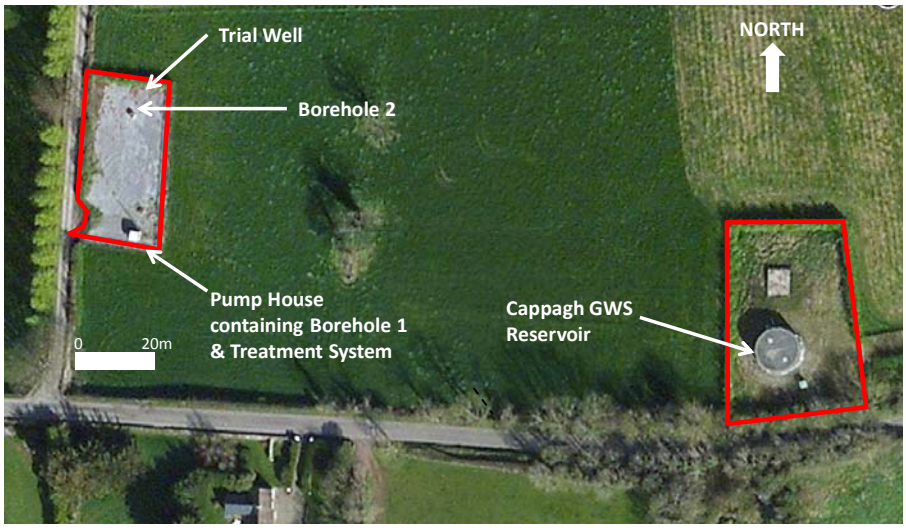


Diagram 2. Schematic Plan of the GWS Enclosure (Source: Bing Maps)



Photo 1: Pump house located within secure compound



Photo 2: Borehole 1 with treatment works in Pump-house



Photo 3: Borehole 2 with secure fence to east.



Photo 4: Well head of Borehole 2 (NB: Not possible to measure water level using dip meter during site visit)

Table 1: Supply Details

Well Name	Borehole 1	Trial Well	Borehole 2
Grid reference	137954, 145276	137956, 145311	137955, 145303
Townland	Callow, Askeaton	Callow, Askeaton	Callow, Askeaton
Source type	Borehole	Borehole	Borehole
Commissioned/Drilled	Early 1960's	13th January 2004	2004
Drilling Contractor	Unknown	Patrick Briody & Son's Ltd.	Uncertain
Owner	Cappagh GWS	Cappagh GWS	Cappagh GWS
Elevation (m OD) (Estimated from OSi 1:50,000 Scale Map)	50	50	50
Total depth (m)	37.5 [3]	109.7	Unknown (but expected to be 110 m deep, similar to the trial well)
Construction details	Unknown	Drilled at 10" diameter to 5.8 m, and 8" to 109.7 m. Installed 8" steel casing to 5.8 m. Borehole lined with 5" PVC Screen from ground level to 109.7 m on instruction from engineer due to large limestone pieces and orange sand deposits returned to surface during drilling.	Unknown
Depth to rock (m bgl)	Approx. 4.5 metres	4.57 m to broken rock	Approx. 4.5 metres
Static water level (SWL) when drilled (m bgl)	(~9.7 m below top of casing on the 5th June 2013) [3]	(6.93 m below top of casing on the 10th February 2004)[4]	(9.7 m below top of casing on the 5th June 2013) [3]
Transmissivity (m^2/day)	Unknown	17.3 (average from pumping test data)	Unknown
Pump intake depth (m bgl)	Unknown	Not installed	60 to 70 metres below ground level
Current abstraction rate (GWS)	99 m^3/day (Average) BH1 and BH2 pumped on alternative nights.	No Abstraction	99 m^3/day (Average) BH1 and BH2 pumped on alternative nights.
Reported yield (m^3/d)	127 m^3/day [5]	195 m^3/day [6]	275 m^3/day based on 14 hours pumping at 14m^3/hour[7]
Pumping Regime	10 hours pumping per alternate day at 10 m^3/hour	Not Pumping	10 hours pumping per alternate day at 10 m^3/hour

[3] GWS Source Data Sheet
[4] Pumping Test Data, 2004
[5] GSI Well Survey Database
[6] T.J. O'Connor & Associates, 2004
[7] Preliminary Source Protection Report, Cappagh GWS, 2007, GES Ltd., Carlow

Geophysical Survey

The trial well was drilled at a location identified in a geophysical survey of the site by George Reynolds, Consultant Geophysicist in June 2003.

The geophysical survey identified a change in the underlying strata approximately 40 metres north of the pump house, which was interpreted as a muddier and/or more permeable bedrock formation. The geophysicist indicated there was a good chance of finding water at that location.

The survey indicated a contact at 9 metres below ground level which was interpreted to indicate the water table. This compares favourably with measured water levels on the site. A second contact at 25 metres deep was interpreted as being a crystalline limestone (Waulsortian Limestone).

The findings of the geophysical survey tally with the geological bedrock maps for the area, where the dark muddy limestone and shaley mudstone of the Rathkeale Formation are mapped as underlying the northern portion of the well compound, overlying the Waulsortian Limestones.

The geophysical survey report is presented in **Appendix 4**.

3. Physical Characteristics and Hydrogeological Considerations

3.1 Physical characteristics of the area

A summary of information on rainfall, land use, topography, hydrology and geology for the area is provided in Table 2 below:

Table 2. Physical Characteristics of the Area of Interest

	Priest Field Wells	Description/Comments
Annual Rainfall (mm)	994	Met Eireann average annual rainfall data 1981-2010
Annual Evapotranspiration Losses (mm)	516	Actual Evapotranspiration, assumed to be 95% of 30 year average Potential Evapotranspiration (PE) from Shannon Airport (1961-1990)
Annual Effective Rainfall (mm)	478	Annual rainfall minus the annual evapotranspiration losses
Topography (**Figure 2**)	The topography in the area is gently undulating, and the ground elevation ranges between 62 m to 40 m above ordnance datum (Figure 2). The local topography is dominated by the elevated peak (~62 m AOD) approximately 170 metres east-southeast of the borehole, where the GWS reservoir is located. The regional gradient falls to the north, towards the River Shannon estuary.	
Land use	Agricultural grassland is the principal land cover. The borehole compound was once part of a large field. This field continues to be cut for silage each year. Rural one-off houses, with individual wastewater treatment systems, form a ribbon development along the country road 30 metres due south of the borehole. There are approximately 14 dwelling houses and 2 farm yards within 500 metres of the borehole. The nearest farm yard and dwelling house is located 80 metres northwest and down gradient of the borehole.	
Surface Hydrology (**Figure 2**)	The regional hydrology is dominated by the Shannon Estuary located approximately 11.5 km north of the borehole. The River Deel, the largest river in the vicinity of the borehole, flows in a north to northwesterly direction, approximately 4.5 km west of the borehole, before discharging to the Shannon Estuary beyond Askeaton, 9.5 km northwest of the borehole. There is strong connection between groundwater and surface water in the vicinity of the Priest's Field boreholes. There is a number of groundwater fed wetlands/fens located within 500 metres of the boreholes. Cappagh Fen (proposed National Heritage Area, Site Code 001429) which is part of the Askeaton Fen Complex Special Area of Conservation (SAC) is located approximately 510 metres northwest of the boreholes. The nearest surface water feature is a wetland located approximately 170 m northwest of the boreholes, which is linked to Cappagh Fen by surface drainage. The drainage density in the vicinity of the boreholes is low. A shallow drain south of the boreholes, reportedly sinks into limestone bedrock close to the railway line.	
Topsoil[8]	Deep and shallow well drained mineral soils with fen peat located in the wetlands.	
Subsoil[4] (**Figure 3**)	Till derived from Limestone Bedrock, with Limestone Bedrock exposed in places. Limestone bedrock outcrops 40 m west of the boreholes. No bedrock is exposed upgradient of the boreholes.	
Groundwater Vulnerability (**Figure 4**)	Generally Extreme to Extreme with rock close to surface (**Appendix 5)**	
Geology Formation: Rock Unit Group (**Figure 5**)	Rathkeale Formation (Dinantian Upper Impure Limestones): Dark muddy limestone and shaley mudstone Waulsortian Limestones (Dinantian Pure Unbedded Limestones): Massive un-bedded lime mudstone The Rathkeale Formation overlies the Waulsortian Formation.	
Aquifer (**Figure 6**)	**Locally Important Bedrock** aquifer, bedrock which is moderately productive only in local zones; And **Regionally Important Karstified** aquifer, dominated by conduit flow (**RKc**)	

[8] EPA Envision Website

Groundwater Body (**Appendix 6**)[9]	Askeaton	Categorised as having a 'good' status.
Recharge Coefficient (**Appendix 7**)	70%	Low drainage density, well drained soils, high permeability subsoils, and extreme to extreme – rock at surface vulnerability, suggest a high recharge coefficient. Therefore, despite an area around the wells being mapped as a Locally Important Aquifer, no recharge cap applies.
Recharge (mm)	335	

[9] Wfdireland.ie

3.2 Hydrochemistry and water quality

Raw water samples from Borehole 1, and from the trial well drilled in 2004, at the end of 72 hours of test pumping, were collected and analysed and/or collated by Limerick County Council as part of the Limerick GWS Design Build Operate (DBO) contract in 2003/2004 and are summarised in Table 3. Treated drinking water samples were collected from various points across the distribution network by Limerick County Council between 2008 and 2011 and are summarised in Table 4 below. The complete data set is presented in **Appendix 8**.

Existing laboratory results have been compared to the European Communities Environmental Objectives (Groundwater) Regulations 2010 Threshold Values (TVs), which were recently adopted in Ireland under S.I. No. 9 of 2010. In the absence of Threshold Values, results have been compared with the drinking water standard (S.I. 122 of 2014).

Table 3: Raw Water Quality 2003/2004, from T.J. O'Connor & Associates

		Borehole 1 Priests Field				Trial Well Borehole 13/2/2004		Threshold Values or Drinking Water Limit
Parameter	Units	No of samples	Min	Max	Ave	No of samples	Result	
Iron	ug/l	15	11	58	20	1	<10	200 (DWL)
Manganese	mg/l	3	3	19	12	1	<10	50 (DWL)
Nitrate	mg/l	0	-	-	-	1	6.0	37.5 (TV)
Nitrite	mg/l	0	-	-	-	1	<10	0.375 (TV)
Coliform Bacteria	no./100ml	14	1	22	6	1	1	0 (DWL Treated Water)
Faecal Coliforms	no./100ml	14	1	2	1	1	1	0 (DWL Treated Water)

DWL = Drinking Water Limit (treated water)

TV = Threshold Value

The presence of *E.Coli* detected in both boreholes indicates microbiological contamination of both groundwater sources can take place. This highlights the vulnerability of the groundwater source to faecal/microbial contamination within the catchment area resulting from human and animal activity. Nitrate levels in the trial borehole were low in 2004. The raw water quality results indicate good chemical groundwater quality from the Priest's Field boreholes.

Table 4: Treated Water Quality from Distribution Network, 2008 to 2011
(*Blend of treated water from Priest's Field and Rosemount Boreholes*)

Cappagh GWS Treated Water Quality Data 2008 - 2011						
Parameter	Units	No of samples	Miniumum	Maximum	Average	Threshold Values or Drinking Water Limit
pH	pH units	23	6.99	8.20	7.3	6.5-9.5 (TV)
Conductivity	µs/cm	14	554	839	764.4	800 - 1875 (TV)
Nitrate	Mg/l	23	8.82	39.16	19.2	37.5 (TV)
Ammonium	Mg/l	5	0.04	0.04	0.0	0.3 (DWL)
Chloride	Mg/l	2	26.9	27.6	27.3	24 -187.5 (TV)
Coliform Bacteria	no./100ml	22	0	1	0.0	0 (DWL Treated Water)
E.Coli	no./100ml	23	0	0	0.0	0 (DWL Treated Water)
Sodium	Mg/l	2	16.6	19.0	17.8	150 (TV)

DWL = Drinking Water Limit (treated water)

TV = Threshold Value

The treated water is hard, which is likely to cause lime-scale issues within the distribution network. The chemical water quality is good. Elevated levels of nitrate detected in the water distribution network are likely to be attributed to groundwater abstracted from the Rosemount groundwater well. A review of treated water samples from the Priest's Field wells indicates nitrate levels in the groundwater have increased from 6 mg/l since 2004 to 16.7 mg/l in 2008, however no samples exceeding the relevant Threshold Value.

4. Zone of Contribution

Conceptual model

The current understanding of the geological and hydrogeological setting is given as follows (see cross section **Diagram 3)**.

The Cappagh Group Water Scheme Priest Field boreholes are located at the bottom of a moderate slope. For the purposes of developing a conceptual site model, they are considered together. The vulnerability maps indicate bedrock will be found within 3 metres of the ground surface (extreme vulnerability).

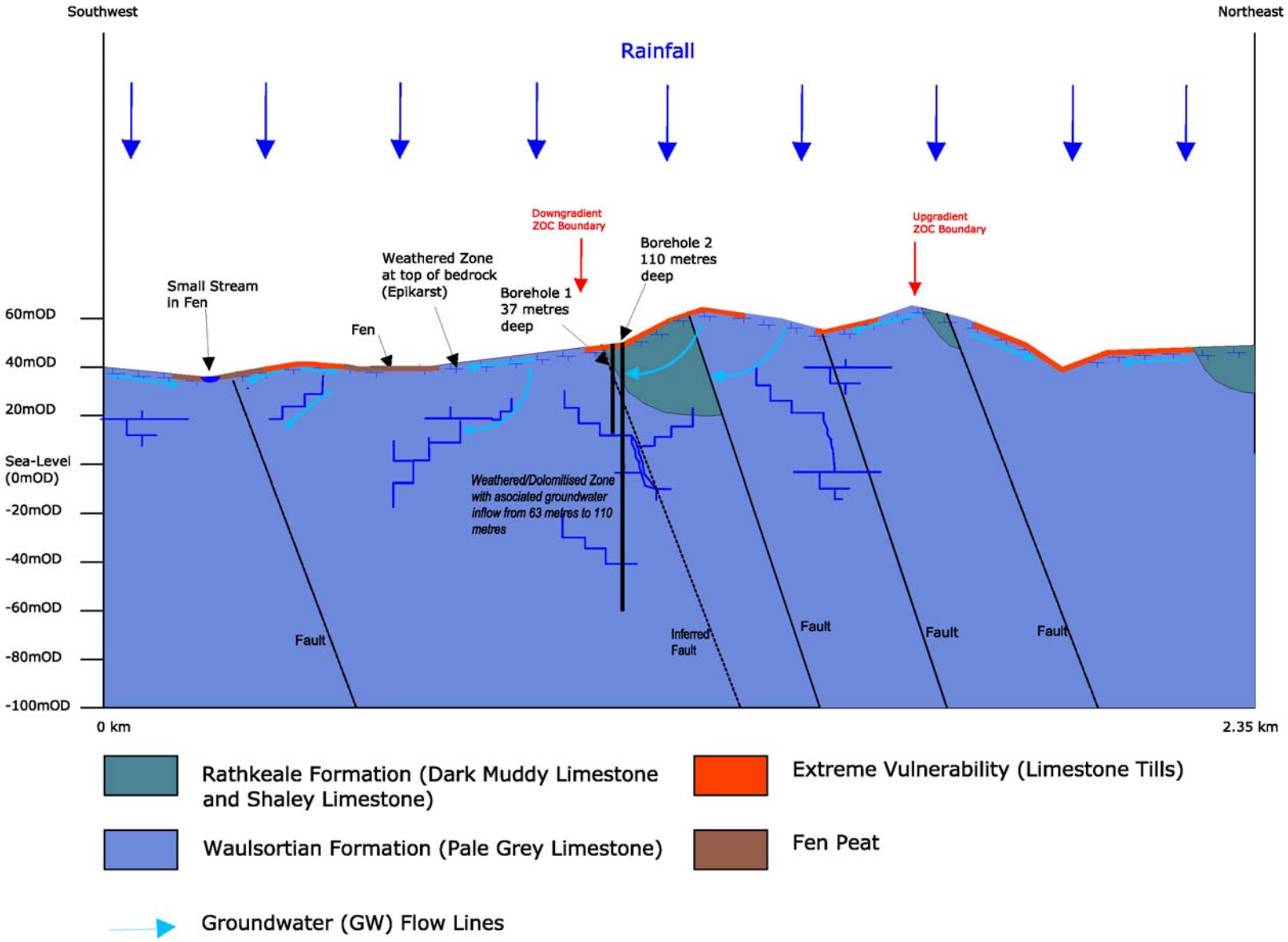
Approximately 70% of the effective rainfall (335 mm) is assumed to infiltrate to groundwater as diffuse recharge though the extreme vulnerability soil cover within the catchment to the well. The remainder is expected to run off to surface water.

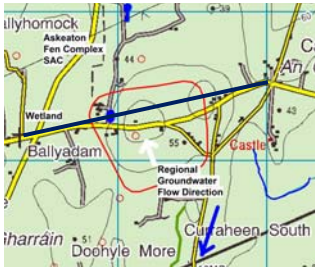
Bedrock groundwater flow occurs in joints, fractures and conduits, and along bedding planes in the limestone bedrock and in a network of interconnected fractures and karst conduits up to 30 metres below the rock surface. Deeper inflows can occur in areas associated with faults or dolomitisation, and conduits have been encountered at 60 metres below ground level in the area (GSI, 2004). Diffuse recharge is expected to recharge to the weathered/fractured epikarst zone at the top of the bedrock. The deeper fractures are likely to be sustained by percolation of water from the overlying epikarst layer.

The shallow water table is likely to mirror the local topographic slope; therefore the localised groundwater flow direction is estimated to the west, towards the boreholes and the fen/wetland beyond. Boreholes will capture flow through the weathered zone where they intersect and are open to it. Deeper conduit development is expected to form along north to northwest trending lineaments in the Waulsortian Limestone, including an inferred fault which is mapped as running in a north-northwesterly direction though the borehole compound. Groundwater flow in the deeper conduit system is expected to be directed to the north-northwest, towards the Shannon Estuary.

Borehole 1 is approximately 37 metres deep. It is likely to draw water from the shallow, epikarst layer, and from deeper fractures or conduits. Borehole 2 is expected to be 110 metres deep (similar to the trial well). Both boreholes are likely to puncture through the mapped Rathkeale Formation into the underlying Waulsortian Formation bedrock. Borehole 2 is likely to draw water from the shallow, epikarst layer, and from the deeper fractures or conduits intercepted by the trial well. The lower portion of the trial well borehole from 63 metres below ground level, encountered yellow weathered bedrock with associated and increase in groundwater inflow. This weathering is typical of limestone which has been fractured and dolomitised. If the fracturing is connected to a deeper regional karst conduit, then the zone of contribution could extend many square kilometres in area, encompassing the zone of contribution to that conduit.

The available water quality data suggest that the chemical water quality is good. The presence of *E. Coli* indicates faecal contamination (human or animal) of the borehole water supply. *E.Coli* could seep into the bedrock aquifer from poorly constructed onsite wastewater treatment systems and slurry pits, and from the land spreading of farmyard manure and slurry on lands where a thin soil cover exists over the limestone bedrock.





Cappagh GWS
Cross Section Line

Diagram 3: Schematic Cross Section and Conceptual Model

Boundaries

The boundaries of the area contributing to the source are considered to be as follows, and are based on a combination of hydrogeological mapping and topography (**Figure 7**):

The **western** boundary is the downgradient boundary. It is located 138 m west and northwest of the Cappagh Priest Field boreholes (**Appendix 9**).

The **north-western** boundary is defined by the downgradient boundary and by groundwater flow lines to the boreholes.

The **south-western** boundary runs parallel to an inferred fault, which is likely to provide a flow pathway for groundwater to reach the boreholes. The boundary is offset to the west from the inferred fault by 100 m.

The **north-eastern** boundary is defined by upgradient ridge line, and encompasses the north-westerly portion of a mapped fault, which is likely to provide a flow pathway for groundwater.

The **south-eastern** boundary is defined to encompass an area which may have unmapped faulting or fractures which will permit groundwater flow to the northwest. Rainfall percolating to ground outside this boundary is likely to flow to the south, away from the boreholes.

The delineation of the boundaries includes a safety margin for some variability in groundwater flow direction, the alignment of faulting and for some variability in the location of the mapped geological units.

Recharge and water balance

Recharge to the ZOC is estimated as 335mm/year (see **Table 2**). At a recharge rate of 335 mm/yr the 150 m^3/day abstraction rate requires a ZOC of 0.16 km^2 to capture the required volume of diffuse recharge to balance the abstraction. The delineated ZOC has an area of 0.44 km^2 and is considered adequate to meet the demand of the scheme.

5. Conclusions

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

The current average abstraction for the Cappagh GWS Priest Field wells is 99 m^3/day, and is provided by two no. boreholes. Borehole 1 was drilled in the 1960's, borehole 2 was drilled in 2004. The boreholes are pumped alternatively, for up to 10 hours on alternative nights.

The ZOC delineation was based on hydrogeological mapping. The extended delineated ZOC has an area of 0.44 km^2 and protects areas locally contributing recharge to the boreholes. The ZOC is more than adequate to provide groundwater for 150% of the current demand (i.e. 99 m^3/day), which conservatively allows for short peaks in demand above the long term abstraction rate, and is the maximum yield capable from the borehole. The relatively large size of the mapped ZOC (3 times the area required as per the water balance calculations) is typical of catchment zones developed in karst limestone terrain, where it is difficult to accurately assess the groundwater flow direction.

The Cappagh GWS Priest Field boreholes are considered to be supplied with groundwater from within the shallow bedrock, from fractures within the Rathkeale Formation and from a karst conduit or fracture system within the Waulsortian Formation. The groundwater vulnerability within the extended ZOC is mapped as Extreme with rock close to the surface (24%), Extreme (54%), and high (23%) indicating there bedrock is close to the surface within 24% of the catchment, and within 3 metres of the surface over 78 % of the catchment. This categorisation enables the GWS to prioritise areas of risk when auditing or mapping potential hazards, or areas to investigate if a pollution incident does occur.

The land-use in the vicinity of the borehole is a mix of agricultural grazing land; farmyards; and one-off residential dwelling houses, each with their own on-site wastewater treatment and disposal systems. There are nine dwelling houses with associated wastewater treatment and disposal systems; and 2 farmyards within the mapped ZOC, which are likely to pose a risk to groundwater quality in the greater catchment.

Raw water quality samples collected and analysed by Limerick County Council indicate the microbiological water quality is generally good, with occasional detections of *E.Coli*. The presence of *E.Coli* detected in both boreholes indicates microbiological contamination of both groundwater sources. This highlights the vulnerability of the groundwater source to faecal/microbial contamination within the catchment area resulting from human and animal activity. Nitrate levels in the new borehole were low in 2004 (6 mg/l). A review of treated water samples from the Priest Field wells indicates nitrate levels in the groundwater have increased since 2004 to 16.7 mg/l in 2008, which may result from land spreading of fertilizer and farmyard manure in the ZOC. Limerick County Council analytical results indicates the chemical water quality from the borehole is good.

6. Recommendations

Essential

Routine analysis of the untreated or raw water along with the existing analysis of treated water around the distribution network should be undertaken. It is recommended that this is carried out on an annual basis, and at least once after a rainfall event.

The following water quality parameters are considered essential:

- total and faecal coliforms, pH, alkalinity, turbidity, hardness, electrical conductivity, nitrate, nitrite, ammonia, iron, manganese, chloride, sodium and potassium.

It is also recommended to analyse for the following parameters:

- clostridium perfringens (cryptosporidium indicator)
- The basic untreated groundwater analytical suite used by the NFGWS in Summer 2014 should be used for monitoring untreated water quality where more detailed assessments of water quality are required (see **Appendix 10**).

No land spreading of fertilizer/slurry should occur within 100 m of the borehole location[10].

Desirable

No land spreading of fertilizer/slurry should occur on lands upgradient of the borehole supply wells, or on lands where bedrock outcrops at the surface within the ZOC.

The GWS should seek advice with respect to undertaking a cryptosporidium risk assessment for this supply.

Comprehensive hazard mapping within the delineated ZOC should be undertaken. Any risks of contamination to the supply, such as onsite wastewater treatment systems, farmyards, can be assessed by comparing these to the delineated ZOC and groundwater vulnerability map (**Figure 4**).

On-site wastewater treatment system and disposal systems within the catchment of the borehole should be inspected, and if necessary upgraded to current wastewater treatment guidelines.

A dip tube should be installed in Borehole 2 to enable monitoring of the borehole water level.

Karst mapping of the area should be undertaken to identify karst features and, in particular, any locations where point recharge can take place within the ZOC (i.e. swallow holes, dolines). Tracer testing should be carried out at the sinking stream, southeast of the borehole location, to establish if there is any connection with the groundwater supply wells.

The following EPA guidelines may serve as future useful reference documents for the Cappagh GWS:

- EPA Drinking Water Advice Note No. 7: Source Protection and Catchment Management to Protect Groundwater Sources. Of particular interest would be Section 4.1 – Step 2 – Hazard Mapping[11].
- EPA Drinking Water Advice Note No. 8: Developing Drinking Water Safety Plans. This document contains checklists for hazards which would assist in hazard mapping within the ZOC[12].

[10] S.I No. 31 of 2014, European Union (Good Agricultural Practice for the Protection of Waters) Regulations, 2014.
[11] http://www.epa.ie/pubs/advice/drinkingwater/epadrinkingwateradvicenote-advicenoteno7.html#.UpNP_eJ9KEp
[12] http://www.epa.ie/pubs/advice/drinkingwater/epadrinkingwateradvicenote-advicenoteno7.html#.UpNP_eJ9KEp

7. References

DELG/EPA/GSI, 1999. Groundwater Protection Schemes. Dept. of the Environment & Local Government; Environmental Protection Agency; Geological Survey of Ireland.

European Communities (Drinking Water) Regulations (2014). S.I. No. 122 of 2014.

European Communities Environmental Objectives (Groundwater) Regulations, 2010. S.I. No. 9 of 2010.

EPA website: www.gis.epa/Envision/

EPS, Abstraction Rates January 2013 to August 2014 (See Appendix 1)

GSI website: www.gsi.ie

Geological Survey of Ireland (2004) Askeaton Draft Groundwater Body Characterisation Report

GES Ltd (2007) Preliminary Source Protection Report, Cappagh GWS

Met Eireann website: www.met.ie

Mills, G. (2000). Modelling the water budget of Ireland—evapotranspiration and soil moisture. *Irish geography*, *33*(2), 99-116.

Sleeman, A.G., and Pracht, M., 1999. Geology of the Shannon Estuary. A Geological Description to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 17, Geology of the Shannon Estuary. Geological Survey of Ireland.

T.J. O'Connor & Associates, (2003). Limerick GWS DBO Contract, Vol. 3, Site Information.

Todd, D.K., 1980. Groundwater Hydrology. 2nd Edition New York: John Wiley & Sons.

Working Group on Groundwater (2005). Guidance on the Assessment of the Impact of Groundwater Abstractions.

Acronyms and glossary of terms

BGL	Below Ground Level
EPA	Environmental Protection Agency
DEHLG	Department of Environment Heritage and Local Government
EQS	Environmental Quality Standard
EU	European Union
GPZ	Groundwater Protection Zone
GSI	Geological Survey of Ireland
GWB	Groundwater Body
GWD	Groundwater Directive (European Union)
GWS	Group Water Scheme
IGI	Institute of Geologist of Ireland
MOD	Metres Ordnance Datum
MRP	Molybdate-Reactive Phosphorus
NRG	National Grid Reference
NRWMC	National Rural Water Monitoring Committee
PVC	Polyvinyl Chloride
SPZ	Source Protection Zones
TOT	Time of Travel
TVs	Threshold Values
UV	Ultra-Violet
ZOC	Zone of Contribution
WFD	Water Framework Directive (European Union)

Glossary of Terms

Aquifer
A subsurface layer or layers of rock, or other geological strata, of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater (Groundwater Regulations, 2010).

Attenuation
A decrease in pollutant concentrations, flux, or toxicity as a function of physical, chemical and/or biological processes, individually or in combination, in the subsurface environment.

Borehole
A particular type of well - a narrow hole in the ground constructed by a drilling machine in order to gain access to the groundwater system.

Conceptual Hydrogeological Model
A simplified representation or working description of how a real hydrogeological system is believed to behave on the basis of qualitative analysis of desk study information, field observations and field data.

Confined Aquifer
A confined aquifer occurs where the aquifer is overlain by low permeability "confining" material. Once all the void space in the aquifer is full of water up to the confining layer, the addition of more water to the aquifer causes the stored water to become pressurised and, the additional water is stored by compression, sealed in by the overlying confining layer (the water is added upgradient where the confining layer is absent). Where a borehole punctures the confining layer, the water will rise up into the borehole to equalise the confining pressure.

Diffuse Sources
Diffuse sources of pollution are spread over wider geographical areas rather than at individual point locations. Diffuse sources include general land use activities and landspreading of industrial, municipal wastes and agricultural organic and inorganic fertilisers.

Direct Input
An input to groundwater that bypasses the unsaturated zone (e.g. direct injection through a borehole) or is directly in contact with the groundwater table in an aquifer either year round or seasonally.

Doline
Or enclosed depressions are relatively shallow bowl or funnel shaped depressions that form in karst landscapes, and serve to funnel or concentrate recharge underground. Their presence indicates that subterranean drainage is in operation.

Dolomitisation
Is a process, whereby the calcite crystals in limestone is replaced by magnesium. This results in an increase in the porosity and permeability of the rock. Dolomitised rocks are a highly weathered, yellow/orange/brown colour and are usually evident in boreholes as loose yellow-brown sand with significant void space and poor core recovery. Dolomitisation often occurs preferentially in both fault zones and purer limestones.

Down-gradient
The direction of decreasing groundwater levels, i.e. flow direction. Opposite of upgradient.

Dry Weather Flow (Receiving Water)
The minimum flow likely to occur in a surface water course during a prolonged drought.

Environmental Quality Standard (EQS)
The concentration of a particular pollutant or group of pollutants in a receiving water which should not be exceeded in order to protect human health and the environment.

Enclosed Depression
See doline

Fissure
A natural crack in rock which allows rapid water movement.

Good Groundwater Status
Achieved when both the quantitative and chemical status of a groundwater body are good and meet all the conditions for good status set out in Groundwater Regulations 2010, regulations 39 to 43.

Groundwater
All water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil (Groundwater Regulations, 2010).

Groundwater Body (GWB)
A volume of groundwater defined as a groundwater management unit for the purposes of reporting to the European Commission under the Water Framework Directive. Groundwater bodies are defined by aquifers capable of providing more than 10 m3/d, on average, or serving more than 50 persons.

Groundwater Protection Scheme (GWPS)
A scheme comprising two principal components: a land surface zoning map which encompasses the hydrogeological elements of risk (of pollution); and a groundwater protection response matrix for different potentially polluting activities (DELG/EPA/GSI, 1999).

Groundwater Protection Responses (GWPR)
Control measures, conditions or precautions recommended as a response to the acceptability of an activity within a groundwater protection zone.

Groundwater Protection Zone (GPZ)
A zone delineated by integrating aquifer categories or source protection areas and associated vulnerability ratings. The zones are shown on a map, each zone being identified by a code, e.g. SO/H (outer source area with a high vulnerability) or Rk/E (regionally important karstified aquifer with an extreme vulnerability). Groundwater protection responses are assigned to these zones for different potentially polluting activities.

Groundwater Recharge
Two definitions: a) the process of rainwater or surface water infiltrating to the groundwater table; b) the volume (amount) of water added to a groundwater system.

Groundwater Resource
An aquifer capable of providing a groundwater supply of more than 10 m3/d as an average or serving more than 50 persons.

Hydraulic Conductivity
The rate at which water can move through a unit volume of geological medium under a potential unit hydraulic gradient. The hydraulic conductivity can be influenced by the properties of the fluid, including its density, viscosity and temperature, as well as by the properties of the soil or rock.

Hydraulic Gradient
The change in total head of water with distance; the slope of the groundwater table or the piezometric surface.

Igneous
Igneous rock is formed through the cooling and solidification of magma or lava.

Indirect Input
An input to groundwater where the pollutants infiltrate through soil, subsoil and/or bedrock to the groundwater table.

Input
The direct or indirect introduction of pollutants into groundwater as a result of human activity.

Karst

A distinctive landform characterised by features such as surface collapses, sinking streams, swallow holes, caves, turloughs and dry valleys, and a distinctive groundwater flow regime where drainage is largely underground in solutionally enlarged fissures and conduits.

Karstification

Karstification is the process whereby limestones are slowly dissolved by acidic waters moving through them. This results in the development of an uneven distribution of permeability with the enlargement of certain fissures at the expense of others and the concentration of water flow into these high permeability zones. Karstification results in the progressive development of distinctive karst landforms such as caves, swallow holes, sinking streams, turloughs and dry valleys, and a distinctive groundwater flow regime. It is an important feature of Irish hydrogeology.

Pathway

The route which a particle of water and/or chemical or biological substance takes through the environment from a source to a receptor location. Pathways are determined by natural hydrogeological characteristics and the nature of the contaminant, but can also be influenced by the presence of features resulting from human activities (e.g., abandoned ungrouted boreholes which can direct surface water and associated pollutants preferentially to groundwater).

Permeability

A measure of a soil or rock‘s ability or capacity to transmit water under a potential hydraulic gradient (synonymous with hydraulic conductivity).

Point Source

Any discernible, confined or discrete conveyance from which pollutants are or may be discharged. These may exist in the form of pipes, ditches, channels, tunnels, conduits, containers, and sheds, or may exist as distinct percolation areas, integrated constructed wetlands, or other surface application of pollutants at individual locations. Examples are discharges from waste water works and effluent discharges from industry.

Pollution

The direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land which may be harmful to human health or the quality of aquatic ecosystems or terrestrial ecosystems directly depending on aquatic ecosystems which result in damage to material property, or which impair or interfere with amenities and other legitimate uses of the environment (Groundwater Regulations, 2010).

Poorly Productive Aquifers (PPAs)

Low-yielding bedrock aquifers that are generally not regarded as important sources of water for public water supply but that nonetheless may be important in terms of providing domestic and small community water supplies and of delivering water and associated pollutants to rivers and lakes via shallow groundwater pathways.

Preferential Flow

A generic term used to describe water movement along favoured pathways through a geological medium, bypassing other parts of the medium. Examples include pores formed by soil fauna, plant root channels, weathering cracks, fissures and/or fractures.

Saturated Zone

The zone below the water table in an aquifer in which all pores and fissures and fractures are filled with water at a pressure that is greater than atmospheric.

Soil (topsoil)

The uppermost layer of soil in which plants grow.

Source Protection Area

The catchment area around a groundwater source which contributes water to that source (Zone of Contribution), divided into two areas; the Inner Protection Area (SI) and the Outer Protection Area (SO). The SI is designed to protect the source against the effects of human activities that may have an immediate effect on the source, particularly in relation to microbiological pollution. It is defined by a 100-day time of travel (TOT) from any point below the water table to the source. The SO covers the remainder of the zone of contribution of the groundwater source.

Specific Yield
The specific yield is the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline of the water table.

Spring
A spring is a natural feature where groundwater emerges at the surface. Springs usually occur where the rate of flow of groundwater is too great to remain underground. The position of a springs usually reflects a change in soil or rocktype or a change in slope.

Subsoil
Unlithified (uncemented) geological strata or materials beneath the topsoil and above bedrock.

Surface Water
An element of water on the land‘s surface such as a lake, reservoir, stream, river or canal. Can also be part of transitional or coastal waters. (Surface Waters Regulations, 2009.).

Swallow Hole
The point where concentrated inflows of water sink underground. They are found in karst environments.

Threshold Values (TVs)
Chemical concentration values for substances listed in Schedule 5 of the Groundwater Regulations (2010), which are used for the purpose of chemical status classification of groundwater bodies.

Till
Unsorted glacial Sediment deposited directly by the glacier. It is the most common Quaternary deposit in Ireland. Its components may vary from gravel, sands and clays.

Transmissivity
Transmissivity is the product of the average hydraulic conductivity of the aquifer and the saturated thickness of the aquifer.

Unsaturated Zone
The zone between the land surface and the water table, in which pores, fractures and fissures are only partially filled with water. Also known as the vadose zone.

Vulnerability
The intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities (Fitzsimmons et al, 2003).

Water Table
The uppermost level of saturation in an aquifer at which the pressure is atmospheric.

Weathering
The breakdown of rocks and minerals at the earth's surface by chemical and physical processes.

Zone of Contribution (ZOC)

The area surrounding a pumped well or spring that encompasses all areas or features that supply groundwater to the well or spring. It is defined as the area required to support an abstraction and/or overflow (in the case of springs) from long-term groundwater recharge.

Figures

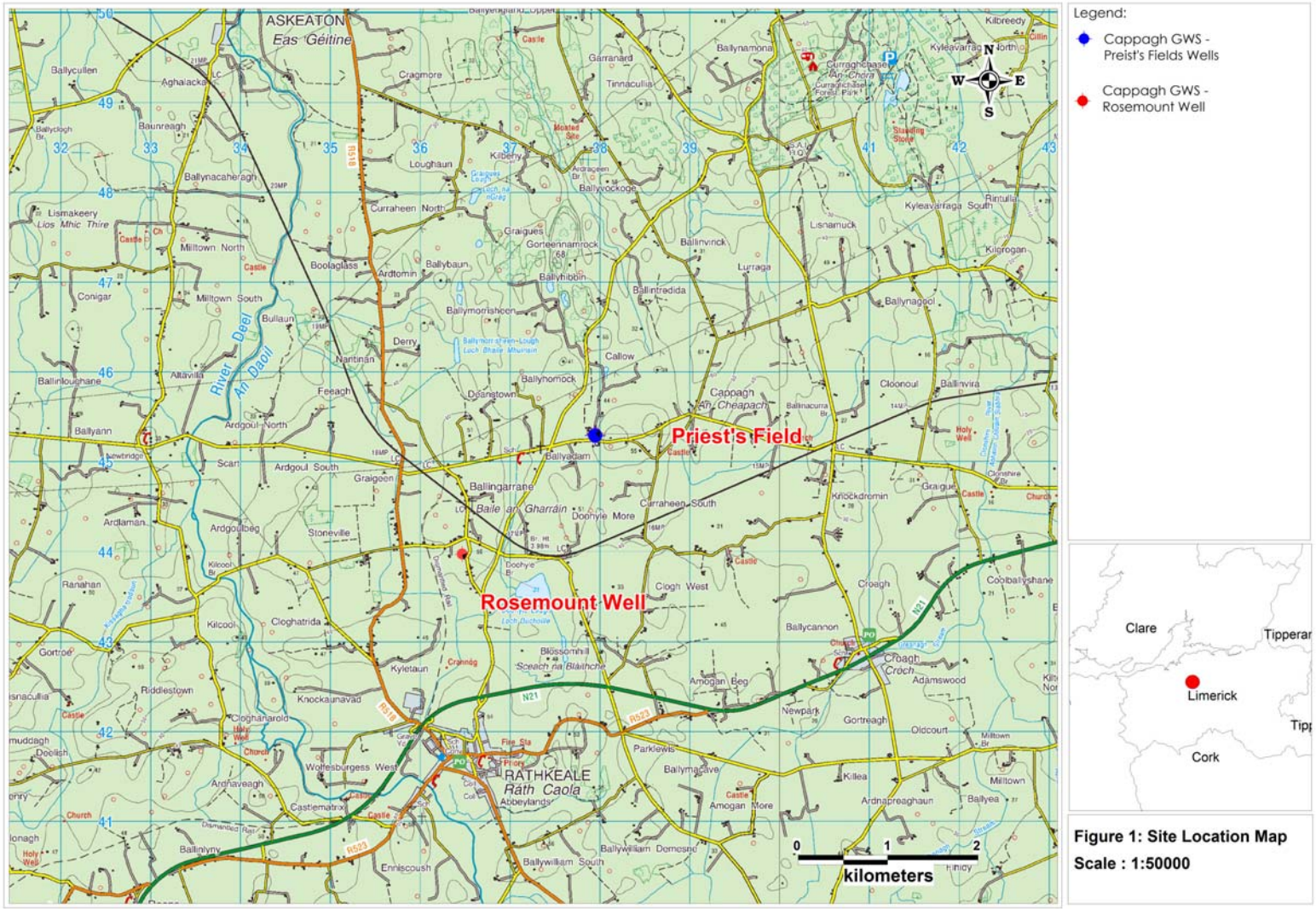


Figure 1: Site Location Map
Scale : 1:50000

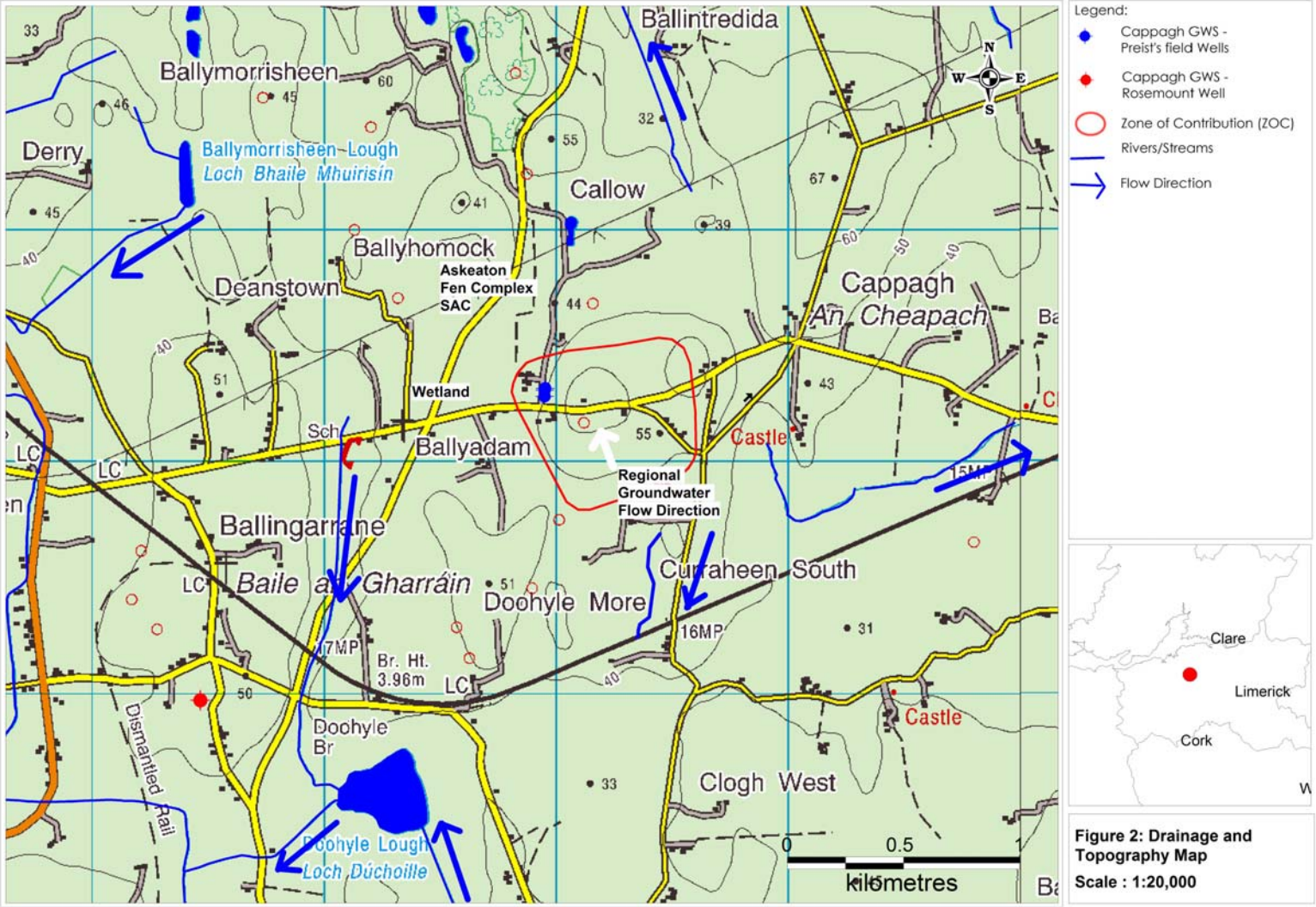


Figure 2: Drainage and Topography Map

Scale : 1:20,000

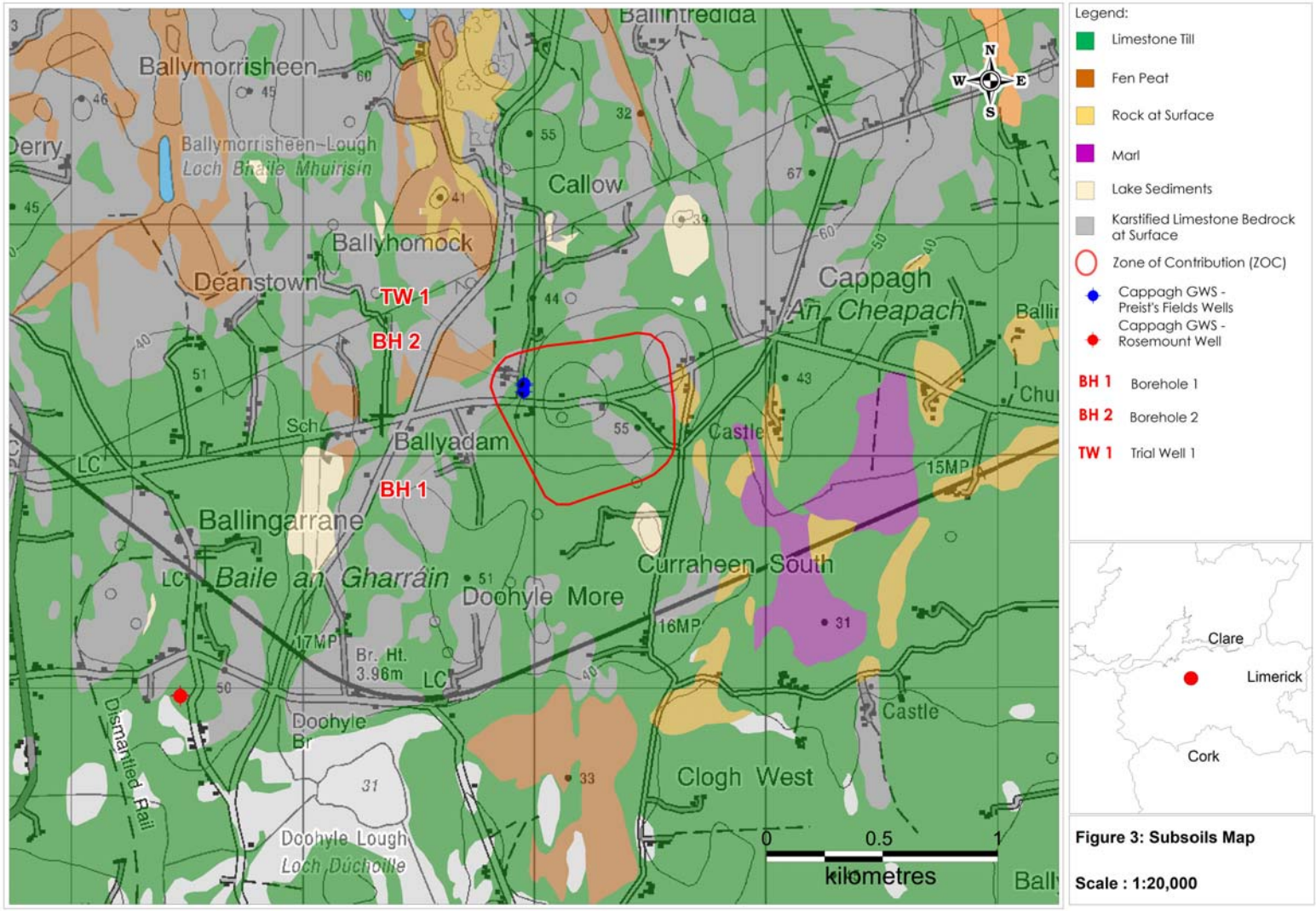


Figure 3: Subsoils Map

Scale : 1:20,000

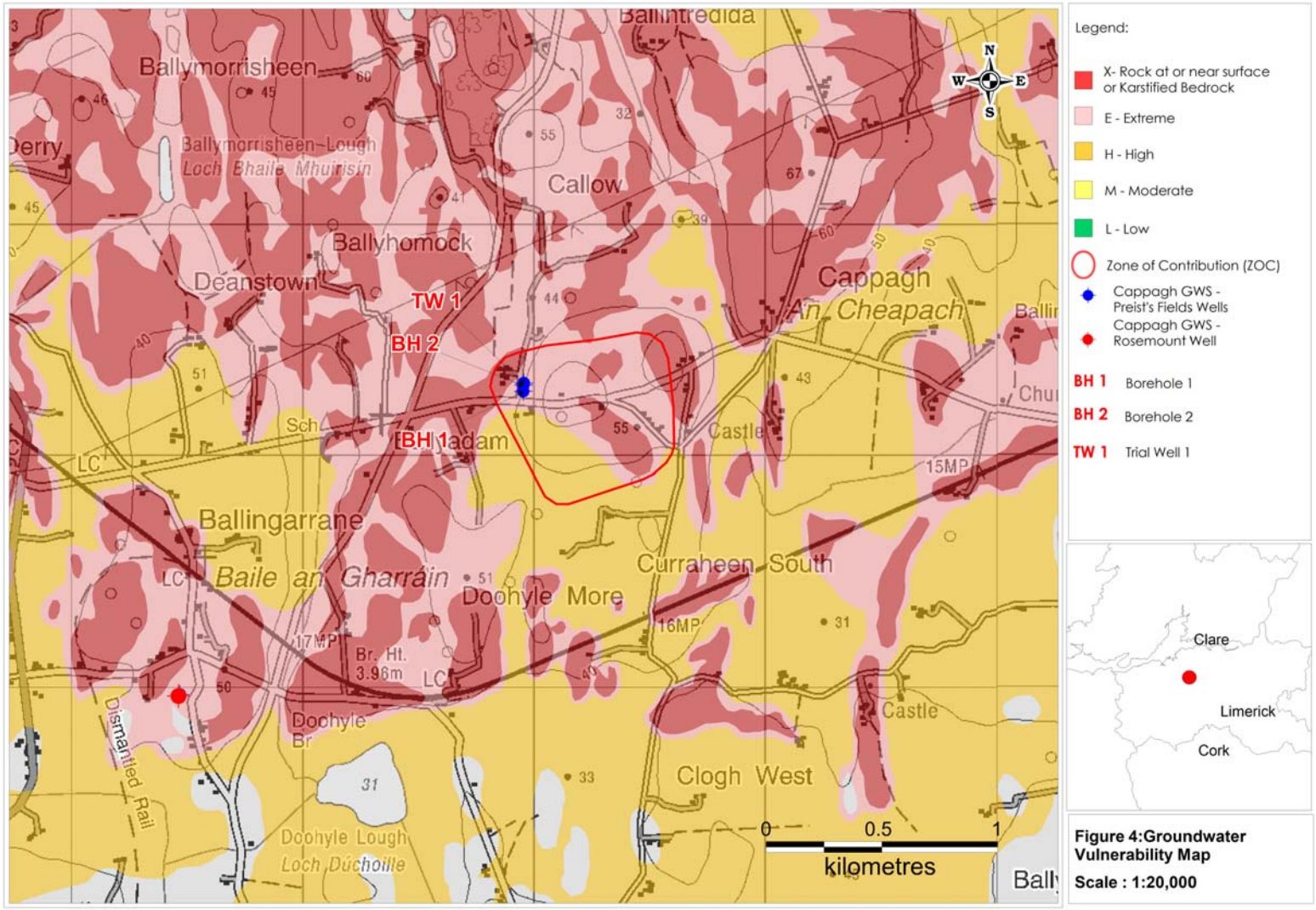
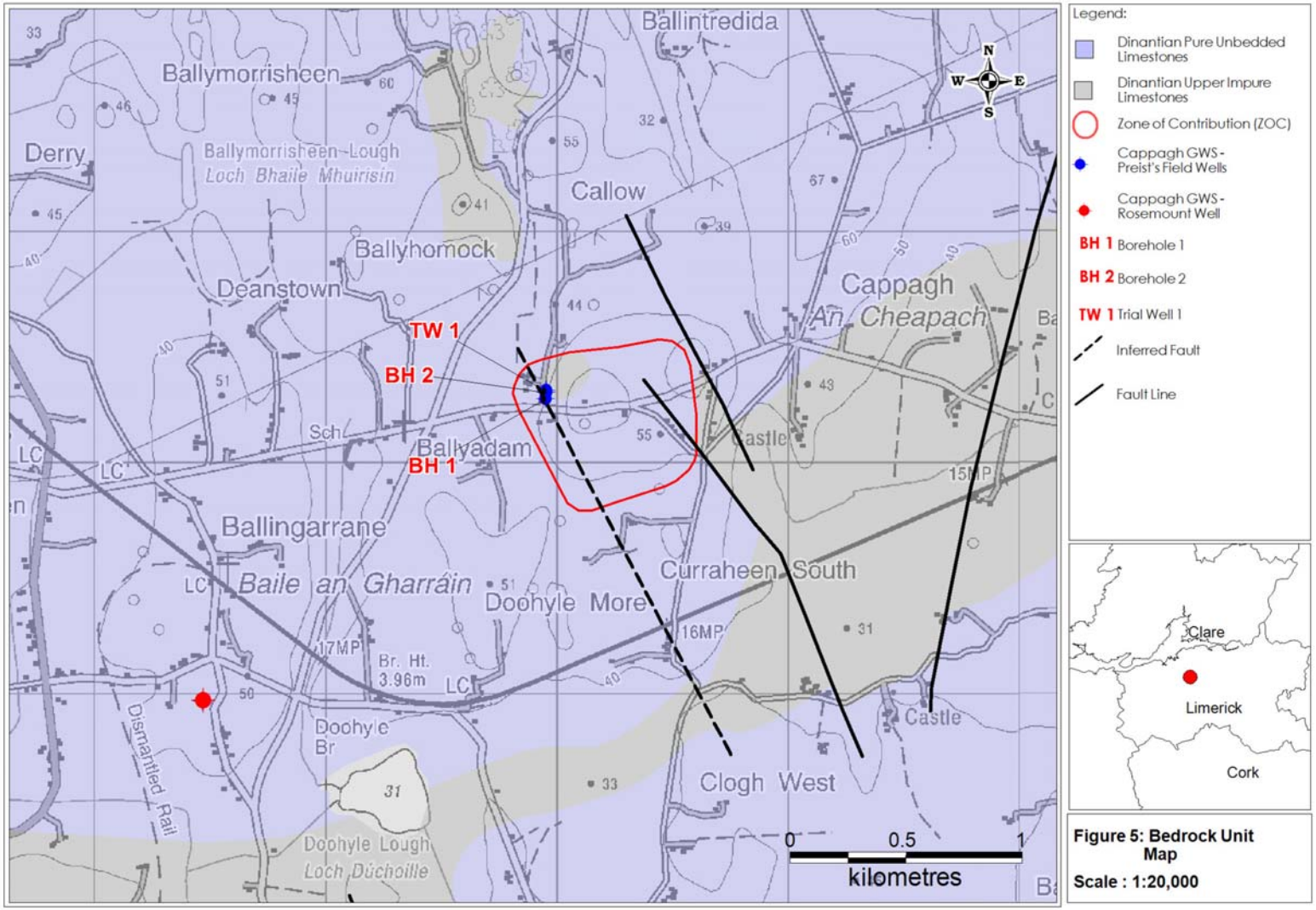


Figure 4:Groundwater Vulnerability Map

Scale : 1:20,000



Legend:

- Dinantian Pure Unbedded Limestones
- Dinantian Upper Impure Limestones
- Zone of Contribution (ZOC)
- Cappagh GWS - Preist's Field Wells
- Cappagh GWS - Rosemount Well
- BH 1 Borehole 1
- BH 2 Borehole 2
- TW 1 Trial Well 1
- Inferred Fault
- Fault Line

Figure 5: Bedrock Unit Map

Scale : 1:20,000

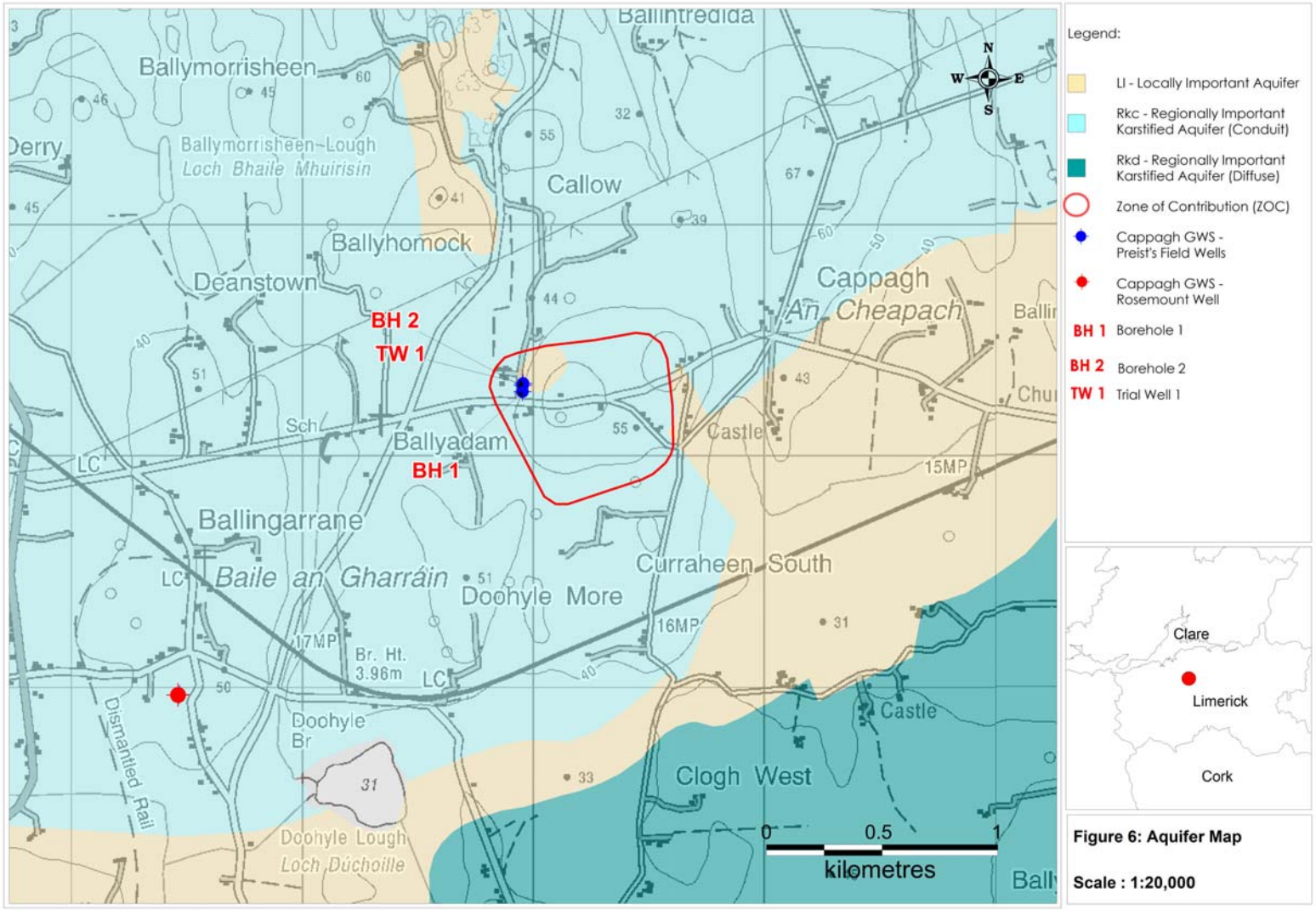


Figure 6: Aquifer Map

Scale : 1:20,000

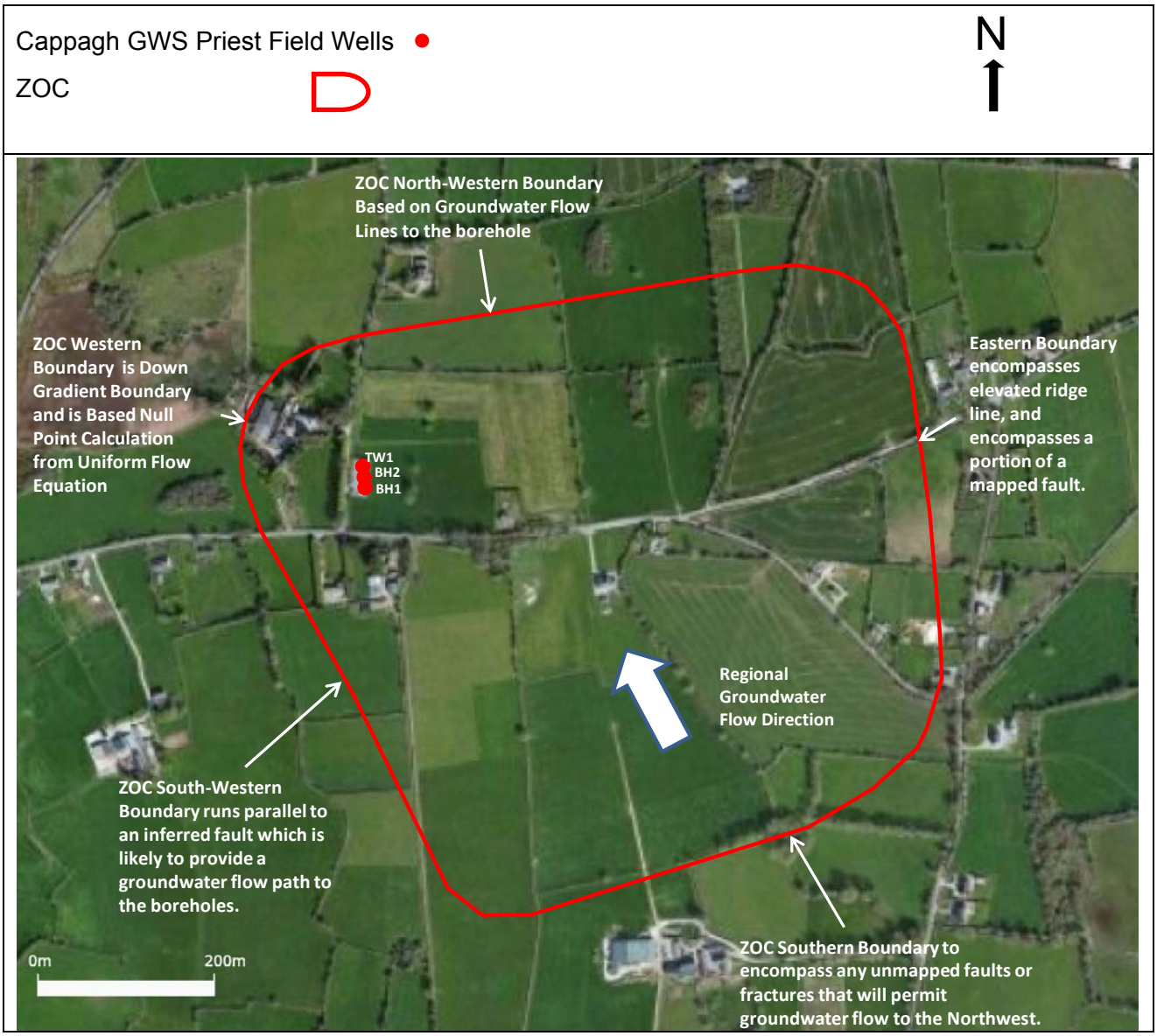


Figure No: 7		Client: Cappagh GWS	Parkmore Environmental Services Ltd	Kilcosgriff, Shanagolden, Co. Limerick. Tel: 087 2823873 Email: info@parkmore.ie Web: parkmore.ie
Sheet Size: A4		Job: Source Protection Zone		
Date: 20/1/2014		Title: ZOC Boundaries		
Scale: Not to Scale		Job Number: C001657		
Drawn By: RL	Checked By: RL	Drawing Number: 07		

Figure 7: ZOC Boundaries (Source: Bing Maps)

APPENDIX 1

Cappagh GWS Abstraction Rates

2013 to 2014

Month	Cappagh Rosemount- Total flow m³	Cappagh Rosemount- Average Daily flow m³	Cappagh Priest Field- Total flow m³	Cappagh Priest Field- Average Daily flow m³	Cappagh GWS Total Daily Flow
Jan-13	747	24	2,817	91	115
Feb-13	649	23	2,485	89	112
Mar-13	868	28	3,168	102	130
Apr-13	1,259	42	2,419	81	123
May-13	847	27	3,090	100	127
Jun-13	937	31	3,516	117	148
Jul-13	1,037	33	3,913	126	159
Aug-13	918	30	3,508	113	143
Sep-13	1,264	42	3,447	115	157
Oct-13	863	28	3,493	113	141
Nov-13	1,431	48	3,185	106	154
Dec-13	1,077	35	4,115	133	168
Jan-14	1,597	52	3,405	110	162
Feb-14	1,808	65	2,639	94	159
Mar-14	1,524	49	3,215	104	153
Apr-14	1,553	52	3,377	113	165
May-14	3,475	112	1,449	47	159
Jun-14	2,969	99	2,069	69	168
Jul-14	3,110	100	2,634	85	185
Aug-14	3,190	103	2,441	79	182
	Average	51.15	Average	99.35	151
	Max	112	Max	133	185
	Minimum	23	Min	47	112

APPENDIX 2

Borehole Log for Trial Well 1

KEY IS beside Telegraph pole, behind WELL

Patrick Briody & Sons Ltd.

DRILLING LOG

AQUADRILL SERVICES **Well Drilling & Site Investigation Contractors**

The Grove,
Rathangan,
Co. Kildare.
Tel (045) 524360
Fax (045) 524785
e-mail: info@briodydrilling.com

Consultant/Engineer T.J. O'Connor & Assoc.

Client Limerick Co. Co.

Borehole Reference No. BH2 Sheet 1 of 1

Borehole Location Cappagh.

№ 0152

Date of Drilling	Depth (from - to) mtrs/ft.	Actual Drilling Diametre	Drilling Conditions / Water Strike
13.1.04.	0 — 1ft	10"	Soil
	1ft — 15ft	"	Firm Clay occ boulder
	15ft — 17ft	"	Broken Rock
	17ft — 36ft	8" from 19ft	Stable Rock. Limestone
	36ft — 38ft	8"	weathered section
	38ft — 59ft.		Stable Rock.
	59ft — 60ft		Soft section water strike 20gph.
	60ft — 106ft		Stable Rock.
	106ft — 118ft.		Weathered Rock small fracture, water
	108ft		Sandy, Clay 100 gph
	114ft		More water 300 gph small fracture
	118ft — 176ft		Stable Rock
	176ft — 177ft		weathered Section
	177ft — 209ft		Stable Rock.
	209ft — 228ft.	223ft 600gph	weathered section fracture
	228ft — 258ft		Stable Rock.
	258ft — 259ft.		Fracture Brown sandy section
			large lumps of weathered limestone
	259ft — 297ft		additional water STRIKE
			Stable Rock.
	297ft — 301ft		weathered section, Sandy orange
	301ft — 317ft		in colour additional water
	317ft — 360ft		STABLE ROCK
			Yellow weathered limestone

Total Depth of Well 360ft

Estimated Yield APPROX 1000 gph

Depth to Rock 15ft to Broken Rock

Steel Casing Installed 21ft 8" STEEL

P.V.C. Casing/~~Screen~~ screen Installed 360ft 5" PVC

Other Remarks Installed 360ft of 5" PVC

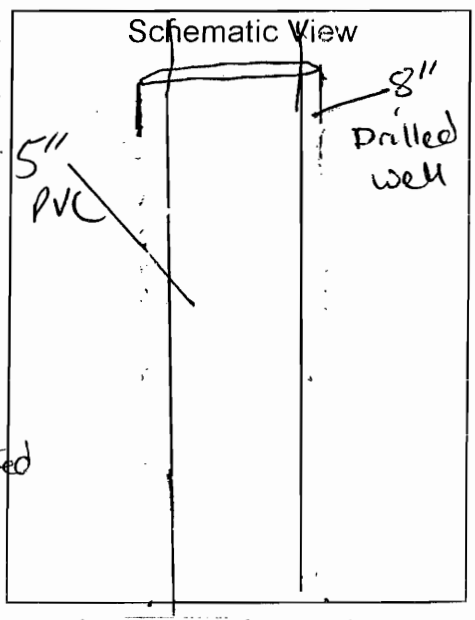
As instructed, as large limestone

Pieces and orange sand deposits

coming to surface, Welded 8" lid and lock fitted

Lead Driller C Boots Drilling Rig Reich

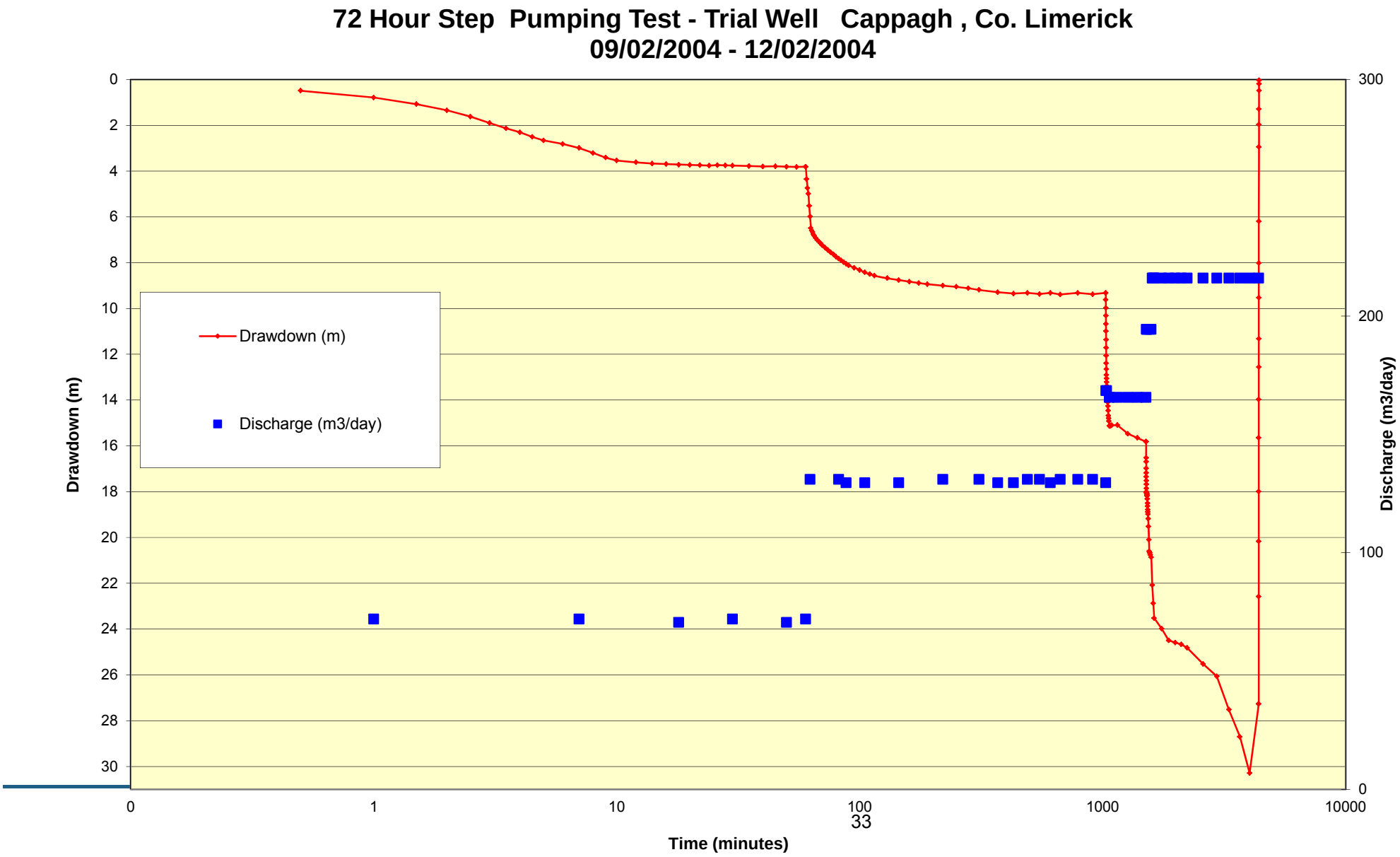
Engineer Approval



Air Lifted well for total of 4 HR until clear.

APPENDIX 3

Pumping Test Data Trial Well 1


72 Hour Step Pumping Test - Trial Well Cappagh , Co. Limerick
09/02/2004 - 12/02/2004
Drawdown (m)
Discharge (m3/day)
Drawdown (m)
Discharge (m3/day)
Time (minutes)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
300
200
100
0
0
1
10
100
1000
10000

.Seamus A kelly

.BOREHOLE LOCATION	CAPPAGH	.WELL NO ;
.COUNTY	LIMERICK	SHEET TYPE ;START STEP 1
PUMP TYPE:	2000 GPH	
.DATE	10/02/2004	WEATHER ;FINE
PUMP INTAKE	55M	
.DIA OF WELL	125mm PLASTIC	DISCHARGE DISTANCE ;100M
HEIGHT OF MEASUREMENT ABOVE G.L : 1.10M		PURCHASE/ ORDER NO.

Time	Elasped Time	WELL NO	OBS WELL	METER	FLOW RATE	
2.48PM	0	6.93	19.01	22204.9		
	0.5	7.42				
	1	7.72			50 L / M	
	1.5	8.01				
	2	8.28				
	2.5	8.55				
	3	8.83				
	3.5	9.06				
	4	9.24				
	4.5	9.44				
	5	9.59				
	6	9.75				
	7	9.92			50 L / M	
	8	10.14				
	9	10.34				
	10	10.47				
	12	10.55				
	14	10.6				
	16	10.62				
	18	10.65			49 L / M	
	20	10.66				
	22	10.67				
	24	10.69				
	26	10.67				
	28	10.68				
	30	10.69			50 L / M	
	35	10.71				
	40	10.73				
	45	10.72				
	50	10.74			49 L / M	
	55	10.75				
	60	10.74		22208.1	50 L / M	
	75					
	90					
	105					
	120					
	150					
	180					
	210					
	240					

.Seamus A kelly

.BOREHOLE LOCATION	CAPPAGH	.WELL NO ;
.COUNTY	LIMERICK	SHEET TYPE ;START STEP 2
PUMP TYPE:	2000 GPH	
.DATE	10/02/2004	WEATHER ;FINE
PUMP INTAKE	55M	
.DIA OF WELL	125mm PLASTIC	DISCHARGE DISTANCE ;100M
HEIGHT OF MEASUREMENT ABOVE G.L : 1.10M		PURCHASE/ ORDER NO.

Time	Elasped Time	WELL NO	OBS WELL	METER	FLOW RATE
3.48PM	0	10.74		22208.3	
	0.5	11.28			
	1	11.67			
	1.5	11.92			
	2	12.45			WATER CASCADING @ 12M
	2.5	12.92			91 L / M
	3	13.42			
	3.5	13.53			
	4	13.6			
	4.5	13.69			
	5	13.75			
	6	13.85			
	7	13.94			91 L / M
	8	14.01			
	9	14.08			
	10	14.16			
	12	14.27			
	14	14.38			
	16	14.48			
	18	14.57			
	20	14.66			
	22	14.75			91 L / M
	24	14.83			
	26	14.91			
	28	14.98			90 L / M
	30	15.05			
	35	15.15			
	40	15.25			
	45	15.35			90 L / M
	50	15.43			
	55	15.5			
	60	15.61		22213.5	
	75	15.69			90 L / M
	90	15.76			
	105	15.82			
	120	15.87		22218.6	
	150	15.93			91 L / M
	180	15.98		22224.5	
	210	16.05			
7.48PM	240	16.12		22229.8	91 L / M

.Seamus A kelly

BOREHOLE LOCATION	CAPPAGH	.WELL NO
.COUNTY	LIMERICK	SHEET TYPE :5-72 HR
PUMP TYPE	2000 GPH	
.DATE	09/02/2004	WEATHER :FINE
PUMP INTAKE	55M	
.DIA OF WELL	125mm PLASTIC	DISCHARGE DISTANCE: 100M
.DEPTH OF CASING		PURCHASE/ ORDER NO.
		DEPTH OF WELL

	Elasped Time	WELL NO	OBS WELL	METER	FLOW RATE
TIME	HOURS				91 L / M
8.48PM	5	16.22	6.25	22235.1	90 L / M
9.48PM	6	16.28		22240.5	90 L / M
10.48PM	7	16.25		22245.9	91 L / M
11.48PM	8	16.3		22251.6	91 L / M
48AM	9	16.25		22256.6	90 L / M
.48AM	10	16.32		22262.3	91 L / M
3.48AM	12	16.25		22272.8	91 L / M
5.48AM	14	16.31		22284.1	91 L / M
7.48AM	16	16.25	22.04	22294.6	90 L / M OPENED TO 115 L / M
9.48AM	18	22.11		22308.5	115 L / M
11.48AM	20	22.4		22322.4	115 L / M
1.48PM	22	22.58		22336.2	115 L / M
3.48 PM	24	22.75	11.12	22350.5	115 L / M OPENED TO 150 L / M
5.48PM	26	30.91		22367.4	150 L / M
7.48PM	28	31.5		22385.5	150 L / M
9.48 PM	30	31.42	8.46	22403.6	150 L / M
11.48PM	32	31.52		22421.6	150 L / M
1.48AM	34	31.6		22439.8	150 L / M
3.48AM	36	31.75	6.58	22457.3	150 L / M
9.48AM	42	32.45		22511.6	150 L / M
3.48PM	48	32.99		22564.5	150 L / M
9.48PM	54	34.45	18.28	22618.6	150 L / M
3.48AM	60	35.63		22673.1	150 L / M
8AM	66	37.22	19.32	22727.2	150 L / M
.48PM	72	34.2	14.08		150 L / M
	TEST WELL RECOVERS WHEN PUMP-HOUSE WELL CUTS OFF				

.Seamus A kelly PUMPING RATE INCREASED FROM 90 L / M TO 115 L / M

.BOREHOLE LOCATION	CAPPAGH	.WELL NO ;
.COUNTY	LIMERICK	SHEET TYPE ; EXTRA MONITORING
PUMP TYPE	2000 GPH	
.DATE	10/02/2004	WEATHER ; FINE
PUMP INTAKE	55M	
.DIA OF WELL	125mm PLASTIC	DISCHARGE DISTANCE ; 100M
HEIGHT OF MEASUREMENT ABOVE G.L : 1.1M		PURCHASE/ ORDER NO.

Time	Elasped Time	WELL NO	OBS WELL	METER	FLOW RATE
7.48AM	0	16.25			
	0.5	16.55			
	1	16.91			
	1.5	17.24			
	2	17.61			117 L / M
	2.5	17.92			
	3	18.29			
	3.5	18.65			
	4	18.99			
	4.5	19.32			
	5	19.58			
	6	19.83			
	7	19.99			117 L / M
	8	20.15			
	9	20.31			
	10	20.46			
	12	20.59			
	14	20.74			
	16	20.9			
	18	21.03			
	20	21.2			
	22	21.39			
	24	21.61			
	26	21.73			
	28	21.85			
	30	22.06			115 L / M
	35	22.07			
	40	22.06			
	45	22.05			
	50	22.04			
	55	22.03			
8.48AM	60	22.02			115 L / M
	75				
	90				
	105				
	120				
	150				
	180				
	210				
	240				

.Seamus A kelly		PUMPING RATE INCREASED FROM 115 L / M TO 150 L / M
.BOREHOLE LOCATION	CAPPAGH	.WELL NO ;
.COUNTY	LIMERICK	SHEET TYPE ; EXTRA MONITORING
PUMP TYPE	2000 GPH	
.DATE	10/02/2004	WEATHER ; FINE
PUMP INTAKE	55M	
.DIA OF WELL	125mm PLASTIC	DISCHARGE DISTANCE ; 100M
HEIGHT OF MEASUREMENT ABOVE G.L : 1.1M		PURCHASE/ ORDER NO.

Time	Elasped Time	WELL NO	OBS WELL	METER	FLOW RATE	
3.48PM	0	22.75				
	0.5	23.45				
	1	23.62				
	1.5	23.91				
	2	24.11				
	2.5	24.28				
	3	24.45			135 L / M	
	3.5	24.61				
	4	24.79				
	4.5	24.93				
	5	24.95				
	6	24.96				
	7	24.98				
	8	24.99			135 L / M	
	9	25.02				
	10	25.05				
	12	25.09				
	14	25.12				
	16	25.25				
	18	25.43			135 L / M	
	20	25.56				
	22	25.72				
	24	25.82				
	26	25.91				
	28	26.11				
	30	26.45				
	35	27.03			135 L / M	
	40	27.53				
	45	27.58				
	50	27.6			135 L / M	
	55	27.69				
4.48PM	60	27.8			135 L / M OPENED TO 150L / M	
	75	29.01			150 L / M	
	90	29.81			150 L / M	
	105	30.45			150 L / M	
5.48PM	120	30.91			150 L / M	
	150					
	180					
	210					
	240					

.Seamus A kelly

.BOREHOLE LOCATION	CAPPAGH	.WELL NO ;
.COUNTY	LIMERICK	SHEET TYPE ;RECOVERY
PUMP TYPE:	2000 GPH	
.DATE	12-02-04	WEATHER ;FINE
PUMP INTAKE	55M	
.DIA OF WELL	125mm PLASTIC	DISCHARGE DISTANCE ;100M
HEIGHT OF MEASUREMENT ABOVE G.L : 1.10M		PURCHASE/ ORDER NO.

Time	Elasped Time	WELL NO	OBS WELL	METER	FLOW RATE
2.48PM	0	34.2			
	0.5				
	1	29.51			
	1.5	27.1			
	2	24.92			
	2.5	22.58			
	3	20.9			
	3.5	19.49			
	4	18.25			
	4.5	16.46			
	5	14.95			
	6	13.12			WATER CASCADING @ 12M
	7				
	8	9.88			
	9	8.9			
	10	8.22			
	12	7.42			
	14	7.12			
	16	6.97			
	18	6.89			
	20				
	22				
	24				
	26				
	28				
	30				
	35				
	40				
	45				
	50				
	55				
	60				
	75				
	90				
	105				
	120				
	150				
	180				
	210				
	240				

APPENDIX 4

Geophysical Survey

June 13, 2003

Geophysical Investigation for Group Scheme Supply at Priest's Field, Cappagh Co. Limérick

June 2003

George A. Reynolds M.Sc., M.B.A.
Geophysical Consultant

TABLE OF CONTENTS

1: SUMMARY 3
2: DISCLAIMER 3
3: INTRODUCTION 4
4: METHODOLOGY 4
5: FIELDWORK COMPLETED 5
6: SURVEY RESULTS 6
7: CONCLUSIONS AND RECOMMENDATIONS 7

APPENDIX
A.1 VLF-resistivity method: 8
A.2 IP/R Sounding 8
A.3 Dipole-Dipole IP/R Profiling 9
A.4 Electrical Properties of Soils and Rocks 9

TABLE OF FIGURES

Fig. 1: Location map - Cappagh.

Fig. 2: Site Plan showing location of VLF-R, IP/R Sounding and Profile.

Fig. 3: IP/R Sounding curves and layered model interpretation.

Fig. 4: Dipole-dipole IP/R Profile (a = 10 m, n = 1 - 4).

Fig. 5: Finite-element 2-D model interpretation of dipole-dipole data.

Geophysical Investigation at Priest's Field, Cappagh

1: SUMMARY

A geophysical investigation has been carried out at Priest's Field, Cappagh, Co. Limerick, on the instructions of Jer Keohane of G.E.S. Ltd. acting on behalf of T.J. O'Connor & Associates. The objective was to locate a site for a second production water well as part of the upgrading of the local group scheme. Depth to bedrock was believed to be shallow (1-3 m?) and the water table at approx. 10 metres.

The geophysical technique selected for this survey was a combination of an electrical resistivity/induced polarisation sounding to determine the vertical variation in resistivity, and a preliminary reconnaissance VLF resistivity survey to establish the general pattern of resistivity variation over the field. The presence of power and telephone lines precluded the use of purely electromagnetic techniques.

The results indicate the presence of very high resistivity bedrock consistent with Waulsortian "Reef" limestone at shallow depth over most of the site. A zone of lower resistivity and high chargeability extends from the pump house to about 40 metres to the north and probably westwards into the adjoining property. This is consistent with a change in bedrock type to a more shaley and/or more permeable formation, possibly an off-reef intercalation on the edge of a Waulsortian mound. This presents the best location for a second well as reef margins are often subject to fracturing on account of differential compaction processes.

2: DISCLAIMER

Geophysical techniques are based on assumptions that earth materials are homogenous and isotropic, i.e. are ideal and uniform materials, and interpretation techniques furthermore assume that these materials are present in simple geometric arrangements of horizontal or dipping layers. Zones of anomalous conditions may arise from several factors which cannot be known in advance and so the interpretation of these anomalies is based on the most likely, but not certain, cause. Drill-testing is therefore the next stage in the exploration process and no responsibility can be accepted if the results of drilling fail to meet expectations.

3: INTRODUCTION

This report describes the results of a geophysical survey at Priest's Field, Cappagh (Adare) Co. Limerick (Fig. 1) on June 4, 2003, as part of a hydrogeological assessment of the site to upgrade the local Group Scheme.

The VLF-R (very low frequency resistivity) method was chosen on account of its ability to provide an initial overview of the site's subsurface conditions and to locate suitable positions for resistivity soundings. This method can give also an approximate depth to bedrock at each measurement site provided that an approximate value for the overburden resistivity can be determined.

The resistivity and induced polarisation (IP/R) sounding provides information on the resistivity and chargeability properties of the subsurface layers and an indication of the depth to bedrock at each sounding location. The values of overburden resistivity indicated by the soundings are then used in conjunction with the VLF-resistivity measurements to extend the interpretation of depth to bedrock over the entire site, where possible.

4: METHODOLOGY

Water wells in Ireland are usually located either in sand and gravel deposits or in bedrock zones of secondary porosity, such as fracture zones and strongly jointed or weathered rocks, as the primary porosity of limestone is low. The presence of water in a fractured formation increases its electrical conductivity - especially at high frequencies - and suggests the use of techniques which can measure conductivity or its inverse, resistivity.

The electromagnetic (EM) techniques are ideal for locating groundwater in fracture zones as they can be deployed to detect these narrow, vertical and often poor conductors, whereas standard four-electrode or "galvanic" methods are relatively insensitive to vertical conductors, being more suited to sand and gravel aquifer detection. By convention, the term "conductivity" is preferred when EM techniques are used and "resistivity" when galvanic techniques are used, although these two terms refer to the same property and its inverse.

Electrical conductivity is not a constant property as it increases with the frequency of the applied current or EM field. Furthermore, the calculation of conductivity or resistivity value as measured in the field is based on the assumption of an equivalent homogenous subsurface, and the values as such are termed "apparent" resistivity (or apparent conductivity). The true or "intrinsic" resistivity of a rock is a complex function of the porosity and permeability, the degree of saturation, and the chemical composition of the water contained in it. The presence of clay minerals lowers the resistivity also, but increasingly so as the applied frequency is increased. A type of

frequency-dependent resistivity measurement, known as induced polarisation, can indicate the presence of clay (or sulphide) minerals, which can adversely affect the permeability of an aquifer and hence its value as a groundwater resource.

In the case of Priest's Field, the use of pure EM techniques was excluded on account of the presence of power and telephone lines, and an electric fence. Instead, a series of EM-derived resistivity measurements were made with a Geonics EM-16R instrument which detects the ground wave of VLF radio signals from military transmitters which penetrates into the ground to depths dependant upon the resistivity of the ground.

An electrical sounding was carried out on an anomaly detected by the VLF-R. This uses a four-electrode array which is expanded outwards in approximately logarithmic steps from a centre point with measurements of both apparent resistivity and chargeability to determine the vertical variations in these properties below that point. A profile using a multi-spaced array was also completed to provide an electrical cross-section across a zone of interest.

5: FIELDWORK COMPLETED

The field work was completed as per original proposal on June 4, 2003. The weather conditions were excellent and access to the site was good. An additional dipole-dipole IP/R profile was carried out to delineate an anomalous zone located by the VLF-R into an adjoining property as it was considered less damaging to the silage crop there. Permission for this one line was obtained from the proprietor, Mr. Arthur Ruttle.

A total of 20 VLF-resistivity measurements, one IP/R sounding and one IP/R profile over 140 m on an W-E section, using a dipole-dipole array (a=10 m, n=1-4), was completed on the site.

The VLF resistivity measurements were made with a Geonics EM-16R tuned to the NAA transmitter (24.0 KHz) on an approximately 25 x 25 m grid positioned by metric tape, using the SW corner of the field as grid origin and the west side of the field as 0E baseline .

The IP/resistivity sounding was located on a VLF-R anomaly at 10E, 90N, i.e. 10 metres out from the west side of the field and about 40 m north of the pumphouse enclosure. A Schlumberger array aligned N-S was used on account of its insensitivity to lateral variations and electrical interference.

The IP/R profile was completed on an E-W line at 75N and extended from 70E to 70W into the adjoining property.

For more specific details of these techniques, see Appendix.

6: SURVEY RESULTS

The VLF-R data (Fig. 2) showed very high values of apparent resistivity ranging from 2000 to 6000 Ohm-metres and phase angles of 1 to 10 degrees. This is consistent with two possible models; a thin conductive overburden overlying a highly resistive bedrock; or a thick (30-60 m) resistive formation overlying a much more highly resistive formation. It is also possible that both conditions, i.e. a three-layer configuration is present but cannot be resolved by a simple interpretation constrained to two-layers. In either case, this is consistent with the geological information already available.

A zone of lower resistivity (700-900 Ohm.m) and higher phase angles 12-25 degrees was located about 40 m north of the pumphouse (90 m from the southern boundary - the pumphouse is shown about 10 m further north than its actual location). Some interference from the powerline supplying the pump precluded more detailed definition of this anomaly and a single additional measurement was made in the adjoining property to minimise trampling of the silage. This anomaly is interpreted as a zone of reduced bedrock resistivity (as opposed to a thickening of the overburden) and as such is attractive as a drilling target, especially as it is the only anomaly on the site.

The IP/R sounding (Fig. 3) was located on this anomaly and shows a thin overburden layer (1 m) overlying increasingly resistive formations. A layer contact at 9 metres with a marked increase in chargeability appears to correspond to the known water table and could be attributed to a shaley formation (the chargeability would be suppressed above the water table). A second contact at 25 metres with an underlying highly resistive and weakly chargeable formation is consistent with a change to a crystalline or micritic limestone, such as found in boulders in the walls around the field. The sounding is in surprisingly good agreement with either possible VLF-R interpretations.

The IP/R profile across the anomaly (Fig. 4) confirms the resistivity anomaly as an asymmetric "low" dipping eastwards at a shallow angle. A corresponding chargeability "high" in the form of an asymmetric arch dipping more steeply westwards confirms the presence of the chargeable layer detected by the sounding. A finite-element model was found which approximates the characteristic features of the observed data. This shows that the chargeable layer is shallow and conductive and dips eastwards. The model also confirms the thin overburden and the resistive, poorly chargeable bedrock and although the it is only an approximate match, it nevertheless corroborates the findings of the other techniques.

7: CONCLUSIONS AND RECOMMENDATIONS

The results of the geophysical surveys indicate the presence of a shaley formation in contact with a very resistive limestone, possible a Waulsortian reef mound. These reef mounds can have an irregular lobate outline in plan with intercalations of off-reef shales, sometimes in faulted contact. The shaley formations are often fractured on account of differential compaction and the difference in mechanical competence between crystalline limestone and shale.

In this scenario, the existing well is on this contact zone and as the anomaly extends further towards the north, it would seem reasonable that a second well be sited on this anomaly and as far away from the existing well as necessary to avoid interference of drawdown cones.

It is recommended therefore to drill a test borehole at a position 80-90 metres north of the SW corner of the field and 10-20 metres out from the fence (but avoiding the overhead line). It is not possible to infer a target depth from the geophysical results, but it would clearly have to be greater than 10 metres, the observed water table, and preferably to a depth of at least 25 metres (as per sounding data).

George A. Reynolds M.Sc., M.B.A.
(Consulting Geophysicist)

APPENDIX

A.1 VLF-resistivity method:

In this mode, a Geonics EM-16R VLF receiver tuned to the 24 kHz signal from the NAA (Cutler, Maine, USA) transmitter was used to measure the electric and magnetic components of the radiated signal. The ratio of these components gives the apparent resistivity of the ground and the phase difference between these components is indicative of depth variations of resistivity.

apparent resistivity $\rho_a = [E_x/H_y]^2 \; 1/(2\Pi f\mu)$ **Ohm-metres** $(\Omega \bullet m)$

- where ρ_a is the ground resistivity in ohm-metres, Ex is the horizontal electric field in volts/metre, **HY** is the perpendicular horizontal magnetic field strength in amps/metre, **f** is the frequency in Hz, and μ is the permeability of the ground in Henrys/metre.

The maximum depth penetration of the signal depends on the resistivity of the ground, being greater for higher resistivity.

depth penetration = 503.8 $\sqrt{(\rho/f)}$ **metres (m)**

- where ρ is the resistivity and **f** is the frequency in kHz.

The depth penetration is about 100-200 metres for ground resistivity values of 1000-4000 Ohm-metres respectively, but is less than 30 metres for typical ground conditions, such as landfill sites.

Each VLF-R measurement is a point measurement and can be interpreted as a simple two-layer earth model if the surface layer resistivity is approximately constant. This is known as "data inversion". As bedrock is usually much more resistive than the overburden, a typical value of overburden resistivity can be entered in the formula, giving a reasonable estimate of bedrock resistivity. Where large variation in the surface resistivity is present, the apparent resistivity data is simply contoured to give an overview of the subsurface conditions.

A.2 IP/R Sounding

The IP/R sounding was carried out using the Schlumberger electrode array, moving the current electrodes outwards from the sounding centre in logarithmic steps from 1 metre to 83 metres, the maximum in the available space. The apparent resistivity and chargeability data were interpreted by

fitting a horizontal layered-earth model calculated by computer to the field data. The layer parameters of resistivity, chargeability and layer thicknesses were adjusted to provide the closest "fit" to the field data. An analysis of "equivalent" models was made to determine the uniqueness of the model fit.

A.3 Dipole-Dipole IP/R Profiling

This technique comprises elements of profiling (to locate lateral variations of resistivity) and sounding (to determine the vertical variations of resistivity). Most electrical "imaging" systems also use this configuration. Two approaches to interpretation are possible:

Imaging: the values of apparent resistivity are converted to an equivalent 2-D model of intrinsic resistivity by means of a digital filter. The resulting model is not an unique solution and shows a continuously-varying resistivity property over the section, i.e. no layered structure is assumed. This approach is ideal for amorphous subsurface conditions, i.e. steeply dipping/folded formations or landfill materials.

Finite-element model: in this case a model consisting of 2-D discrete layers and "bodies" is constructed on a fine mesh or grid and the dipole-dipole IP/R values are calculated for a set of electrodes on the "surface" of the model. This is compared to the observed values and is adjusted by trial-and-error until a satisfactory "match" is obtained. This is a time-consuming process but has the advantage of using available geological knowledge and geophysical parameters derived from the other techniques. This approach is suitable for shallow-dipping layered formations with planar contacts e.g. faults.

A.4 Electrical Properties of Soils and Rocks

The resistivity of a rock or soil "layer" is a function of porosity, clay content and water content and water chemistry, rather than a direct function of the rock or soil minerals. However, it does correspond to individual geological formations generally. Thus, limestone will have resistivity values ranging from the low hundreds to tens of thousands of Ohm-metres, whereas soil and overburden materials will have values from tens to hundreds of Ohm.m. Gravel resistivity values can range up to thousands of Ohm.m if they are above the water table, and landfill material tends to have very low resistivity values, usually less than 10-30 Ohm.m.

The chargeability parameter relates to the content and particle size of the clay mineral content, and to some extent on the permeability also, as the ionic charges moving in the capillaries of the rock are blocked by strongly polarised clay mineral particles. Thus gravels and crystalline limestone have low values of chargeability, 1-5 mV/V while shale and mineral deposits will have elevated values of 10-40 mV/V.

Cappagh, Co. Limerick

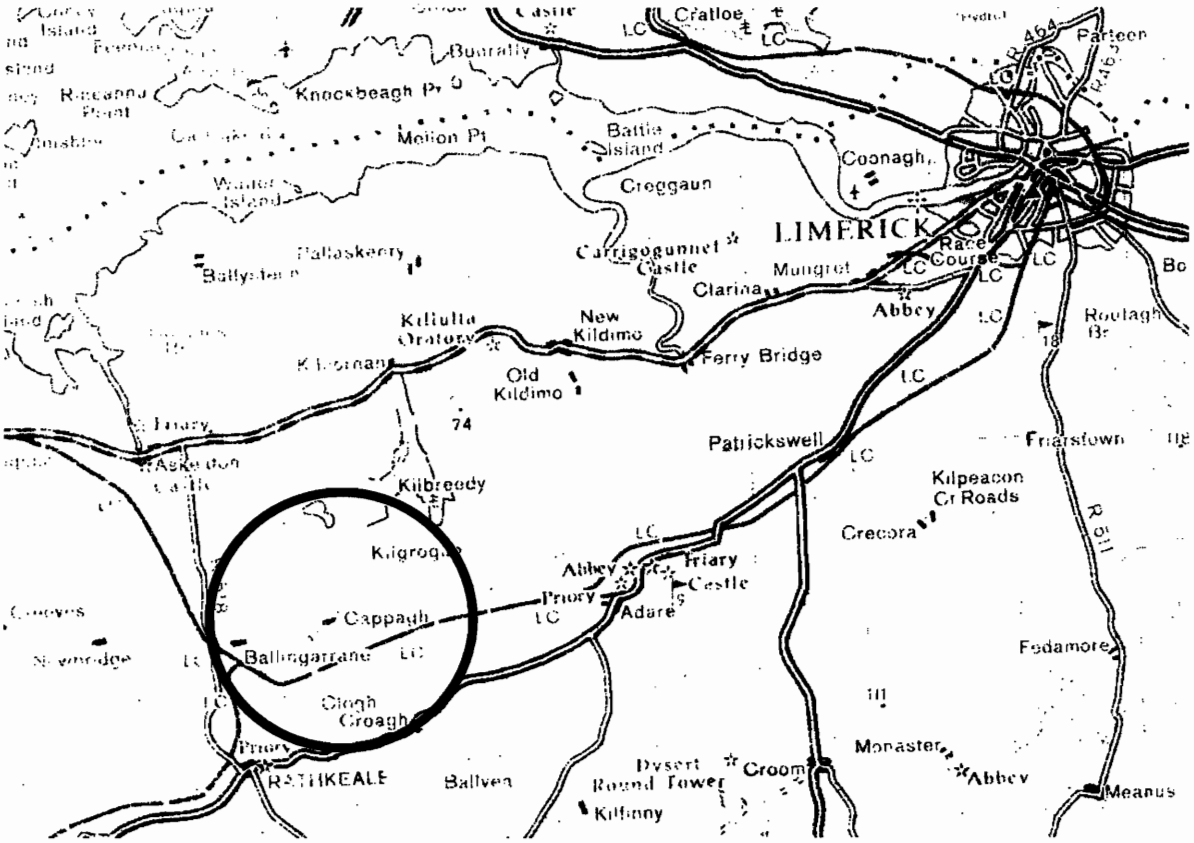
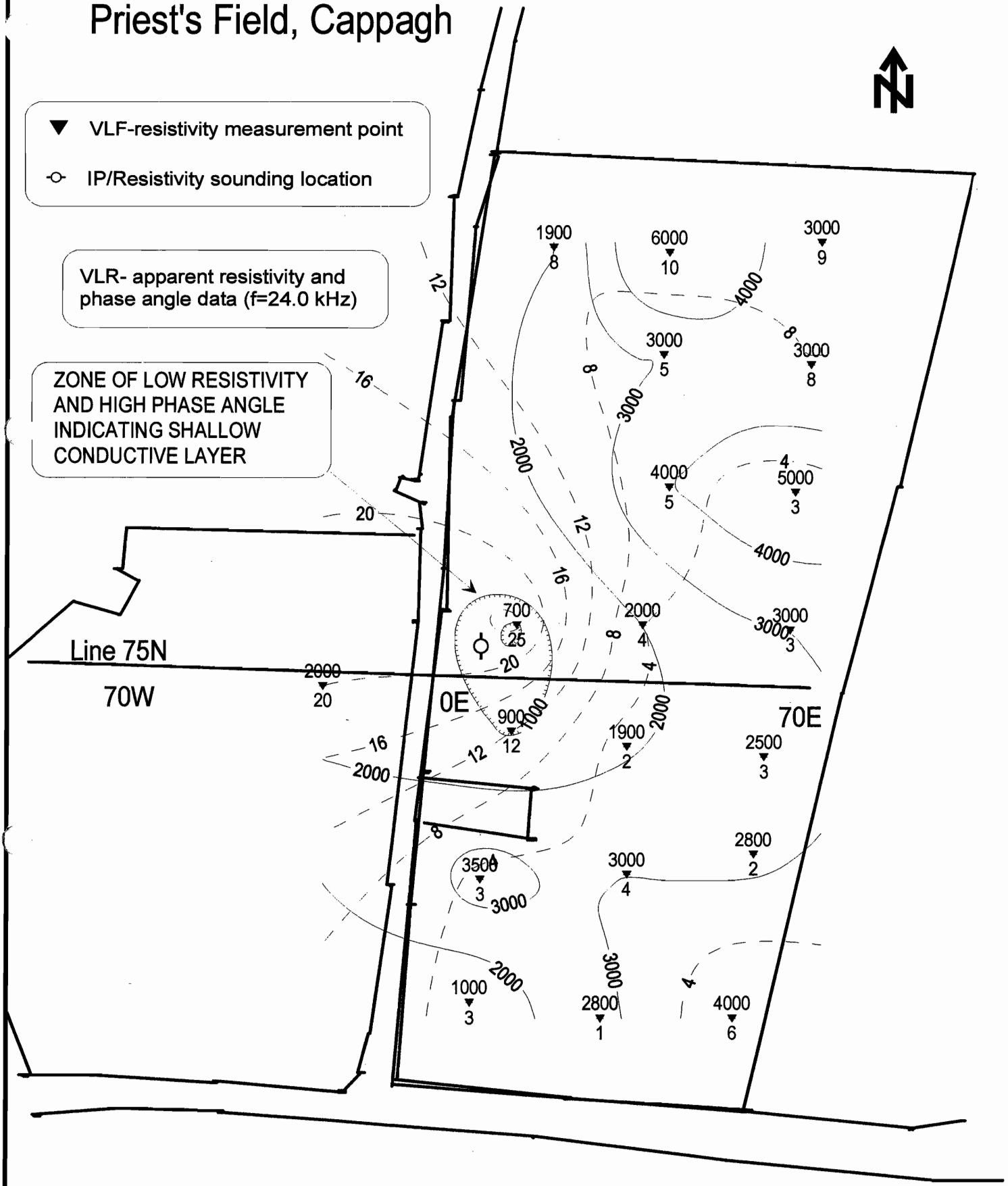


Fig. 1: Location Map - Cappagh

GROUP WATER SCHEME
Priest's Field, Cappagh

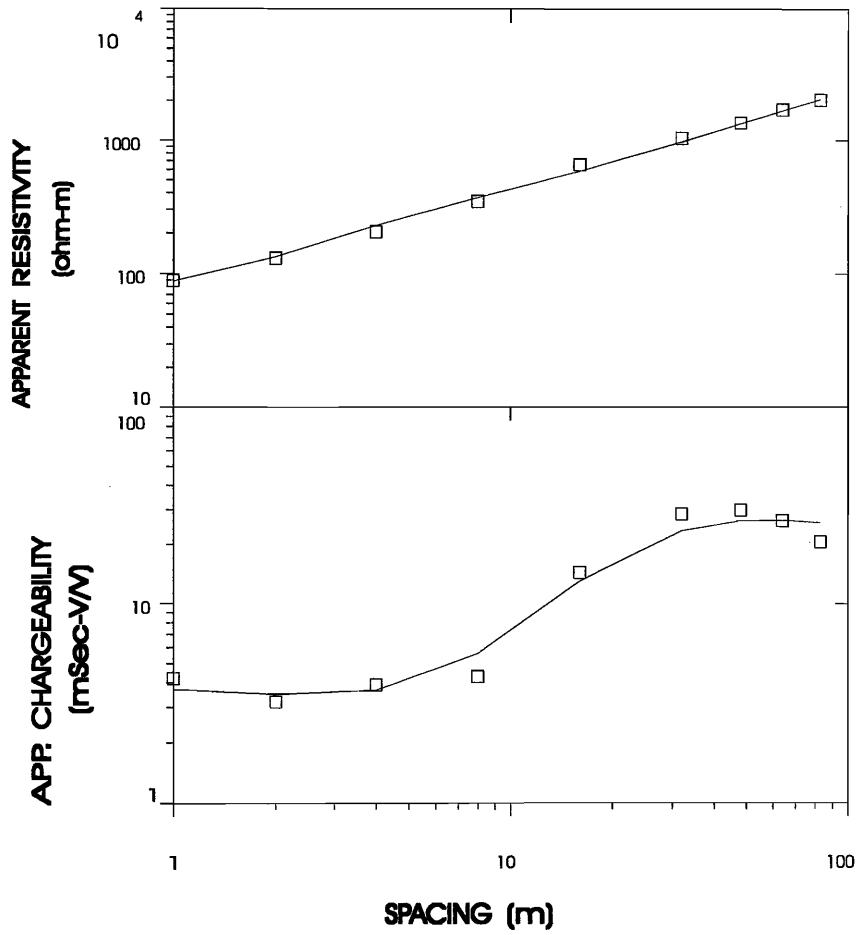


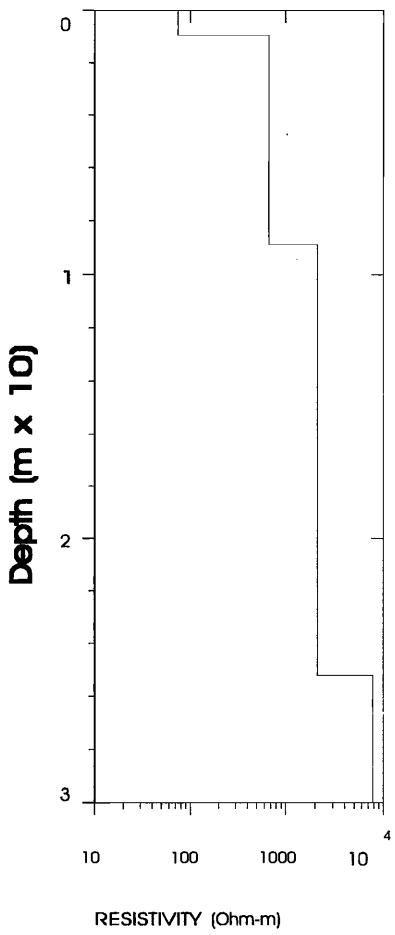
0 25 50

Scale: 1:1000, metres

Fig. 2.

VLF-R, IP/R Sounding & Profile	
Client: G.E.S. Ltd.	Date: June 4, 2003
Priest's Field, Cappagh Adare, Co. Limerick.	George A. Reynolds, Consulting Geophysicist Annamoe, Co. Wicklow. Tel. 0404-45505





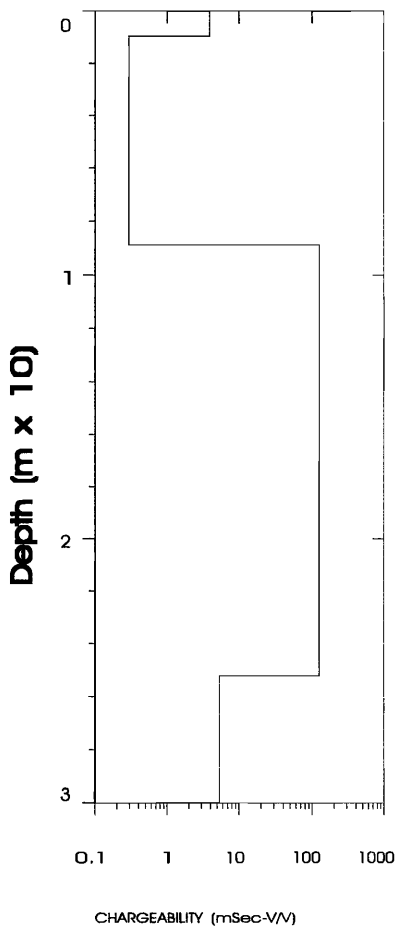
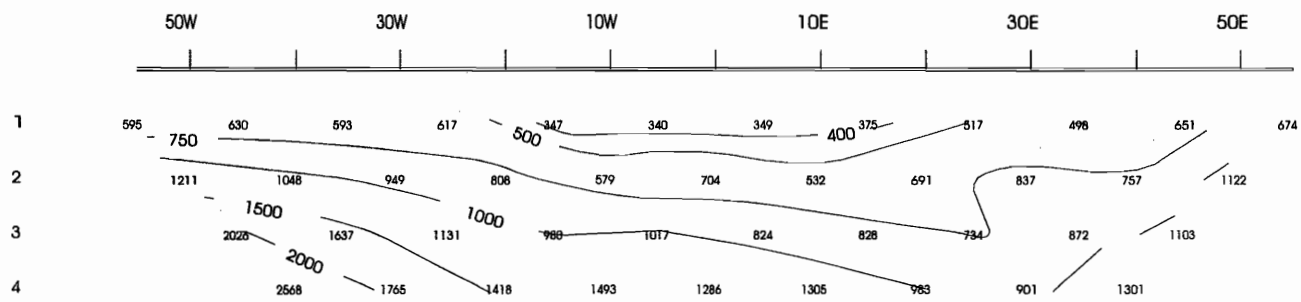
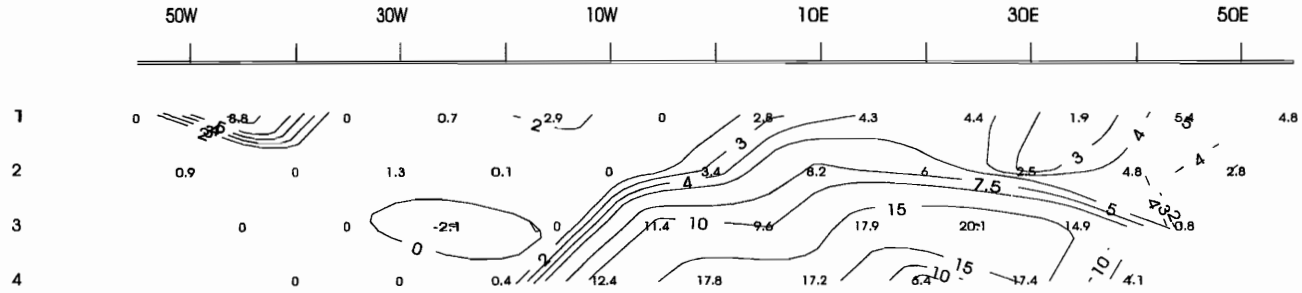


Plate: 3

for: G.E.S.	**Resistivity/IP Sounding** (Schlumberger Array)
by: George A. Reynolds	Group Water Scheme **Cappagh, Co. Limerick**
Data Set: PRIEST-1 / Date: Jun 4 2003	
Equipment: IPR10/IPC8 / Sounding: IPR-1	**Azimuth: 0.00 Deg NORTH**



APPARENT RESISTIVITY (OHM-M)



CHARGEABILITY (MSEC)

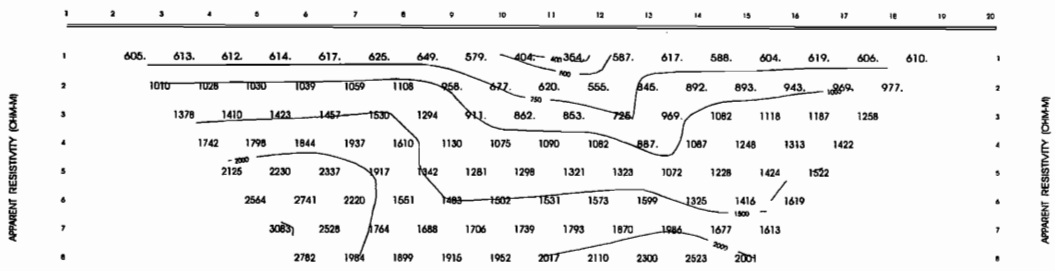
INDUCED POLARIZATION

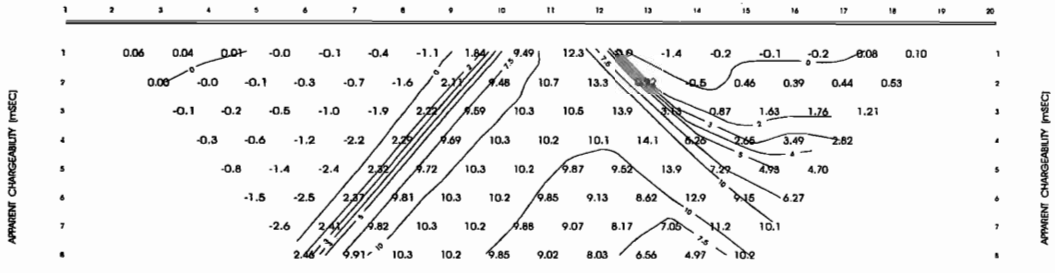
ARRAY:.....DIPOLE-DIPOLE
FREQUENCY:.....2/2 seconds
CONTOUR MULTIPLES:.....
..... 1 2 4 8 10 12 16 20
SPACING:.....10 m
SURVEY DATE:.....04-JUN-03
OPERATOR:.....GAR
Rx:.....Scintrex IPR-10
Tx:.....Scintrex IPC-8 200W

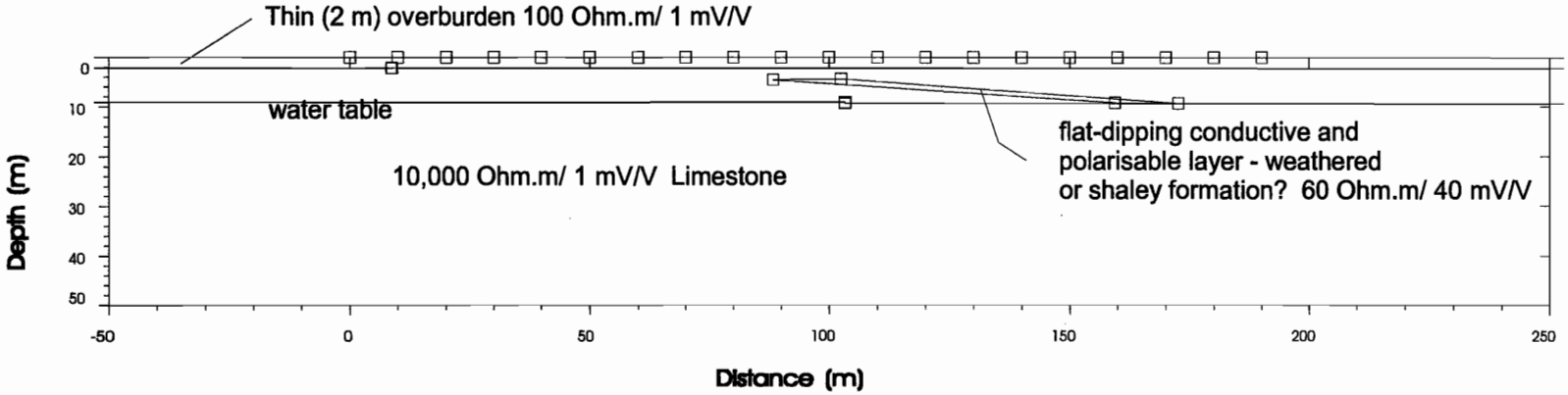
DIPOLE LENGTH: 10 m

PLATE **4**

DIPOLE-DIPOLE RESISTIVITY/IP	
Group Water Scheme	
W-E Profile 75N	
a = 10 metres	
AREA: Priests Field, Cappagh, Co. Limerick	
for: **G.E.S.**	
George A. Reynolds	
Surveyed by: G.Reynolds	Date: June4 2003
Plotted by: GAR	Project No:







FINITE ELEMENT 2D MODEL INTERPRETATION OF DIPOLE-DIPOLE INDUCED POLARISATION AND RESISTIVITY PROFILE.

Plate: 5

for: GES Ltd.		GROUP WATER SCHEME
by: George A. Reynolds		Priest's Field, Cappagh Adare, Co. Limerick
Data Set: PRIEST-1	Date: June 4 2003	
Array: Dipole-Dipole	a-Spacing: 10.	Grid (x by z): 125 by 13

APPENDIX 5

Groundwater Vulnerability

Introduction

The term 'vulnerability' is used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities (DELG *et al.,* 1999). The vulnerability of groundwater depends on:

- the time of travel of infiltrating water (and contaminants)
- the relative quantity of contaminants that can reach the groundwater
- the contaminant attenuation capacity of the geological materials through which the water and contaminants infiltrate.

All groundwater is hydrologically connected to the land surface; the effectiveness of this connection determines the relative vulnerability to contamination. Groundwater that readily and quickly receives water (and contaminants) from the land surface is more vulnerable than groundwater that receives water (and contaminants) more slowly and in lower quantities. The travel time, attenuation capacity and quantity of contaminants are a function of the following natural geological and hydrogeological attributes of any area:

- the type and permeability of the subsoils that overlie the groundwater
- the thickness of the unsaturated zone through which the contaminant moves
- the recharge type – whether point or diffuse.

In other words, vulnerability is based on evaluating the relevant hydrogeological characteristics of the protecting geological layers along the pathway, and the possibility of bypassing these layers. In summary, the entire land surface is divided into four vulnerability categories: **E**xtreme, **H**igh, **M**oderate and **L**ow, based on the geological and hydrogeological characteristics. Further details of the hydrogeological basis for vulnerability assessment can be found in 'Groundwater Protection Schemes' (DELG et al., 1999).

The Groundwater Vulnerability Map shows the vulnerability of the first groundwater encountered, in either sand/gravel or bedrock aquifers, by contaminants released at depths of 1-2 m below the ground surface. Where the water-table in bedrock aquifers is below the top of the bedrock, the target needing protection is the water-table. However, where the aquifer is fully saturated, the target is the top of the bedrock. The vulnerability map aims to be a guide to the likelihood of groundwater contamination, if a pollution event were to occur. It does not replace the need for site investigation. Note also that the characteristics of individual contaminants are not considered.

Except where point recharge occurs (*e.g*. at swallow holes), the groundwater vulnerability depends on the type, permeability and thickness of the subsoil.

The groundwater vulnerability map is derived by combining the permeability and depth to bedrock maps, using the three subsoil permeability categories: high, moderate and low; and four depths to rock categories: <3m, 3–5m, 5–10m and >10m. The resulting vulnerability classifications are shown in Table 1.

Table 1 Vulnerability mapping guidelines (adapted from DELG et al, 1999)

Thickness of Overlying Subsoils	Hydrogeological Requirements for Vulnerability Categories				
	Diffuse Recharge			**Point Recharge**	**Unsaturated Zone**
	Subsoil permeability and type				
	High permeability (*sand/gravel*)	moderate permeability (*sandy subsoil*)	low permeability (*clayey subsoil, clay, peat*)	*(swallow holes, losing streams)*	(*sand & gravel aquifers only)*
0–3 m	**Extreme**	**Extreme**	**Extreme**	Extreme **(30 m radius)**	**Extreme**
3–5 m	**High**	**High**	**High**	**N/A**	**High**
5–10 m	**High**	**High**	**Moderate**	**N/A**	**High**
>10 m	**High**	**Moderate**	**Low**	**N/A**	**High**

Notes: (i) N/A = not applicable.
(ii) Release point of contaminants is assumed to be 1–2 m below ground surface.
(iii) Permeability classifications relate to the engineering behaviour as described by BS5930.
(iv) Outcrop and shallow subsoil (i.e. generally <1.0 m) areas are shown as a sub-category of extreme vulnerability
(amended from Deakin and Daly (1999) and DELG/EPA/GSIa (1999))

Sources of Vulnerability Data

Specific vulnerability field mapping and assessment of previously collected data were carried out as part of this project. Fieldwork focused on assessing the permeability of the different subsoil deposit types (Figure 3), so that they could be subdivided into the three permeability categories. This involved:

- Describing selected exposures/sections according to the British Standard Institute *Code of Practice for Site Investigations* (BS 5930:1999).
- Collection of subsoil samples for laboratory particle size analyses
- Assessing the recharge characteristics of selected sites using natural and artificial drainage, vegetation and other recharge indicators.

The following additional sources of data were used to assess the vulnerability and produce the map:

- Subsoils Map (EPA/Teagasc Subsoil Map, 2006), which is the basis for the main permeability boundaries. 'Clean' sands and gravels are usually high permeability. Alluvium deposits are either moderate or low permeability.
- Depth to bedrock map, compiled by the mapping team for the current project in the Geological Survey of Ireland, using data compiled from GSI, consultant and county council reports, along with purpose-drilled auger holes
- Geological Survey of Ireland Bedrock Geology Map
- Geological Survey of Ireland well and karst database, which supplied information on well yields and depth to bedrock, as well as locations of point recharge.
- General Soils Map of Ireland (Gardiner and Radford, 1980). This gives additional, indirect information on subsoil permeability in the areas mapped by Teagasc as 'till'.

Thickness of the Unsaturated Zone

The thickness of the unsaturated zone, or the depth of ground free of intermittent or permanent saturation, is only relevant in vulnerability mapping over unconfined sand and gravel aquifers. As described in Table 6.1, the critical unsaturated zone thickness is 3m; unconfined gravels with unsaturated zones thicker than 3m are classed as having a 'high' vulnerability, while those with unsaturated zones thinner than 3m are classed as having an 'extreme' vulnerability.

APPENDIX 6

Groundwater Body Description

Askeaton GWB: Summary of Initial Characterisation.

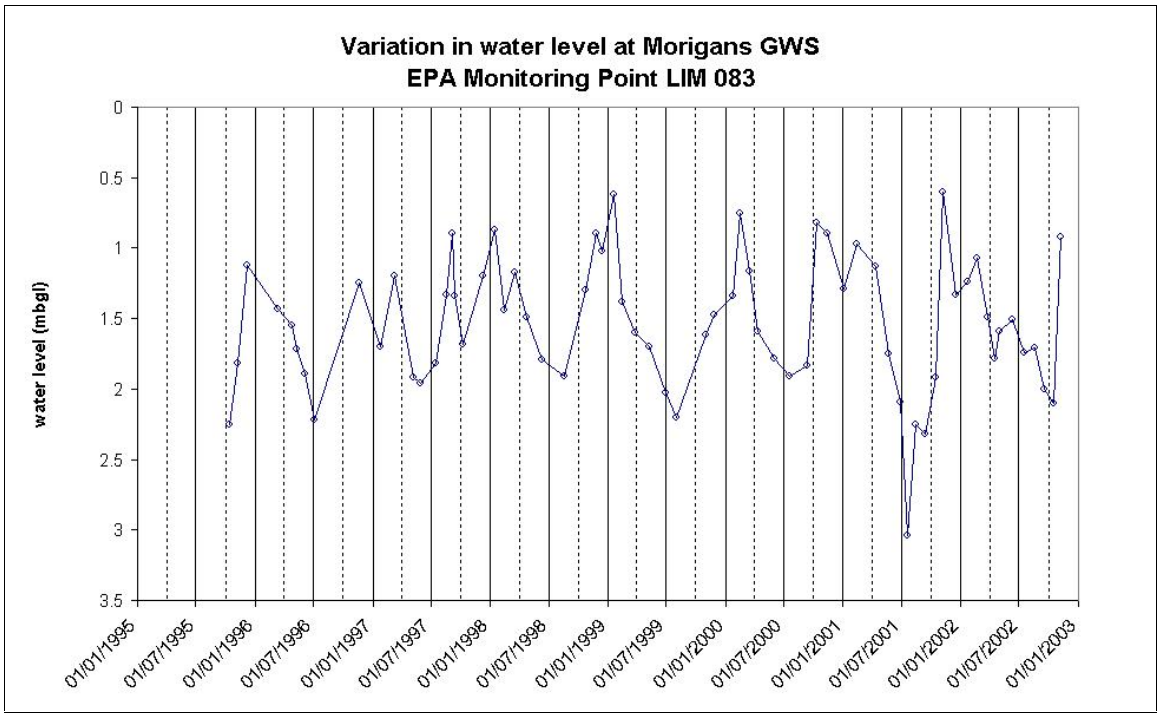
Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
24 - Deel/ Shannon Estuary South Limerick Co. Co.	Rivers: Ahacronane, Deel, Robertstown; Streams: Lismakeery; Loughs: Quayfield, Poulaweala, Mornane, Blue (two separate loughs), Ballymorrisheen, Dromore, Glenisca, Graigues, Doohyle.	Inner Shannon Estuary – South Shore (000435), Dromore and Bleach Loughs (001030), Gorteennamrock (Fen) (001433), Ballinvirick Marsh (001427), Ballymorrisheen Marsh (001425), Cappagh Fen (001429).	125 (this figure does not include Aughinish Island)

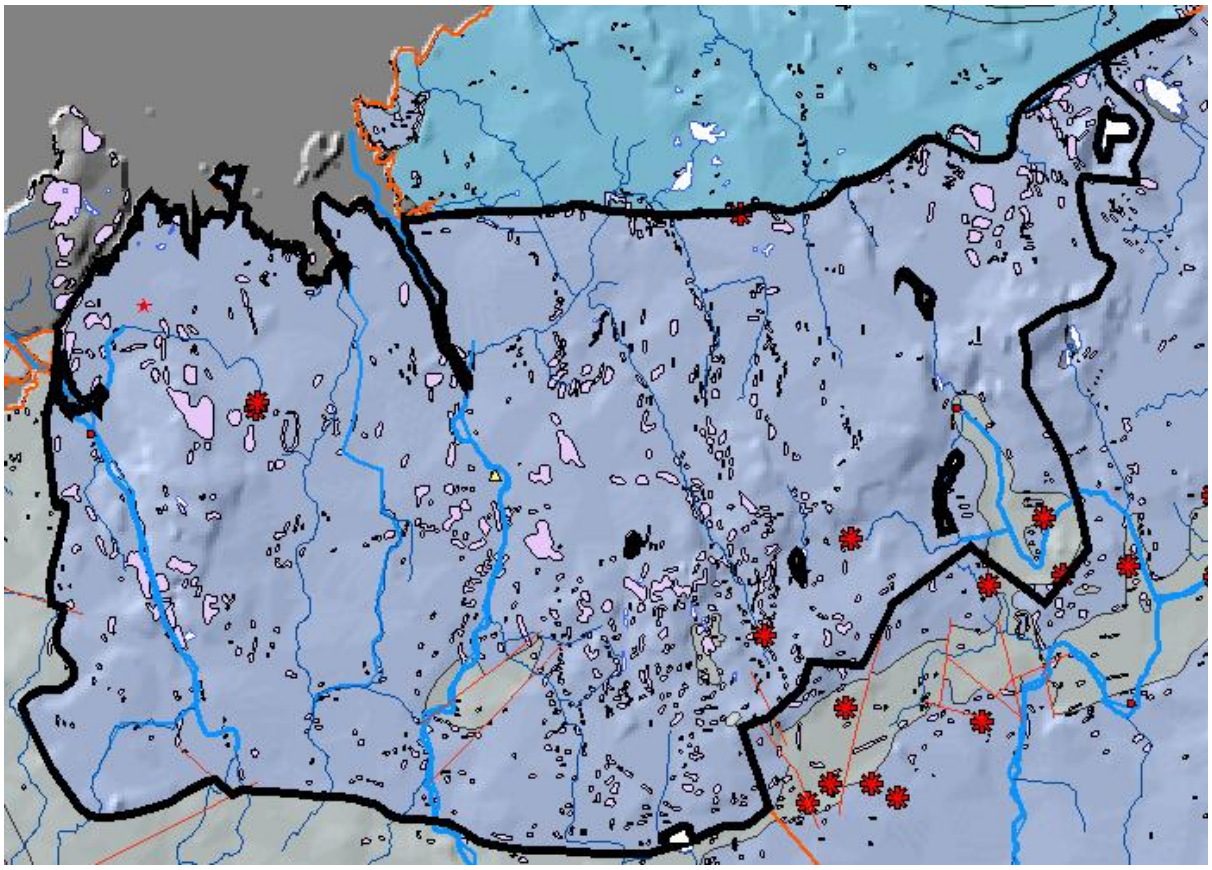
Topography	The groundwater body is roughly rectangular and is elongated east-west. The ground elevation decreases from around 100 maOD in the west and south to sea level along the Shannon Estuary. Much of the ground is gently undulating, and approximately 40 maOD. Some rivers (e.g. the Ahacronane) incise into the ground surface, but most are gently meandering across gently sloped ground.	
Geology and Aquifers	Aquifer categories	The majority of the GWB comprises **Rk^c**: Regionally important karstified aquifer dominated by conduit flow. There are small areas in the south and southeast where the bedrock is **Ll:** Locally important aquifer which is moderately productive only in local zones.
	Main aquifer lithologies	The dominant rock unit group in the GWB is the Dinantian Pure Unbedded Limestones. There are small areas of Dinantian Upper Impure Limestones in the south-centre of the GWB, and at the southeast corner.
	Key structures	The rocks occur near the core of a WSW–ENE oriented syncline. Faults approximately parallel and at right angles to the fold axis are mapped near the edge of the groundwater body; they are likely to occur within the GWB also. North-easterly faults are noted at Aughinish; fault zones are up to 20 m wide and are associated with dolomitisation and solution. Bedding dips range between 15^o and 50^o, with the steepness probably reflecting the steep pre-folding bedding surfaces and not only deformation.
	Key properties	Transmissivity in the karstified pure unbedded limestones will be in the range 200–2000 m^2/d. Due to the focussed nature of the flow, very high transmissivity zones will be close very low transmissivities zones. In the impure limestones, transmissivities will range from 2–30 m^2/d, and will tend to be towards the lower end of this range. Groundwater gradients are very low in the pure limestones (0.001-0.003); they may be slightly higher in the impure limestones, but not by much, since although the impure limestones are lower permeability, the ground underlain by them has very low relief. *(data sources: Rock Unit Group Aquifer Chapters, Limerick GWPS Report, see references; estimation from maps)*
	Thickness	The Dinantian Pure Unbedded Limestones (Waulsortian Limestones) attain maximum thicknesses of more than 1200 m. However, the effective flowing thickness is likely to be about 30 m. An epikarstic layer of a couple of metres is likely to exist at the top of the aquifer; fieldwork is required to verify this. Deep karst conduits (60 mbsl) are known to exist, but the flux within the conduits is not known.
Overlying Strata	Lithologies	*[Information to be added at a later date]*
	Thickness	Subsoil thicknesses are typically in the range 0–10 m, with much rock exposed, especially in the west of the GWB.
	% area aquifer near surface	*[Information to be added at a later date]*
	Vulnerability	*[Information to be added at a later date]*
Recharge	Main recharge mechanisms	Recharge will occur directly to the aquifer via outcrops, and by percolating through the shallow subsoil. There is likely to be an epikarst layer which will readily accept recharge, which will then redistribute the groundwater in the subsurface before it enters the main aquifer body. Point recharge to the aquifer may also occur via swallow holes. Where the water table intersects the surface and fen areas are formed, potential recharge may be rejected.
	Est. recharge rates	*[Information to be added at a later date]*
Discharge	Springs and large known abstractions (m^3/d)	Aughinish WS (1200 m^3/d – not sure if still in use); Morigans GWS (?); Cappagh GWS (Ballingarrane) (153 m^3/d); Coolmin GWS (131 m^3/d); Cappagh GWS (Cappagh) (50 m^3/d); Ballyshonickbane GWS (218 m^3/d); Ballyvogue GWS (?) (50 m^3/d); Barrigone GWS (195 m^3/d); Rintulla WS (not sure if in use) *[More information to be added at a later date]*
	Main discharge mechanisms	The main discharge zones of the aquifer are the Shannon Estuary in the northwest, the Rivers Deel and Ahacronane, and the tributary of the Maigue River. In winter, turloughs act as temporary discharge zones. There are numerous springs in the GWB. Some of these occur at the base of the hill that forms the catchment divide boundary at the south of the GWB. Others occur at the junction between the karst of this GWB and the low transmissivity rocks of the Ballysteen GWB.

	Hydrochemical Signature	No hydrochemical data are available for this GWB. The hydrochemistry of the Waulsortian limestone aquifer near Croom, 19 km southeast of Askeaton, shows a very hard (370–400 mg/l $CaCO_3$), calcium bicarbonate type water with high alkalinity (330–350 mg/l $CaCO_3$). Background chloride concentrations will be higher than in the Midlands, due to proximity to the sea. The bedrock strata of this aquifer are **calcareous**.
Groundwater Flow Paths		Groundwater flow is concentrated in conduits. The intensity of karstification is thought to decrease eastwards. Site investigations in the Aughinish area have shown extensive karstification (solution) of the limestone and large variations in permeability (Ercon, 1974; Gutmanis, 1981; Clarke et al., 1981). There is evidence of permeability variations with depth: two unconnected sets of water bearing fissures were observed – one at sea level and one at approximately 60 m below present day sea level. Failed wells adjacent to productive ones, cavities recorded in boreholes, and the presence of turloughs indicate concentration of groundwater into conduits. Annual groundwater fluctuations at Aughinish are reported by Ercon (1974) to be about 6 m. The hydrograph at Morigan's GWS shows an average annual fluctuation of about 1.5 m. Groundwater levels are typically 3–9 mbgl. However, some SWLs are significantly deeper (15 – 25 mbgl), and may be tapping a deeper conduit system – some of these water levels (if they are not affected by pumping) are below sea level. In this area of shallow rock, the water table is generally below the base of the subsoil. Groundwater flow paths in this aquifer are generally long, and can be up to km's long. Groundwater may also discharge locally to surface water features or springs, however, if the topography is variable. In the western part of the GWB, groundwater flow is generally northwards to the Shannon Estuary, although more locally, groundwater flow will be more east-west to the nearest surface water course. In the southeast of the GWB, groundwater flow is to the southeast.
Groundwater & Surface water interactions		The nature of the karstic system leads to rapid interchanges of water between surface and underground. Swallow holes and caves receive surface water, and groundwater is discharged to surface as springs or as baseflow to rivers crossing the groundwater body. The loughs act as groundwater stores – seasonal water levels can vary significantly. Data do not exist to assess the contribution by the aquifer to river flows, or vice versa. However, several groundwater-dependent ecosystems are known in the area: Ballinvirick marsh (NHA 001427) is a small wetland site with adjacent grassland and scattered scrub habitats. It is one of a network of small lakes and fens which include Cappagh (NHA 001429) and Ballymorrisheen (NHA 001425) fens. Recent drainage schemes in particular to the east of the lake have greatly reduced the water level of the lake. Ballymorrisheen Fen is a small to medium sized wetland site characterised by 3 small lakes surrounded by a fen vegetation. Cappagh Fen is a fen lake site with almost total dominance by reed beds. Gorteenamrock Fen (NHA 001433) is a small wetland site sheltered by higher scrub-covered ground. Dromore and Bleach Loughs (NHA 001030) are likely to be almost entirely groundwater fed, with their alkalinity determined by the nature of the bedrock. There are fens surrounding the loughs which are dependent on groundwater. The Shannon Estuary (000435) has fringing reedbeds, swamps, salt marsh and wet marsh habitats. Potential pollution could quickly enter the estuary via groundwater flow.
Conceptual model		• The groundwater body is elongated east-west and is roughly rectangular. The northwestern boundary is formed by the Shannon Estuary. The northern, western and western part of the southern boundaries are contacts with low transmissivity impure limestones (the Ballysteen and Patrickswell GWBs). The eastern boundary is a surface water catchment divide. The area is generally very low-lying, and topography is gently undulating. • Karstification is pervasive, especially around Aughinish. The degree of karstification is thought to decrease eastwards. These are highly transmissive and variable limestones, with low storativity. • Recharge occurs diffusely across the entire groundwater body, especially where there is rock outcrop or thin subsoil. An epikarst layer is likely to redistribute the recharge in the subsurface before it enters the aquifer proper. Point recharge is likely to occur, although, in this GWB, swallow holes are not recorded in the GSI database at present. Potential recharge may be rejected in the areas where the water table is very close to or intersects the surface. • The entire aquifer is unconfined. There can be large variations in well yields, indicating concentration of groundwater flow in karstified zones. There are two levels of conduits – one set is at sea level and one set is at around 40-60 m below sea level. The more active conduit system is likely to be the upper one, with the lower system reflecting ancient lower sea levels. Flow velocities within the conduits will be significant (10's to 100's m/h). • Groundwater discharges to the streams and rivers crossing the GWB (e.g., Deel and Ahacronane), and to the springs within the GWB. At the northwestern margin of the GWB, groundwater discharges to the Shannon Estuary. Near the southern edge of the GWB, groundwater in the karstic aquifer comes to the surface at the base of the slope forming the surface water catchment divide. • There are several important ecosystems within the GWB that are dependent on groundwater. Several of these (the system that includes Ballinvirick Marsh) are at risk from drainage that lowers the groundwater levels. Potential pollution could enter the Shannon estuary via groundwater flow.
Attachments		Groundwater hydrograph (Figure 1).
Instrumentation		Stream gauges: 24019, 24029*, 24081. *(Adjusted dry weather flow calculated for stations marked with *)* EPA Water Level Monitoring boreholes: Morigan's GWS (LIM083).

Information Sources	Clarke, R. G., *et al*. (1981*). Engineering geology for a major industrial complex at Aughinish Island, Limerick, Ireland*. Quat. J. Eng. Geol., Vol. 14, pp. 231–39. Deakin, J., Daly, D. and Coxon, C. (1998) *County Limerick Groundwater Protection Scheme*. Geological Survey of Ireland Report to Limerick Co. Co., 72 pp. Ercon (1974) *Report on hydrogeological investigation, Bauxite benefication plant, Aughinish*. Report No. 6488, 19 pp. Gutmanis, J. C. (1981) *The geology of Aughinish Island and the preservation of probable Tertiary deposits in an ancient karst system*. Paper for submission to the Journal of Earth Sciences. Aquifer chapters: Dinantian Pure Unbedded Limestones, Dinantian Upper Impure Limestones.
Disclaimer	Note that all calculations and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae

Figure 1: Groundwater hydrograph





Rock units in GWB

Rock unit name and code	Description	Rock unit group
Waulsortian Limestones (WA)	Massive unbedded lime-mudstone	Dinantian Pure Unbedded Limestones
Rathkeale Formation (RK)	Dark muddy limestone and shaley limestone	Dinantian Upper Impure Limestones

APPENDIX 7

Groundwater Recharge

Introduction

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

The main parameters involved in the estimation of recharge are: annual rainfall; annual evapotranspiration; and a recharge coefficient (Table 1). The recharge coefficient is estimated using Guidance Document GW5 (Groundwater Working Group 2005).

Table 2: Recharge coefficients for different hydrogeological settings.

Vulnerability category		Hydrogeological setting	Recharge coefficient (rc)		
			Min (%)	Inner Range	Max (%)*
Extreme	1.i	Areas where rock is at ground surface	60	80-90	100
	1.ii	Sand/gravel overlain by 'well drained' soil	60	80-90	100
		Sand/gravel overlain by 'poorly drained' (gley) soil			
	1.iii	Till overlain by 'well drained' soil	45	50-70	80
	1.iv	Till overlain by 'poorly drained' (gley) soil	15	25-40	50
	1.v	Sand/ gravel aquifer where the water table is ≤ 3 m below surface	70	80-90	100
	1.vi	Peat	15	25-40	50
High	2.i	Sand/gravel aquifer, overlain by 'well drained' soil	60	80-90	100
	2.ii	High permeability subsoil (sand/gravel) overlain by 'well drained' soil	60	80-90	100
	2.iii	High permeability subsoil (sand/gravel) overlain by 'poorly drained' soil			
	2.iv	Moderate permeability subsoil overlain by 'well drained' soil	35	50-70	80
	2.v	Moderate permeability subsoil overlain by 'poorly drained' (gley) soil	15	25-40	50
	2.vi	Low permeability subsoil	10	23-30	40
	2.vii	Peat	0	5-15	20
Moderate	3.i	Moderate permeability subsoil and overlain by 'well drained' soil	25	30-40	60
	3.ii	Moderate permeability subsoil and overlain by 'poorly drained' (gley) soil	10	20-40	50
	3.iii	Low permeability subsoil	5	10-20	30
	3. iv	Basin peat	0	3-5	10
Low	4.i	Low permeability subsoil	2	5-15	20
	4.ii	Basin peat	0	3-5	10
High to Low	5.i	High Permeability Subsoils (Sand & Gravels)	60	85	100
	5.ii	Moderate Permeability Subsoil overlain by well drained soils	25	50	80
	5.iii	Moderate Permeability Subsoils overlain by poorly drained soils	10	30	50
	5.iv	Low Permeability Subsoil	2	20	40
	5.v	Peat	0	5	20

Acknowledgement: many of the recharge coefficients in this table are based largely on a paper submitted by Fitzsimons and Misstear (in press).

APPENDIX 8

Water Quality Analytical Results

Table 9.2a

Commissioned Survey Water Quality Data

Cappagh GWS Borehole 1 (Rosemount)

	pH	Ammonia (mgN/l)	Nitrate (mgN/l)	Nitrite (mgN/l)	Iron (µg Fe/l)	Manganese (µg Mn/l)	Tot. Coli (no./100ml)	F. coli (no./100ml)
26/05/03					37	-	5	1
03/06/03	-	-	-	-	33	-	8	NF
10/06/03	-	-	-	-	11	-	1	NF
17/06/03	-	-	-	-	45	-	NF	NF
24/06/03	-	-	-	-	24	-	3	NF
01/07/03	-	-	-	-	20	-	NF	NF
07/07/03	-	-	-	-	37	-	NF	NF
15/07/03	-	-	-	-	22	-	NF	NF
22/07/03	-	-	-	-	22	-	1	NF
29/07/03	-	-	-	-	21	-	1	NF
23/09/03	-	-	6.3	-	22	-	NF	NF
02/10/03	-	-	-	-	58	-	NF	NF
06/10/03	-	-	-	-	16	-	NF	NF
14/10/03	-	-	-	-	-	-	-	NF
28/10/03	-	-	-	-	19	<10	1	NF
04/11/03	-	-	-	-	24	<10	NF	NF
11/11/03	-	-	-	-	38	<10	NF	NF
18/11/03	-	-	-	-	30	<10	1	NF
24/11/03	-			-	-	-	-	NF
01/12/03	-	0.3	7.0	-	24	<10	5	NF
08/12/03	-	-	-	-	24	<50	1	NF

15/12/03	-	-	-	-	-	-	-	NF
07/01/03	-	-	7.8	0.06	24	19	NF	NF
13/01/03	-	-	-	-	21	12	1	NF
20/04/04						<50		
04/05/04						<50		
19/05/04						<50		
02/06/04						<10		
14/06/04						<10		
28/06/04						<50		
12/07/04						<10		
27/07/04						<10		
10/08/04						<10		

Table 9.2b

Commissioned Survey Water Quality Data

Cappagh GWS Borehole 2 (Priest's Field)

	pH	Ammonia (mgN/l)	Nitrate (mgN/l)	Nitrite (mgN/l)	Iron (µg Fe/l)	Manganese (µg Mn/l)	Tot. Coli (no./100ml)	F. coli (no./100ml)
27/05/03					26	-	NF	NF
03/06/03	-	-	-	-	15	-	<200	>200
10/06/03	-	-	-	-	26	-	4	2
17/06/03	-	-	-	-	17	-	NF	NF
24/06/03	-	-	-	-	16	-	NF	NF
01/07/03	-	-	-	-	16	-	2	1
07/07/03	-	-	-	-	18	-	NF	NF
15/07/03	-	-	-	-	14	-	NF	NF

22/07/03	-	-	-	-	17	-	NF	NF
12/08/03	-	-	-	-	16	-	NF	NF
19/08/03	-	-	-	-	22	-	NF	NF
02/10/03	-	-	-	-	15	-	-	-
06/10/03	-	-	-	-	15	3	NF	NF
14/10/03	-	-	-	-	-	-	-	-
28/10/03	-	-	-	-	15	<10	22	NF
04/11/03	-	-	-	-	15	<10	1	NF
11/11/03	-	-	-	-	-	-	-	-
18/11/03	-	-	-	-	-	-	-	-
24/11/03	-			-	-	-	-	-
01/12/03	-	-	-	-	-	-	-	-
08/12/03	-	-	-	-	-	-	-	-
15/12/03	-	-	-	-	-	-	-	-
07/01/03	-	-	-	-	-	-	-	-
13/01/03	-	-	-	-	-	-	-	-

Table 9.2c

Trial Well Water Quality Data

Cappagh GWS Borehole Source

	pH	Ammonia (mgN/l)	Nitrate (mgN/l)	Nitrite (mgN/l)	Iron (µg Fe/l)	Manganese (µg Mn/l)	Tot. Coli (no./100ml)	F.coli (no./100ml)
13/02/04			6	<0.01	<10	<10	1	1

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	Private Hse beside school	2008	E. coli	08/09/2008 12:00	0
CAPPAGH PVT GWS	Private Hse beside school	2008	Lead	08/09/2008 12:00	0.4
CAPPAGH PVT GWS	Private Hse beside school	2008	Nitrate	08/09/2008 12:00	23.7
CAPPAGH PVT GWS	Private Hse beside school	2008	Ammonium	08/09/2008 12:00	0.04
CAPPAGH PVT GWS	Private Hse beside school	2008	Colour	08/09/2008 12:00	10
CAPPAGH PVT GWS	Private Hse beside school	2008	Conductivity	08/09/2008 12:00	772
CAPPAGH PVT GWS	Private Hse beside school	2008	pH	08/09/2008 12:00	7.3
CAPPAGH PVT GWS	Private Hse beside school	2008	Odour	08/09/2008 12:00	0
CAPPAGH PVT GWS	Private Hse beside school	2008	Taste	08/09/2008 12:00	0
CAPPAGH PVT GWS	Private Hse beside school	2008	Coliform Bacteria	08/09/2008 12:00	0
CAPPAGH PVT GWS	Private Hse beside school	2008	Turbidity (at tap)	08/09/2008 12:00	0.53
CAPPAGH PVT GWS	Private Hse beside school	2008	Total Chlorine	08/09/2008 12:00	0
CAPPAGH PVT GWS	Private Hse beside school	2008	Free Chlorine	08/09/2008 12:00	0
CAPPAGH PVT GWS	Treated Water Priest's Field	2008	E. coli	04/09/2008 12:00	0
CAPPAGH PVT GWS	Treated Water Priest's Field	2008	Nitrate	04/09/2008 12:00	16.7
CAPPAGH PVT GWS	Treated Water Priest's Field	2008	Nitrite (at tap)	04/09/2008 12:00	0.07
CAPPAGH PVT GWS	Treated Water Priest's Field	2008	Colour	04/09/2008 12:00	5
CAPPAGH PVT GWS	Treated Water Priest's Field	2008	pH	04/09/2008 12:00	6.99
CAPPAGH PVT GWS	Treated Water Priest's Field	2008	Iron	04/09/2008 12:00	20
CAPPAGH PVT GWS	Treated Water Priest's Field	2008	Manganese	04/09/2008 12:00	5
CAPPAGH PVT GWS	Treated Water Priest's Field	2008	Coliform Bacteria	04/09/2008 12:00	0
CAPPAGH PVT GWS	Treated Water Priest's Field	2008	Total Organic Carbon	04/09/2008 12:00	0.4
CAPPAGH PVT GWS	Treated Water Priest's Field	2008	Turbidity (at tap)	04/09/2008 12:00	0.01
CAPPAGH PVT GWS	Community Centre	2009	E. coli	27/01/2009 12:30	0
CAPPAGH PVT GWS	Community Centre	2009	Nitrate	27/01/2009 12:30	22.9
CAPPAGH PVT GWS	Community Centre	2009	Ammonium	27/01/2009 12:30	0.04
CAPPAGH PVT GWS	Community Centre	2009	Colour	27/01/2009 12:30	10
CAPPAGH PVT GWS	Community Centre	2009	Conductivity	27/01/2009 12:30	787
CAPPAGH PVT GWS	Community Centre	2009	pH	27/01/2009 12:30	7.4
CAPPAGH PVT GWS	Community Centre	2009	Odour	27/01/2009 12:30	0

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	Community Centre	2009	Coliform Bacteria	27/01/2009 12:30	1
CAPPAGH PVT GWS	Community Centre	2009	Turbidity (at tap)	27/01/2009 12:30	0.09
CAPPAGH PVT GWS	Community Centre	2009	Total Chlorine	27/01/2009 12:30	0.27
CAPPAGH PVT GWS	Community Centre	2009	Free Chlorine	27/01/2009 12:30	0.16
CAPPAGH PVT GWS	Community Centre	2009	Hardness (as CaCO3)	27/01/2009 12:30	422
CAPPAGH PVT GWS	House On L6021	2009	E. coli	09/03/2009 15:08	0
CAPPAGH PVT GWS	House On L6021	2009	Nitrate	09/03/2009 15:08	23.4
CAPPAGH PVT GWS	House On L6021	2009	Ammonium	09/03/2009 15:08	0.04
CAPPAGH PVT GWS	House On L6021	2009	Colour	09/03/2009 15:08	10
CAPPAGH PVT GWS	House On L6021	2009	Conductivity	09/03/2009 15:08	754
CAPPAGH PVT GWS	House On L6021	2009	pH	09/03/2009 15:08	7.4
CAPPAGH PVT GWS	House On L6021	2009	Odour	09/03/2009 15:08	0
CAPPAGH PVT GWS	House On L6021	2009	Taste	09/03/2009 15:08	0
CAPPAGH PVT GWS	House On L6021	2009	Coliform Bacteria	09/03/2009 15:08	0
CAPPAGH PVT GWS	House On L6021	2009	Turbidity (at tap)	09/03/2009 15:08	0.55
CAPPAGH PVT GWS	House On L6021	2009	Total Chlorine	09/03/2009 15:08	0.21
CAPPAGH PVT GWS	House On L6021	2009	Free Chlorine	09/03/2009 15:08	0.17
CAPPAGH PVT GWS	House On L6021	2009	Hardness (as CaCO3)	09/03/2009 15:08	414
CAPPAGH PVT GWS	House On L8064	2009	E. coli	30/03/2009 13:10	0
CAPPAGH PVT GWS	House On L8064	2009	Nitrate	30/03/2009 13:10	23
CAPPAGH PVT GWS	House On L8064	2009	Ammonium	30/03/2009 13:10	0.04
CAPPAGH PVT GWS	House On L8064	2009	Colour	30/03/2009 13:10	10
CAPPAGH PVT GWS	House On L8064	2009	Conductivity	30/03/2009 13:10	769
CAPPAGH PVT GWS	House On L8064	2009	pH	30/03/2009 13:10	7.4
CAPPAGH PVT GWS	House On L8064	2009	Odour	30/03/2009 13:10	0
CAPPAGH PVT GWS	House On L8064	2009	Taste	30/03/2009 13:10	0
CAPPAGH PVT GWS	House On L8064	2009	Coliform Bacteria	30/03/2009 13:10	0
CAPPAGH PVT GWS	House On L8064	2009	Turbidity (at tap)	30/03/2009 13:10	0.32
CAPPAGH PVT GWS	House On L8064	2009	Total Chlorine	30/03/2009 13:10	0.15
CAPPAGH PVT GWS	House On L8064	2009	Free Chlorine	30/03/2009 13:10	0.12

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	House On L8064	2009	Hardness (as CaCO3)	30/03/2009 13:10	348
CAPPAGH PVT GWS	Private House On L6176	2009	E. coli	16/02/2009 13:10	0
CAPPAGH PVT GWS	Private House On L6176	2009	Nitrate	16/02/2009 13:10	23.7
CAPPAGH PVT GWS	Private House On L6176	2009	Ammonium	16/02/2009 13:10	0.04
CAPPAGH PVT GWS	Private House On L6176	2009	Colour	16/02/2009 13:10	10
CAPPAGH PVT GWS	Private House On L6176	2009	Conductivity	16/02/2009 13:10	795
CAPPAGH PVT GWS	Private House On L6176	2009	pH	16/02/2009 13:10	7.6
CAPPAGH PVT GWS	Private House On L6176	2009	Odour	16/02/2009 13:10	0
CAPPAGH PVT GWS	Private House On L6176	2009	Taste	16/02/2009 13:10	0
CAPPAGH PVT GWS	Private House On L6176	2009	Coliform Bacteria	16/02/2009 13:10	0
CAPPAGH PVT GWS	Private House On L6176	2009	Turbidity (at tap)	16/02/2009 13:10	0.36
CAPPAGH PVT GWS	Private House On L6176	2009	Total Chlorine	16/02/2009 13:10	0.08
CAPPAGH PVT GWS	Private House On L6176	2009	Free Chlorine	16/02/2009 13:10	0.04
CAPPAGH PVT GWS	Private House On L6176	2009	Hardness (as CaCO3)	16/02/2009 13:10	30
CAPPAGH PVT GWS	House On L6021	2010	E. coli	09/03/2010 12:41	0
CAPPAGH PVT GWS	House On L6021	2010	Nitrate	09/03/2010 12:41	19.6
CAPPAGH PVT GWS	House On L6021	2010	Ammonium	09/03/2010 12:41	
CAPPAGH PVT GWS	House On L6021	2010	Colour	09/03/2010 12:41	
CAPPAGH PVT GWS	House On L6021	2010	Conductivity	09/03/2010 12:41	762
CAPPAGH PVT GWS	House On L6021	2010	pH	09/03/2010 12:41	7.4
CAPPAGH PVT GWS	House On L6021	2010	Odour	09/03/2010 12:41	0
CAPPAGH PVT GWS	House On L6021	2010	Taste	09/03/2010 12:41	0
CAPPAGH PVT GWS	House On L6021	2010	Coliform Bacteria	09/03/2010 12:41	0
CAPPAGH PVT GWS	House On L6021	2010	Turbidity (at tap)	09/03/2010 12:41	0.18
CAPPAGH PVT GWS	House On L6021	2010	Total Chlorine	09/03/2010 12:41	0.07
CAPPAGH PVT GWS	House On L6021	2010	Free Chlorine	09/03/2010 12:41	0.04
CAPPAGH PVT GWS	Priests Field	2010	E. coli	09/11/2010 12:00	0
CAPPAGH PVT GWS	Priests Field	2010	Nitrate	09/11/2010 12:00	13.47
CAPPAGH PVT GWS	Priests Field	2010	Nitrite (at tap)	09/11/2010 12:00	
CAPPAGH PVT GWS	Priests Field	2010	Ammonium	09/11/2010 12:00	

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	Priests Field	2010	Colour	09/11/2010 12:00	
CAPPAGH PVT GWS	Priests Field	2010	Conductivity	09/11/2010 12:00	554
CAPPAGH PVT GWS	Priests Field	2010	pH	09/11/2010 12:00	7.02
CAPPAGH PVT GWS	Priests Field	2010	Iron	09/11/2010 12:00	
CAPPAGH PVT GWS	Priests Field	2010	Manganese	09/11/2010 12:00	
CAPPAGH PVT GWS	Priests Field	2010	Odour	09/11/2010 12:00	0
CAPPAGH PVT GWS	Priests Field	2010	Coliform Bacteria	09/11/2010 12:00	0
CAPPAGH PVT GWS	Priests Field	2010	Total Organic Carbon	09/11/2010 12:00	2.5
CAPPAGH PVT GWS	Private House On L1219	2010	E. coli	09/03/2010 12:55	0
CAPPAGH PVT GWS	Private House On L1219	2010	Nitrate	09/03/2010 12:55	19.9
CAPPAGH PVT GWS	Private House On L1219	2010	Ammonium	09/03/2010 12:55	
CAPPAGH PVT GWS	Private House On L1219	2010	Colour	09/03/2010 12:55	
CAPPAGH PVT GWS	Private House On L1219	2010	Conductivity	09/03/2010 12:55	768
CAPPAGH PVT GWS	Private House On L1219	2010	pH	09/03/2010 12:55	7.5
CAPPAGH PVT GWS	Private House On L1219	2010	Odour	09/03/2010 12:55	0
CAPPAGH PVT GWS	Private House On L1219	2010	Taste	09/03/2010 12:55	0
CAPPAGH PVT GWS	Private House On L1219	2010	Coliform Bacteria	09/03/2010 12:55	0
CAPPAGH PVT GWS	Private House On L1219	2010	Turbidity (at tap)	09/03/2010 12:55	0.77
CAPPAGH PVT GWS	Private House On L1219	2010	Total Chlorine	09/03/2010 12:55	
CAPPAGH PVT GWS	Private House On L1219	2010	Free Chlorine	09/03/2010 12:55	0.06
CAPPAGH PVT GWS	Rosemount	2010	E. coli	06/12/2010 12:00	0
CAPPAGH PVT GWS	Rosemount	2010	Cadmium	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Chromium	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Copper	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Cyanide	06/12/2010 12:00	0.9
CAPPAGH PVT GWS	Rosemount	2010	1,2-dichloroethane	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Fluoride	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Lead	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Mercury	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Nickel	06/12/2010 12:00	

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	Rosemount	2010	Enterococci	06/12/2010 12:00	0
CAPPAGH PVT GWS	Rosemount	2010	Nitrate	06/12/2010 12:00	18.3
CAPPAGH PVT GWS	Rosemount	2010	Nitrite (at tap)	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	PAH	06/12/2010 12:00	0
CAPPAGH PVT GWS	Rosemount	2010	Selenium	06/12/2010 12:00	0.509
CAPPAGH PVT GWS	Rosemount	2010	Trihalomethanes(Total)	06/12/2010 12:00	8.162
CAPPAGH PVT GWS	Rosemount	2010	Vinyl Chloride	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Aluminium	06/12/2010 12:00	25
CAPPAGH PVT GWS	Rosemount	2010	Ammonium	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Chloride	06/12/2010 12:00	27.6
CAPPAGH PVT GWS	Rosemount	2010	Clostridium Perfringens	06/12/2010 12:00	0
CAPPAGH PVT GWS	Rosemount	2010	Colour	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Conductivity	06/12/2010 12:00	824
CAPPAGH PVT GWS	Rosemount	2010	pH	06/12/2010 12:00	7.13
CAPPAGH PVT GWS	Rosemount	2010	Iron	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Manganese	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Odour	06/12/2010 12:00	0
CAPPAGH PVT GWS	Rosemount	2010	Antimony	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Sulphate	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Sodium	06/12/2010 12:00	18.97
CAPPAGH PVT GWS	Rosemount	2010	Taste	06/12/2010 12:00	0
CAPPAGH PVT GWS	Rosemount	2010	Colony Count @ 22Â°C	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Coliform Bacteria	06/12/2010 12:00	0
CAPPAGH PVT GWS	Rosemount	2010	Total Organic Carbon	06/12/2010 12:00	1.4
CAPPAGH PVT GWS	Rosemount	2010	Turbidity (at tap)	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Arsenic	06/12/2010 12:00	0.512
CAPPAGH PVT GWS	Rosemount	2010	Benzene	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Benzo(a)pyrene	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Boron	06/12/2010 12:00	
CAPPAGH PVT GWS	Rosemount	2010	Bromate	06/12/2010 12:00	

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	Treated Water	2010	E. coli	03/02/2010 12:00	0
CAPPAGH PVT GWS	Treated Water	2010	Nitrate	03/02/2010 12:00	21.53
CAPPAGH PVT GWS	Treated Water	2010	Nitrite (at tap)	03/02/2010 12:00	
CAPPAGH PVT GWS	Treated Water	2010	Colour	03/02/2010 12:00	
CAPPAGH PVT GWS	Treated Water	2010	pH	03/02/2010 12:00	7.2
CAPPAGH PVT GWS	Treated Water	2010	Iron	03/02/2010 12:00	
CAPPAGH PVT GWS	Treated Water	2010	Manganese	03/02/2010 12:00	
CAPPAGH PVT GWS	Treated Water	2010	Coliform Bacteria	03/02/2010 12:00	0
CAPPAGH PVT GWS	Treated Water	2010	Total Organic Carbon	03/02/2010 12:00	2.24
CAPPAGH PVT GWS	Treated Water	2010	Turbidity (at tap)	03/02/2010 12:00	0.69
CAPPAGH PVT GWS	Treated Water	2010	E. coli	01/07/2010 12:00	0
CAPPAGH PVT GWS	Treated Water	2010	Nitrate	01/07/2010 12:00	10.68
CAPPAGH PVT GWS	Treated Water	2010	Colour	01/07/2010 12:00	
CAPPAGH PVT GWS	Treated Water	2010	pH	01/07/2010 12:00	7.1
CAPPAGH PVT GWS	Treated Water	2010	Iron	01/07/2010 12:00	
CAPPAGH PVT GWS	Treated Water	2010	Manganese	01/07/2010 12:00	
CAPPAGH PVT GWS	Treated Water	2010	Total Organic Carbon	01/07/2010 12:00	
CAPPAGH PVT GWS	Treated Water	2010	Turbidity (at tap)	01/07/2010 12:00	
CAPPAGH PVT GWS	Community Centre	2011	E. coli	18/04/2011 10:40	0
CAPPAGH PVT GWS	Community Centre	2011	Nitrate	18/04/2011 10:40	20.6
CAPPAGH PVT GWS	Community Centre	2011	Ammonium	18/04/2011 10:40	
CAPPAGH PVT GWS	Community Centre	2011	Colour	18/04/2011 10:40	
CAPPAGH PVT GWS	Community Centre	2011	Conductivity	18/04/2011 10:40	737
CAPPAGH PVT GWS	Community Centre	2011	pH	18/04/2011 10:40	7.3
CAPPAGH PVT GWS	Community Centre	2011	Odour	18/04/2011 10:40	0
CAPPAGH PVT GWS	Community Centre	2011	Taste	18/04/2011 10:40	0
CAPPAGH PVT GWS	Community Centre	2011	Coliform Bacteria	18/04/2011 10:40	0
CAPPAGH PVT GWS	Community Centre	2011	Turbidity (at tap)	18/04/2011 10:40	0.22
CAPPAGH PVT GWS	Community Centre	2011	Total Chlorine	18/04/2011 10:40	0.09
CAPPAGH PVT GWS	Community Centre	2011	Free Chlorine	18/04/2011 10:40	0.04

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	Private House In Village	2011	E. coli	18/04/2011 11:15	0
CAPPAGH PVT GWS	Private House In Village	2011	Nitrate	18/04/2011 11:15	20.4
CAPPAGH PVT GWS	Private House In Village	2011	Ammonium	18/04/2011 11:15	
CAPPAGH PVT GWS	Private House In Village	2011	Colour	18/04/2011 11:15	
CAPPAGH PVT GWS	Private House In Village	2011	Conductivity	18/04/2011 11:15	815
CAPPAGH PVT GWS	Private House In Village	2011	pH	18/04/2011 11:15	7.3
CAPPAGH PVT GWS	Private House In Village	2011	Odour	18/04/2011 11:15	0
CAPPAGH PVT GWS	Private House In Village	2011	Taste	18/04/2011 11:15	0
CAPPAGH PVT GWS	Private House In Village	2011	Coliform Bacteria	18/04/2011 11:15	0
CAPPAGH PVT GWS	Private House In Village	2011	Turbidity (at tap)	18/04/2011 11:15	0.13
CAPPAGH PVT GWS	Private House In Village	2011	Total Chlorine	18/04/2011 11:15	0.11
CAPPAGH PVT GWS	Private House In Village	2011	Free Chlorine	18/04/2011 11:15	0.07
CAPPAGH PVT GWS	Private House In Village	2011	E. coli	22/11/2011 12:30	0
CAPPAGH PVT GWS	Private House In Village	2011	Cadmium	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Chromium	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Copper	22/11/2011 12:30	0.006
CAPPAGH PVT GWS	Private House In Village	2011	Cyanide	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	1,2-dichloroethane	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Fluoride	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Lead	22/11/2011 12:30	0.4
CAPPAGH PVT GWS	Private House In Village	2011	Mercury	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Nickel	22/11/2011 12:30	1.4
CAPPAGH PVT GWS	Private House In Village	2011	Enterococci	22/11/2011 12:30	0
CAPPAGH PVT GWS	Private House In Village	2011	Nitrate	22/11/2011 12:30	17.78
CAPPAGH PVT GWS	Private House In Village	2011	Pesticides - Total	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	PAH	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Selenium	22/11/2011 12:30	1.3
CAPPAGH PVT GWS	Private House In Village	2011	Tetrachloroethene & Tri	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Trihalomethanes(Total)	22/11/2011 12:30	8.49
CAPPAGH PVT GWS	Private House In Village	2011	Aluminium	22/11/2011 12:30	

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	Private House In Village	2011	Ammonium	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Chloride	22/11/2011 12:30	26.9
CAPPAGH PVT GWS	Private House In Village	2011	Colour	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Conductivity	22/11/2011 12:30	749
CAPPAGH PVT GWS	Private House In Village	2011	pH	22/11/2011 12:30	7.3
CAPPAGH PVT GWS	Private House In Village	2011	Iron	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Manganese	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Odour	22/11/2011 12:30	0
CAPPAGH PVT GWS	Private House In Village	2011	Antimony	22/11/2011 12:30	0.1
CAPPAGH PVT GWS	Private House In Village	2011	Sulphate	22/11/2011 12:30	18.9
CAPPAGH PVT GWS	Private House In Village	2011	Sodium	22/11/2011 12:30	16.6
CAPPAGH PVT GWS	Private House In Village	2011	Taste	22/11/2011 12:30	0
CAPPAGH PVT GWS	Private House In Village	2011	Coliform Bacteria	22/11/2011 12:30	0
CAPPAGH PVT GWS	Private House In Village	2011	Total Organic Carbon	22/11/2011 12:30	1.82
CAPPAGH PVT GWS	Private House In Village	2011	Turbidity (at tap)	22/11/2011 12:30	0.36
CAPPAGH PVT GWS	Private House In Village	2011	Total Chlorine	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Arsenic	22/11/2011 12:30	0.5
CAPPAGH PVT GWS	Private House In Village	2011	Free Chlorine	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Benzene	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Benzo(a)pyrene	22/11/2011 12:30	
CAPPAGH PVT GWS	Private House In Village	2011	Boron	22/11/2011 12:30	0.03
CAPPAGH PVT GWS	Private House In Village	2011	Bromate	22/11/2011 12:30	
CAPPAGH PVT GWS	Rosemount	2011	E. coli	12/04/2011 12:00	0
CAPPAGH PVT GWS	Rosemount	2011	Nitrate	12/04/2011 12:00	26.76
CAPPAGH PVT GWS	Rosemount	2011	Nitrite (at tap)	12/04/2011 12:00	
CAPPAGH PVT GWS	Rosemount	2011	Colour	12/04/2011 12:00	
CAPPAGH PVT GWS	Rosemount	2011	pH	12/04/2011 12:00	8.2
CAPPAGH PVT GWS	Rosemount	2011	Iron	12/04/2011 12:00	
CAPPAGH PVT GWS	Rosemount	2011	Manganese	12/04/2011 12:00	
CAPPAGH PVT GWS	Rosemount	2011	Coliform Bacteria	12/04/2011 12:00	0

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	Rosemount	2011	Total Organic Carbon	12/04/2011 12:00	1.45
CAPPAGH PVT GWS	Rosemount	2011	Turbidity (at tap)	12/04/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	E. coli	04/01/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Nitrate	04/01/2011 12:00	12.71
CAPPAGH PVT GWS	Treated Water	2011	Nitrite (at tap)	04/01/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Colour	04/01/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	pH	04/01/2011 12:00	7.09
CAPPAGH PVT GWS	Treated Water	2011	Iron	04/01/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Manganese	04/01/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Coliform Bacteria	04/01/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Total Organic Carbon	04/01/2011 12:00	0.93
CAPPAGH PVT GWS	Treated Water	2011	Turbidity (at tap)	04/01/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	E. coli	08/03/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Nitrate	08/03/2011 12:00	17.59
CAPPAGH PVT GWS	Treated Water	2011	Nitrite (at tap)	08/03/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Colour	08/03/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	pH	08/03/2011 12:00	7.24
CAPPAGH PVT GWS	Treated Water	2011	Iron	08/03/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Manganese	08/03/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Coliform Bacteria	08/03/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Total Organic Carbon	08/03/2011 12:00	1.4
CAPPAGH PVT GWS	Treated Water	2011	Turbidity (at tap)	08/03/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	E. coli	03/05/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Colour	03/05/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Conductivity	03/05/2011 12:00	777
CAPPAGH PVT GWS	Treated Water	2011	pH	03/05/2011 12:00	7.29
CAPPAGH PVT GWS	Treated Water	2011	Iron	03/05/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Manganese	03/05/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Odour	03/05/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Taste	03/05/2011 12:00	0

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	Treated Water	2011	Coliform Bacteria	03/05/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Total Organic Carbon	03/05/2011 12:00	0.82
CAPPAGH PVT GWS	Treated Water	2011	Turbidity (at tap)	03/05/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	E. coli	02/06/2011 12:04	0
CAPPAGH PVT GWS	Treated Water	2011	Nitrate	02/06/2011 12:04	39.16
CAPPAGH PVT GWS	Treated Water	2011	Nitrite (at tap)	02/06/2011 12:04	
CAPPAGH PVT GWS	Treated Water	2011	Colour	02/06/2011 12:04	
CAPPAGH PVT GWS	Treated Water	2011	pH	02/06/2011 12:04	7.09
CAPPAGH PVT GWS	Treated Water	2011	Iron	02/06/2011 12:04	
CAPPAGH PVT GWS	Treated Water	2011	Manganese	02/06/2011 12:04	
CAPPAGH PVT GWS	Treated Water	2011	Coliform Bacteria	02/06/2011 12:04	0
CAPPAGH PVT GWS	Treated Water	2011	Total Organic Carbon	02/06/2011 12:04	1.39
CAPPAGH PVT GWS	Treated Water	2011	Turbidity (at tap)	02/06/2011 12:04	
CAPPAGH PVT GWS	Treated Water	2011	E. coli	04/07/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Nitrate	04/07/2011 12:00	10.01
CAPPAGH PVT GWS	Treated Water	2011	Nitrite (at tap)	04/07/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Colour	04/07/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	pH	04/07/2011 12:00	7.17
CAPPAGH PVT GWS	Treated Water	2011	Iron	04/07/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Manganese	04/07/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Coliform Bacteria	04/07/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Total Organic Carbon	04/07/2011 12:00	0.81
CAPPAGH PVT GWS	Treated Water	2011	Turbidity (at tap)	04/07/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	E. coli	06/09/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Nitrate	06/09/2011 12:00	8.82
CAPPAGH PVT GWS	Treated Water	2011	Nitrite (at tap)	06/09/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Colour	06/09/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	pH	06/09/2011 12:00	7.2
CAPPAGH PVT GWS	Treated Water	2011	Iron	06/09/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Manganese	06/09/2011 12:00	

Scheme Name/Water Supply	Location	yearofreturn	parameter	sampledate	result
CAPPAGH PVT GWS	Treated Water	2011	Coliform Bacteria	06/09/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Total Organic Carbon	06/09/2011 12:00	0.74
CAPPAGH PVT GWS	Treated Water	2011	Turbidity (at tap)	06/09/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	E. coli	09/11/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Nitrate	09/11/2011 12:00	12.01
CAPPAGH PVT GWS	Treated Water	2011	Nitrite (at tap)	09/11/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Ammonium	09/11/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Colour	09/11/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Conductivity	09/11/2011 12:00	839
CAPPAGH PVT GWS	Treated Water	2011	pH	09/11/2011 12:00	7.39
CAPPAGH PVT GWS	Treated Water	2011	Iron	09/11/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Manganese	09/11/2011 12:00	
CAPPAGH PVT GWS	Treated Water	2011	Odour	09/11/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Taste	09/11/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Coliform Bacteria	09/11/2011 12:00	0
CAPPAGH PVT GWS	Treated Water	2011	Total Organic Carbon	09/11/2011 12:00	1.4
CAPPAGH PVT GWS	Treated Water	2011	Turbidity (at tap)	09/11/2011 12:00	

APPENDIX 10

Proposed Raw Water Analytical Suite of Parameters for Routine Monitoring

RAW WATER ANALYSIS PARAMETERS REQUIRED FOR ZOC DELINEATION
PHYSICO-CHEMICAL PARAMETERS (measure on site with hand held meter)
pH
Dissolved Oxygen
Conductivity @20C
Temperature
MAJOR IONS
Calcium, total
Magnesium, total
Sodium, total
Potassium, total
Alkalinity, total
Sulphate
Chloride
Nitrate as NO3
MINOR CONSTITUENTS
Total Hardness (Kone)
Iron, total
Colour, apparent
Turbidity
Orthophosphate as PO4-P
Manganese, total
Ammonium as NH4
Total Organic Carbon
MICROBIOLOGICAL PARAMETERS
E coli (Filtration) (Environmental Waters)
Total Coliforms (Filtration) (Environmental Waters)
OPTIONAL EXTRAS:
Additional metals: Al, As, Cd, Cr, Cu, Pb, Ni, Zn, Ba, Sr
Fluoride (by Ion Selective Electrode)
Nitrite as N
Silica
BOD (incl. separate COD analysis prior to BOD)
Clostridium perfringens

RAW WATER ANALYSIS PARAMETERS REQUIRED FOR ZOC DELINEATION
Onsite filtration kit is required for additional metals consisting of ziplock bag containing luer/lock syringe for trace metals, 0.45um syringe filter, 50ml sample tube) Note: Sampler needs to wear clean pair of powder free gloves before touching any of the items in the bag to prevent cross contamination.