

Establishment of Groundwater Zones of Contribution

Ballintrillick Group Water Scheme, Co. Sligo

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Project description

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

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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. The speed of flow through this network is relatively fast, delivering groundwater, and a large proportion of the contaminants present in the groundwater, to its destination e.g. borehole, spring, river and 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 the overlying soil and subsoil; thick, impermeable clay soil and subsoil provide good protection while thin gravel will provide limited protection. Therefore variation in subsoil type and thickness is 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 underground¹. 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.

Ballintrillick GWS (NFGWS Ref. SO001) is supplied from one of a pair of springs, by groundwater which flows through conduits in a regionally important karstified limestone aquifer and fractures and fissures in a locally important limestone aquifer. The springs are also supplied by shallow groundwater emerging from scree deposits. The GWS abstracts 82 m³/d.

¹ Geological Survey of Ireland, 2000.

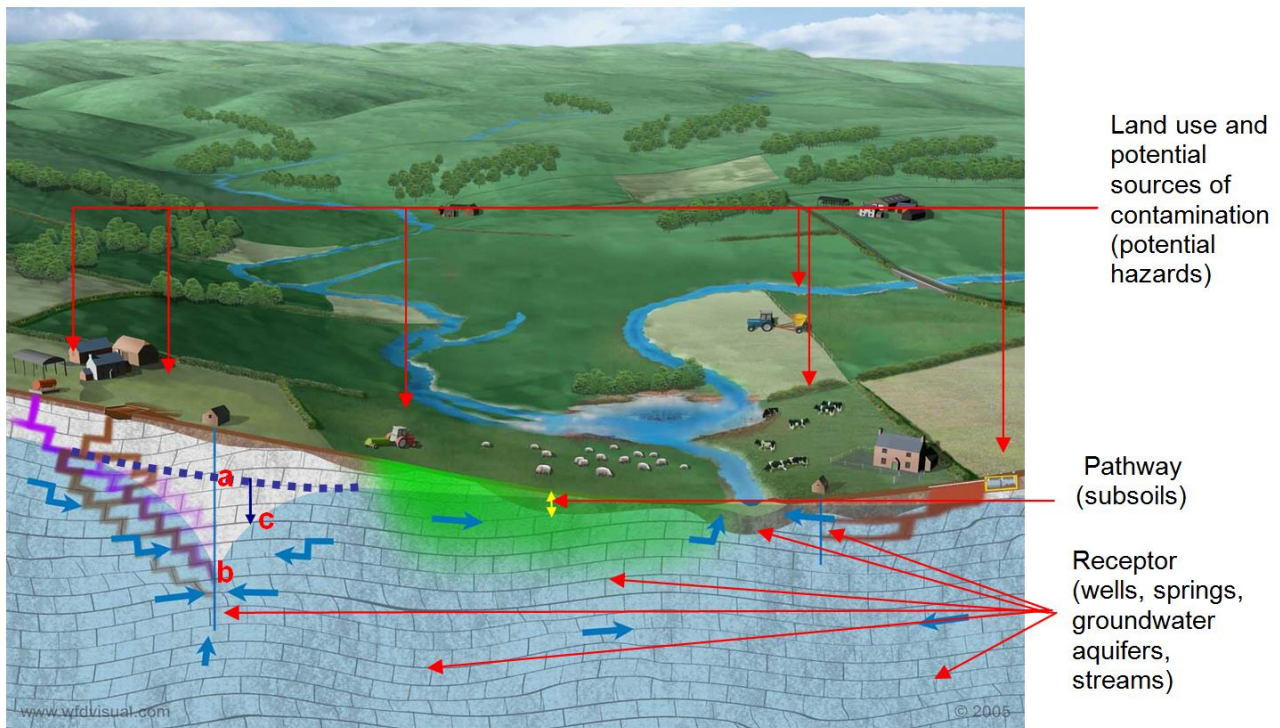


Diagram 1. Rural Landscape Highlighting the Interaction between Surface Water, Groundwater and Potential Land Use Hazards

2 Location, Site Description, Supply Details and Wellhead Protection

The zone of contribution (ZOC) for the Ballintrillick Group Water Scheme (GWS) has been delineated according to the principles and methodologies set out in 'Groundwater Protection Schemes'² and in the GSI/EPA/IGI Training course on Groundwater SPZ Delineation.

Ballintrillick GWS source is located in the townland of Moodoge, on the west facing slope of Truskmore Mountain, approximately 8 km north north-east of Sligo town (See **Figure 1**). It is currently supplied by one groundwater spring (Spring 1) and has previously supplemented this source with flow from a second spring (Spring 2) (See **Diagram 2** below). Spring 1 is surrounded by a concrete/block chamber where it emerges from the bedrock. A pipe arising within the chamber conveys water by gravity to a collection tank. Spring 2, though not currently used, is open and the majority of the flow is directed into a pipe. This pipe is currently directed to a drain within the treatment compound and thence to a roadside drain. The overflow from Spring 2 is the source of a permanent watercourse. A third spring, not strictly used as part of the supply, is the source of a watercourse which drains around the outside wall of the collection tank. It is likely that this surface water is not excluded from this collection tank. This watercourse discharges to a drain in the treatment compound and then to the roadside drain.

The scheme currently serves a total of 130 connections with an average total usage of 82 m³/d (average measured by DBO operator 2011- September 2015). The connections comprise 45 domestic, 70 house and lands and 15 others (a school, businesses, etc.). The network is metered and has been upgraded to deal with leaks³.

² DELG/EPA/GSI, 1999

³ GWS committee member

The Scheme has needed to supplement the flow with water from Spring 2 very occasionally to ensure full supply. This occurred only in the years before usage was significantly reduced in response to a reduction in leakage and the introduction of metering.

Currently, flow is piped under gravity from the collection tank to a sump tank at the treatment plant. Flow into the sump tank is controlled by a float valve. Overflow therefore occurs at the Spring 1 chamber. The treatment plant has a design capacity of 138 m³/day. Raw water is pumped through the treatment plant in response to levels in the treated water reservoir, which has a storage capacity of 180 m³⁴. Pumping is for 8 hours per day on average (recorded by DBO operator 2011 - September 2015). Distribution through the network is by gravity.

The treatment system is run by the DBO operator, Coffey Water Ltd. It comprises a sequence of sand filter, UV disinfection and chlorine disinfection. The treatment system is linked by SCADA to the DBO operator, with continuous monitoring and recording of key parameters. There is a local DBO operator who performs daily checks and a regular schedule of maintenance.

Summary details are presented in **Table 1**.

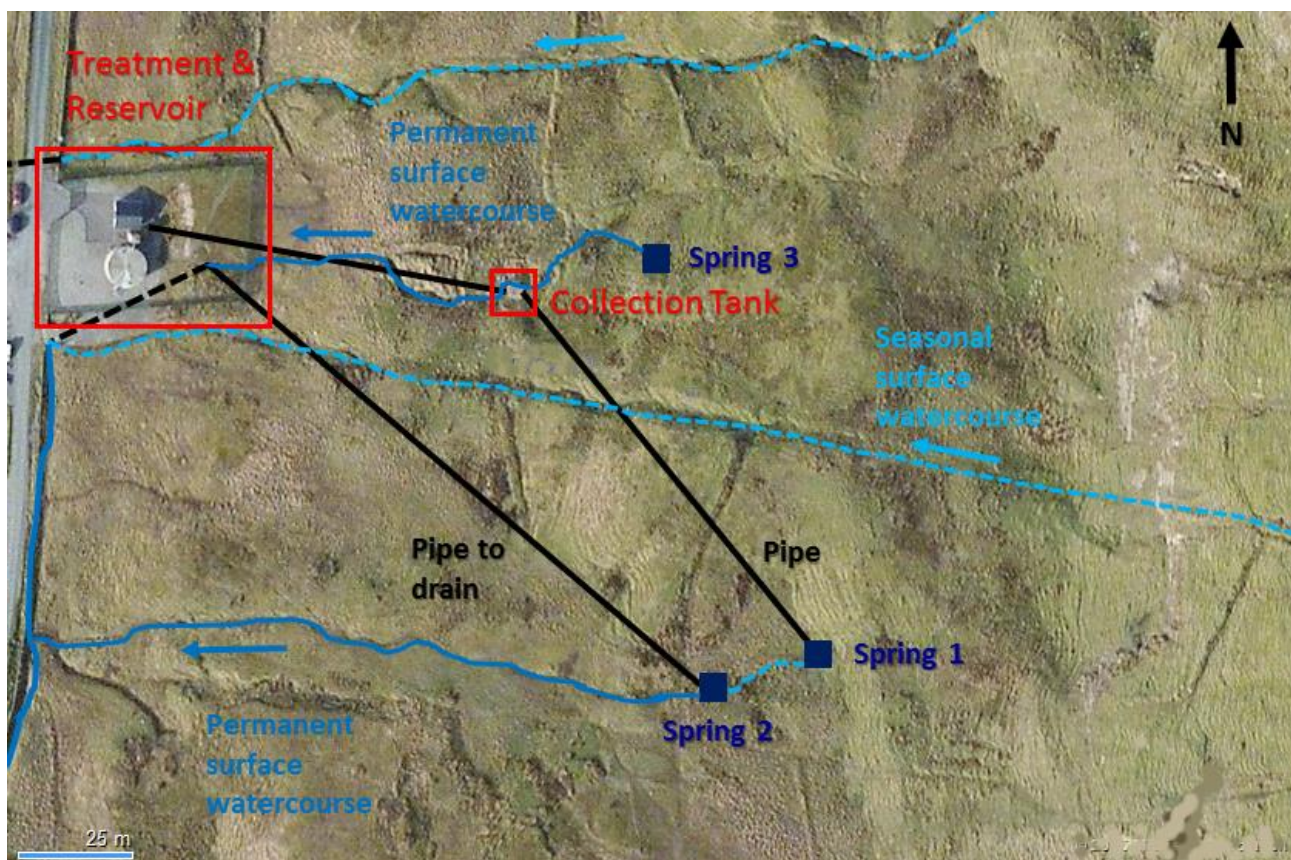


Diagram 2. Aerial photo showing location of GWS springs and collection tank

⁴ T.J. O'Connor & Associates (2010) *North West Sligo DBO Bundle Cryptosporidium Risk Assessment Recommendation*



Photo 1. Spring 1. Scree and exposed bedrock to east.



Photo 2. Spring 1 chamber with overflow.



Photo 3. Spring 1 inflow to chamber.



Photo 4. Spring 2. Spring 1 in background.



Photo 5. Spring 3 discharges into channel (channel obscured by grass).



Photo 6. Collection Tank for flow from Spring 1 in mid ground. Treatment plant and reservoir in background.

Table 1. Water Supply Details

NFGWS No: SO13	Spring 1	Spring 2
Grid reference	Irish Grid: E 174763, N 347617	Irish Grid: E 174733, N 347610
Townland	Moodoge	Moodoge
Source type	Spring discharging from exposed bedrock face at break in slope of topographic hollow.	Spring discharging from exposed bedrock faces downslope from Spring1.
Developed	Spring chamber and tank since 1984 and ongoing; Treatment infrastructure upgraded under DBO contract with Coffey Water Ltd. which commenced in 2006.	
Owner	Ballinrillick GWS.	
Elevation (m a.O.D.) (Estimated from OSI 1:50:000 Map)	280 m O.D.	278 m O.D.
Construction details	Spring chamber (approx. internal dimensions of area 0.6 x 0.6 depth 0.5m) is built of open blockwork against the bedrock outcrop on the upgradient wall. The base and other sides are blockwork, rendered on the inside. The box top is concrete with a well fitted recessed cover. Overflow is through an unscreened outlet in the top of the blockwork and is <0.1 m above ground level. Collection is by a 0.08 m I.D. Wavin pipe within the chamber and then gravity flow to the downhill collection tank. Fencing around the spring is not stockproof.	No chamber surrounding spring. Collection via a 3.8 cm diameter Wavin pipe. Overflow around pipe source of a watercourse. No fencing around source. Access by livestock possible.
	Collection tank of approximate area 3.5x3 m, depth approx. 0.75 m. The tank cover is recessed, locked and probably waterproof. At least two walls of the tank are composed of un-grouted stonework, probably dating from an older collection tank on the site. Part of the tank is concrete block/concrete. It is not possible to see whether the base of the tank is concrete or sat on top of bedrock. The tank is very unlikely to be watertight. There are no discharge meters on either the spring outflow or the collection tank. Fencing around the tank is not fully stock-proof.	
Water level (metres below top of chamber)	0.46 m b.t.o.c on 03/10/15. Overflows at 0.25 m above base of chamber.	No chamber – discharges at ground level
Depth to rock (m bgl)	0	0
Current abstraction rate	82 m ³ /d average, 156 m ³ /d maximum, 36 m ³ /d minimum (measured by DBO operator 2011- September 2015)	
Total spring flow	Spring 1 estimated to be an average of the order of 200 m ³ /day. Spring 2 estimated to be an average of the order of 70 m ³ /day. (Estimated from abstraction records, discussion with GWS member and flows measured in October 2015)	
Population served	360	

3 Physical Characteristics and Hydrogeological Considerations

3.1 Physical characteristics of the area

An overview of the relevant information on rainfall, land use, topography, hydrology and geology for the area around the GWS is provided in **Table 2**.

Table 2. Physical Characteristics of the Area of Interest

	Description/Comments	
Topography (Figure 1 & Figure 2)	The topography is dominated by Truskmore Mountain, at 647 m O.D. The mountain slopes very steeply to the west and north west. The springs are located close to the base of a sub-vertical section of slope, where the slope decreases. Steep gullies caused by seasonal and permanent watercourses run straight down the steep hill side.	
Land use	The area uphill of and surrounding the Springs is fenced land, with commonage higher up the mountain. Both areas are grazed by sheep. Most sheep are taken in during winter months. There are no roads, houses or farmyards within the zone of contribution.	
Surface Hydrology (Figure 1 & Figure 2)	Stream flows are strongly controlled by the steep topography of the mountain. Both permanent and seasonal watercourses cause incised gullies on the steep slopes. Spring 3 is the source of a permanent watercourse. Spring 2 overflow is the source of a permanent watercourse. Spring 1 uphill was probably the natural origin of this watercourse and provides overflow to it seasonally (See Diagram 2 for detail).	
Topsoil http://gis.epa.ie/envision	Poorly drained peat soils occur on the mountain top and are interspersed with exposed rock. Exposed rock and scree occur on the cliff face and steep slopes. Very thin, poorly drained peat and peaty soils occur around the springs.	
Subsoil (Figure 3) www.gsi.ie/mapping	Peat soils and exposed rock occur on the mountain top. Exposed limestone rock and scree occur on the steepest slopes, interspersed with some thin peats. Thin peat and peaty subsoils derived from sandstones and shales occur on areas of shallower slope.	
Groundwater Vulnerability (Figure 4) www.gsi.ie/mapping	Vulnerability is mapped as either extreme or extreme rock near surface (Appendix 1).	
Geology (Figure 5) www.gsi.ie/mapping	The horizontal layers of bedrock are exposed on the side of the mountain. Sandstones form the top of the plateau, and overlie a vertical sequence of Mixed Sandstones, Shales and Limestones, Pure Bedded Limestones, Impure Limestones, and Shales and Limestones.	
Aquifers (Figure 6) www.gsi.ie/mapping	The Pure Bedded Limestones are classified as a Regionally Important Karst Aquifer dominated by conduit flow (Rk_c). The Impure Limestones and the Shales and Limestones units are classified as Locally Important Aquifers which are moderately productive in local zones only (LI). The Sandstone unit is classified as a Locally Important aquifer which is generally moderately productive (Lm)	
Groundwater Body (GWB) www.wfdireland.ie	The area comprises two groundwater bodies, the Tievebaun karstic GWB and the Rossinver poorly productive GWB. Groundwater status is classified as 'good' for both www.gsi.ie/Programmes/Groundwater/Projects/Groundwater+Body+Descriptions	
Recharge Coefficient % (Appendix 3)	22.5 - 85	High recharge rates (in the order of 85%) occur where karst or sandstone rock is exposed at the surface. Recharge rates of approximately 60% are mapped in areas where scree and non-peat subsoils occur. Recharge is capped at 200 mm/year in areas underlain by fractured shaley bedrock which has a lower recharge acceptance capacity. Recharge rates are as low as 22.5 % under peat subsoils. Annual average recharge values are obtained from the national recharge map (www.gsi.ie). Recharge rates have been increased on the scree slopes and parts of the Dinantian Impure Limestone to take account of local conditions.
Recharge (mm) www.gsi.ie/mapping	200-1201	

3.2 Hydrochemistry and water quality

DBO Operator monthly check monitoring for the years 2013 to August 2015, Rural Water Scheme monitoring in 2000 to 2001 and a single GWS sample on 29/7/2015 were used to assess the hydrochemistry and water quality for Ballintrillick GWS. All available water quality data are presented in **Appendix 3**. Samples were collected from the raw water tap at the treatment plant indicated on **Diagram 2**, above. No samples from the individual springs have been collected.

The data are summarised in **Table 3**, where they have been compared to the drinking water limits (DWL) from the Drinking Water Regulations (S.I. No. 122 of 2014) and/or threshold values (TV) from the European Communities Environmental Objectives (Groundwater) Regulations 2010 (S.I. No. 9 of 2010).

Table 3. Key Hydrochemistry and Water Quality values in untreated water samples

Parameter	No. of samples	Min	Max	Average	Drinking Water Limit (DWL) or Threshold Value (TV)
Total Hardness (mg/l as CaCO ₃)	1	126	126	n/a	[-]
Electrical Conductivity (µS/cm)	10	155	320	222	800 (TV), 2,500 (DWL)
pH (laboratory measurement)	33	6.9	8.1	7.6	6.5 – 9.5 (DWL)
Total Coliforms (MPN ⁵ /100 ml)	44	0	395	28 exceedances (<100 counts) 13 exceedances (>100 counts)	0 (DWL)
Faecal Coliforms (<i>E. Coli</i>) (MPN/100 ml)	40	0	322	26 exceedances (<100 counts) 5 exceedance (>100 counts)	0 (DWL)
Clostridium Perfringens (CFU/100ml)	34	0	79	7 exceedances	0 (indicator)
Turbidity	44	0.2	9.57	1	n/a
Nitrate (mg/l NO ₃)	11	0.2	18.1	2.5	50 (DWL) 37.5 (TV)
Chloride (mg/l)	1	11.8	11.8	n/a	250 (DWL), 24 (TV)
Ammonium (mg N/l)	10	0.008	0.46	0.143	0.175 as N/l (TV) 0.23 as N/l (DWL)
Iron (µg/l)	11	6	50	n/a	200 (DWL)
Manganese (µg/l)	11	<0.03	11	14.9	50 (DWL)
Potassium:sodium ratio	1	0.1	0.1	n/a	0.4 (indicator)

Electrical conductivity values, pH and total hardness values accompanied by an alkalinity value of 124 mg/l CaCO₃ indicate that the sampled water comes from a combination of Dinantian pure bedded and mixed limestones and sandstones⁶. The values and variations of these parameters indicate potential surface water inputs as well as shallow and deep groundwater sources.

Turbidity is very variable, with high values occurring sporadically. The DBO operator has observed that turbidity levels can increase within an hour of high rainfall events.

⁵ MPN is most probable number

⁶ O'Callaghan Moran and Associates (2007)

There are persistent and frequently high levels of microbial contamination. 95% of samples contained Total Coliforms, and 78% of samples contained E.Coliforms. More than half of the samples were grossly contaminated (in excess of 100 MPN). 20% of samples contained Clostridium Perfringens. These exceedances occur throughout the year and are associated both with conditions of high pH, high E.C. and low turbidity and with conditions of low pH, low E.C. and high turbidity. This indicates that the microbial contamination of the collected water is occurring both during periods of high rainfall when fresh rainfall has resulted in surface water inflow to the collection point and/or flushed through the shallow aquifer and also during periods of lower rainfall when groundwater that has been in the aquifer for longer periods provides most of the spring flow.

Drinking water limits and/or threshold values for ammonium are exceeded. These exceedances are associated with other parameter values that indicate surface water inputs.

Nitrate, chloride, iron, manganese and the potassium:sodium ratio sampled are within acceptable limits.

The single full chemical analysis (GWS, 2015) has parameter values below the relevant limits, with the exception of the microbiological parameters discussed above. It did not show any other naturally-occurring elements dissolved into the groundwater at concentrations that would cause concern for human health.

The water quality results indicate contamination of the supply by organic wastes. Sheep have access to large areas of the ZOC on the mountainside commonage and within the owned land and are the most likely source of the organic wastes. Wildlife and birds may also be minor contributors. There are no other pressures, such as land-spreading, farmyards or on-site waste water treatment systems, which could result in this type of contamination.

- All three spring flows are likely to be contaminated by the collection of animal wastes in run-off from very steep areas of exposed rock on the mountainside entering scree and becoming rapid, shallow groundwater flow. Equally, direct contamination of very shallow groundwater in the scree, can occur.
- Pollution could possibly also result from direct contamination of surface water run-off which drains into the topographic hollow surrounding the Spring 1 collection box, which is unlikely to fully exclude surface water. The spring is surrounded by bedrock which is exposed or very close to the surface and into which contaminated surface water may percolate and then re-emerge, without any filtration by subsoils, at the spring.
- Contamination is considered likely to be resulting from direct contamination, by animal wastes, of surface water arising from Spring 3, and which then drain around the exterior walls of the Collection Tank (See Diagram 3). This collection tank cannot be confirmed as excluding surface water.
- Spring 2 is not enclosed in any infrastructure, therefore is open to direct contamination should it be brought into use.

Treated water Total Coliform E. Coliform, and C. Perfringens parameter values, recorded in the DBO Operator monthly check monitoring for the years 2013 to August 2015, are all below the DWLs. The treatment system therefore appears effective in treating for these microbiological parameters, and demonstrates the importance of a correctly functioning and maintained treatment system.

4 Zone of Contribution

4.1 Conceptual model

The current understanding of the geological and hydrogeological setting is given as follows and as shown schematically in **Diagram 3**.

Two springs (Spring 1 and 2) potentially contribute to the scheme supply. The zone of contribution includes both springs, since they are in close proximity and are considered to share a common catchment.

Rainfall is high in the area. Almost all available rainfall replenishes (recharges) groundwater in the fractured sandstone rocks high on the mountain. Significant groundwater recharge occurs where effective rainfall⁷ percolates into karstified limestones. Where there is peat overlying the bedrock, a lower proportion of effective rainfall can percolate down to the water table, with the rest becoming surface water run-off. On the steepest slopes, a high proportion of rainfall becomes surface water run-off, resulting in seasonal surface water flow in very steep gullies.

Water entering the rocks (recharge) flows downwards through the weathered zone and fractures of the sandstone and mixed rock types. Some of this water emerges as springs on the mountainside, but the majority continues downwards and is concentrated in fissures and conduits in the underlying and adjacent karstified pure limestone bedrock. The flow continues downwards into fissures and fractures in the underlying upper impure limestone bedrock. The low permeability shales and limestones beneath the karstified and fractured rocks act as a barrier to further downward groundwater flow, resulting most of the groundwater flowing almost horizontally along its top surface, to discharge at the spring locations.

In addition, surface water run-off from the steep slopes (including any groundwater which has discharged from springs) percolates into the high permeability scree deposits which cover the steep rock slopes in a band uphill of the springs. This water becomes shallow, fast flowing groundwater, which emerges as the springs from the bottom edge of the scree, which also coincides with the change in bedrock type.

Groundwater and surface water flow directions are both strongly controlled by the steep topography of Truskmore Mountain and are both towards the west.

All of the zone of contribution and surrounding area is classified as having extreme vulnerability to groundwater pollution, due to the shallow soils and subsoils.

4.2 Boundaries

The groundwater Zone of Contribution (ZOC), delineated for Springs 1 and 2 of Ballintrillick GWS, is based on a combination of hydrogeological mapping and inferences.

The **eastern**, uphill, boundary represents the eastern extent of the area considered to contribute recharge to groundwater which will flow west towards the springs. The groundwater and surface water divides are assumed to coincide at the high point of the topography, which determines the direction of groundwater flow.

The **northern and southern boundaries** are based on an assessment of local groundwater flow directions, and are located along interpreted groundwater flow lines. Groundwater flow lines are estimated by considering all available water level data, and assume that the groundwater table is a subdued reflection of topography. In this instance groundwater flow directions (and therefore flow lines) are considered to be strongly controlled by the steeply sloping topography, with flow direction towards the west.

⁷ Effective rainfall is the proportion of rainfall which is not taken up by plants or evaporated and is the amount which is available for recharge of groundwaters and surface water run-off.

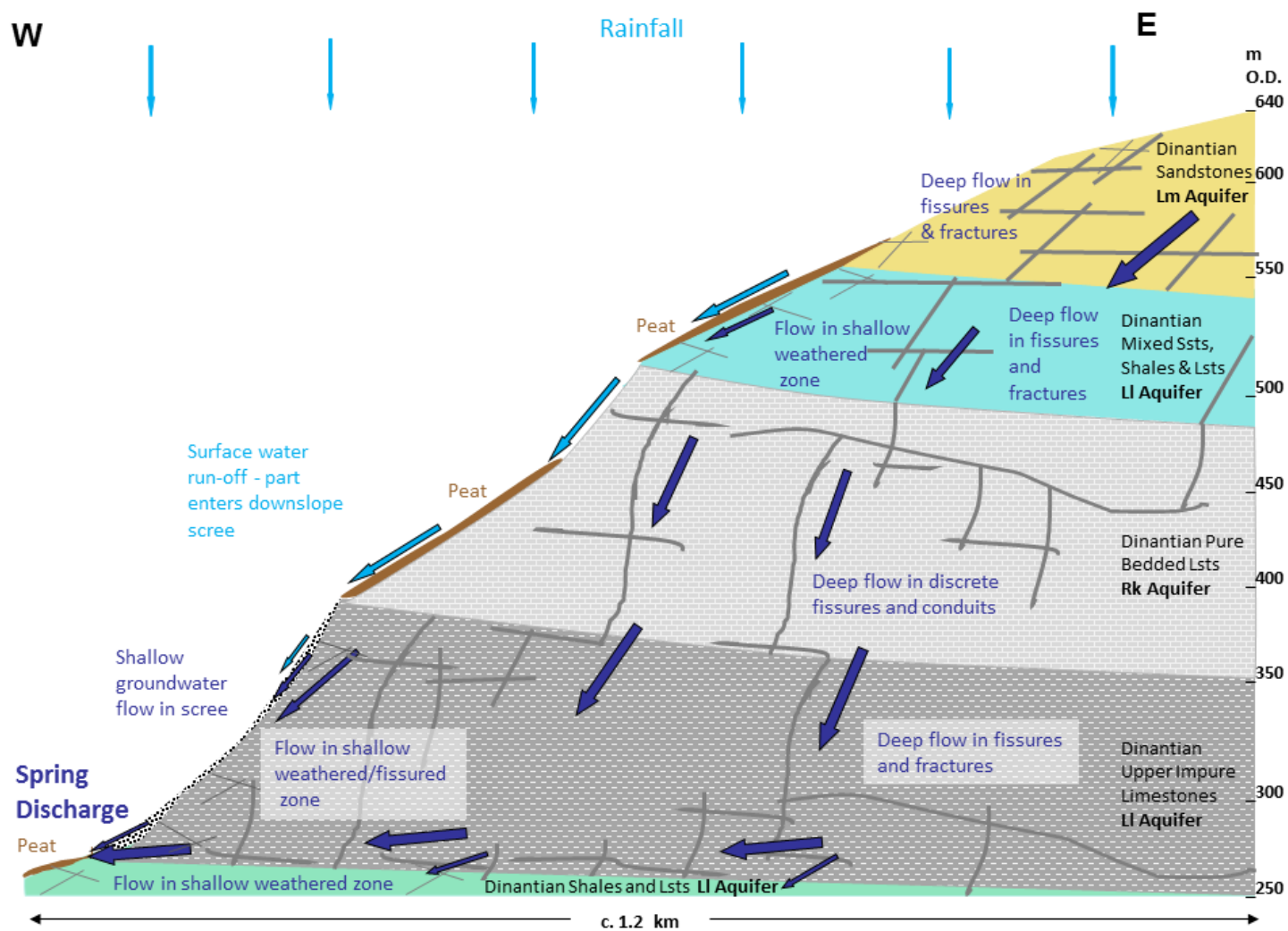


Diagram 3. Vertical cross section showing conceptual model of groundwater flow

The **western**, downhill boundary is defined by the location of the springs. A buffer zone of 30 m downhill of the springs has been added to assist protection of the springs from direct pollution.

A surface water zone of contribution has also been defined in this report for a section of watercourse which almost certainly contributes some water to the supply collection tank. This surface water zone of contribution comprises the area which contributes surface water run-off to the watercourse arising from Spring 3, which subsequently flows around the collection box. It is assumed that Spring 3 is not providing a significant quantity of water to the supply, though this has not necessarily been proved. As such no groundwater Zone of Contribution has been delineated for Spring 3.

The small surface water Zone of Contribution (catchment) to the watercourse which arises from Spring 3 is defined by topography. It comprises the watercourse and the area from which surface run-off can drain to the watercourse.

4.3 Recharge and water balance

The recharge and water balance calculations are used to support the hydrogeological mapping and to confirm that the groundwater ZOC delineated is big enough to support the quantity of water at the springs.

The recharge rate assigned to part of the ZOC area has been increased above that published by the G.S.I, in order to take account of the scree deposits and local variations in the impure limestone bedrock unit.

Recharge occurring in the ZOC area of 0.126 km² supplies an annual average combined volume to the two springs of 270 m³/day. This is consistent with the estimated average total combined flow from the two springs.

5 Conclusions

Ballintrillick GWS is currently sourced from one (Spring 1) of a pair of springs with an average combined discharge of approximately 270 m³/day. The Zone of Contribution has been delineated for the combined flow from the two springs. Spring 2 has been used in the past to supplement the supply from Spring 1 and the infrastructure remains available. The discharge from the combined springs is subject to seasonal variation. A third spring (Spring 3) located close by is not used as a supply source. Some of the surface water flow arising from Spring 3 is likely to be entering the collection tank to which water is piped from Spring 1. A surface water Zone of Contribution (catchment) has been delineated for this watercourse.

The GWS currently abstracts an average of 83 m³/d from a collection tank to which flow from Spring 1 is piped.

Groundwater and surface water flow directions are both strongly controlled by the steep topography of Truskmore Mountain and are therefore both towards the west.

Rainfall falling onto bedrock, which is exposed at the surface or covered with thin peat soils, percolates downwards through fissures and fractures and also in karst conduits. It emerges at the surface predominantly at the supply springs, where a less permeable shale bedrock acts as a barrier to continued downward groundwater percolation. Groundwater then flows horizontally, which emerges as springs where the slope of the hillside intersects the groundwater table. Surface water run-off, rainfall, and water from any small spring flows emerging above the main supply springs percolate into scree deposits on the steep slopes. This results in rapid, shallow groundwater flows in the scree and in the underlying bedrock. This emerges from the lower edge of the scree at the supply springs.

The persistent and frequently significant occurrences of Total and Faecal Coliforms and Clostridium Perfringens indicate that the supply is contaminated by localised organic waste. This almost certainly occurs due to the movement of surface water run-off into rapid shallow groundwater flow in scree, or by direct recharge into the scree, on steep areas of the mountainside. Water from the lower edge of the scree

discharges at the supply springs. It is likely that surface water arising from Spring 3, contaminated directly or by entrainment of animal wastes, is entering the collection box. There could possibly also be some occasional contamination of Spring 2 by entrainment of wastes in surface water run-off which is directed towards the spring chamber.

The treatment process appears to be effective in treating for the microbiological and other parameters monitored under the DBO monthly check monitoring programme.

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.

6 Recommendations

Essential:

- A regular survey of individual water quality parameters at each of the two springs of untreated water should include coliforms (total and faecal), pH, alkalinity, hardness, electrical conductivity, nitrate, ammonia, chloride, iron, manganese, potassium and sodium. The DBO contractor currently measures some of these parameters and the number of parameters required could be reduced by co-ordination with the DBO operator. This survey should be taken on a monthly basis for the first year and should incorporate samples following a variety of wet and dry rainfall conditions in the preceding week. The results should be shared with the GSI. The need for future monitoring can be determined on the basis of these results, and in discussion with a hydrogeologist.
- Measurement of piped flow into, and outflow from, the collection box. In addition, sampling of water from Spring 1, Spring 2, collection box and surface water just before it reaches collection box for analysis of microbial, nitrogen, E.C., turbidity and pH parameters. The purpose of this is to validate the assumption that the collection box is not watertight and that surface water arising from Spring 3 is entering the collection tank and is a source of turbidity and pollutants. If the results indicate surface water inflow to the collection box, then exclude Spring 3 water from the collection tank by either or both diverting surface water away from the collection tank and upgrading tank to make it waterproof. Measuring the inflow and outflow would also indicate what proportion of the abstraction (if any) is being sourced from the watercourse arising from Spring 3. If a significant proportion of the supply is arising from Spring 3, then water should be piped directly from the spring source.
- It is assumed that Spring 3 is not providing a significant quantity of water to the supply, though this has not necessarily been proved. As such no groundwater Zone of Contribution has been delineated for Spring 3. If Spring 3 is contributing a significant amount to the supply via leakage of surface water into the collection tank, then the discharge from this spring would need to be quantified and a Zone of Contribution delineated for it.
- Keep the abstraction volume below the design capacity of the treatment plant which is 138 m³/day. The maximum recorded daily abstraction in the period 2011-2015 was 156 m³/d, which exceeded the design capacity.
- Put in place stock proof fencing around Spring 1.

Desirable:

- Interception drainage around the upslope side of each spring;
- Put stock proof fencing around Spring 2 and build a watertight spring chamber with an internal collection pipe around the spring if there is any likelihood that it will be used to supplement the supply.

Other:

- The following EPA guidelines may serve as future useful reference documents for the 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 Mapping⁸.
 - 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 ZOC⁹.
 - EPA Drinking Water Advice Note No. 14. Borehole Construction and Wellhead Protection¹⁰ (NB, although this relates to boreholes, the principles of sanitary protection at the abstraction point are relevant).

7 References

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

EPA website www.epa.ie

EPA (2004) Guidance on Landspreading of Organic Waste.

EPA (2011) Drinking Water Advice Note No. 7: Source Protection and Catchment Management to Protect Groundwater Sources.

EPA (2011) Drinking Water Advice Note No. 8: Developing Drinking Water Safety Plans.

EPA (2013) Drinking Water Advice Note No. 14. Borehole Construction and Wellhead Protection

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.

GSI website www.gsi.ie

Hunter Williams, N.H., Misstear, B.D., Daly, D. and Lee, M. (2013) Development of a national groundwater recharge map for the Republic of Ireland. Quarterly Journal of Engineering Geology and Hydrogeology. Vol. 46, No. 4, pp. 493-506.

IGI (2007) Guidelines for Drilling Wells for Private Water Supplies (March 2007).

<http://www.igi.ie/publications/codes-guidelines.htm>

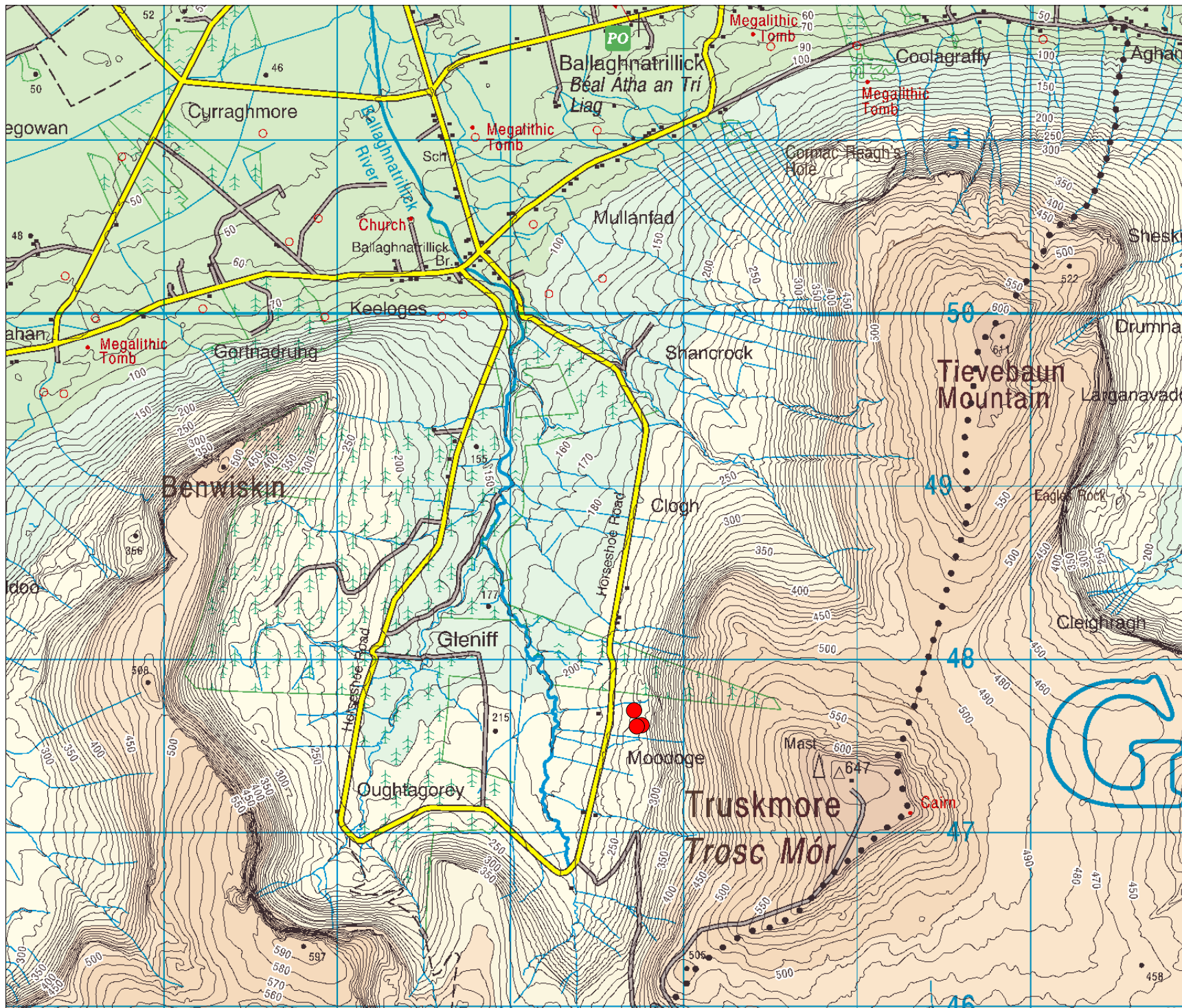
O'Callaghan, Moran and Associates (2007). Establishing Natural Background Levels for Groundwater in Ireland. South Eastern River Basin District Project team and O'Callaghan Moran and Associates.

⁸ http://www.epa.ie/pubs/advice/drinkingwater/epadrinkingwateradvisenote-advisenoteno7.html#.UpNP_eJ9KEp

⁹ <http://www.epa.ie/pubs/advice/drinkingwater/epadrinkingwateradvisenote-advisenoteno8.html#.UpNQf-J9KEo>

¹⁰ <http://www.epa.ie/pubs/advice/drinkingwater/advisenote14.html#.UpNR8eJ9KEo>

Figures



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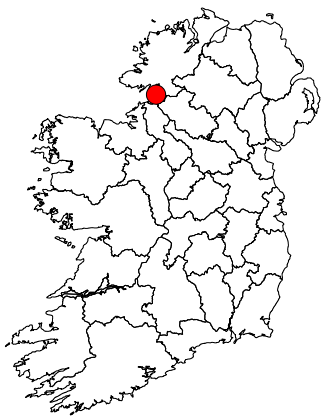


Ballinatrillick Springs



Zone of Contribution

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Title:

Figure 1 Regional Setting

Drawing No: 125_1

Project:

Zone of Contribution Delineation

Stage:

Client:
Ballinatrillick Group Water Scheme

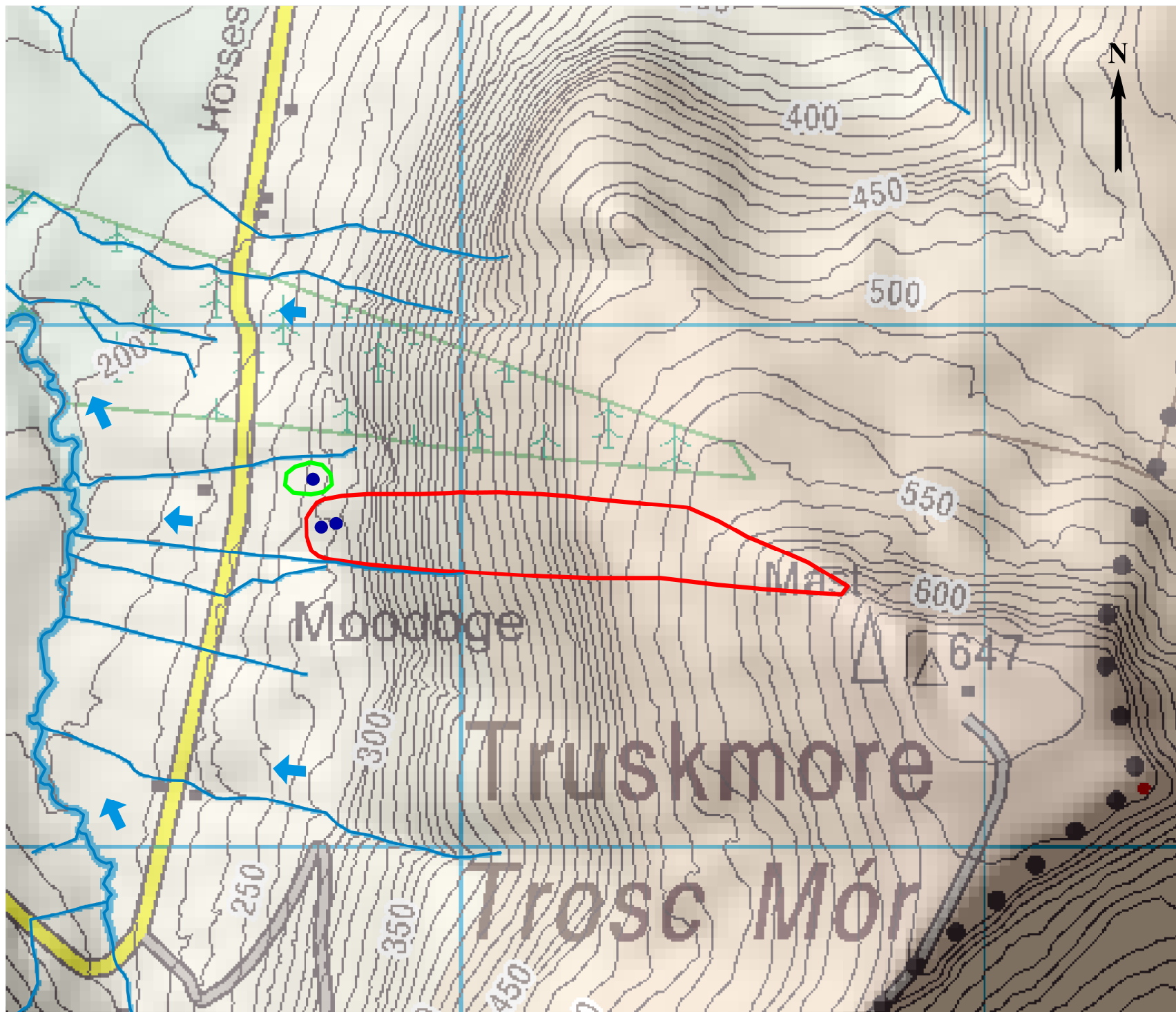
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surveyed	drawn ST	checked	date 05/02/15
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Revisions: Rev B

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Legend:

- Spring Location
- Groundwater ZOC
- Surface Water ZOC (Catchment)
- Surface Watercourses & Drainage Direction

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Title:
Figure 2 Topography & Regional Drainage

Drawing No: 130_2

Project:
Zone of Contribution Delineation

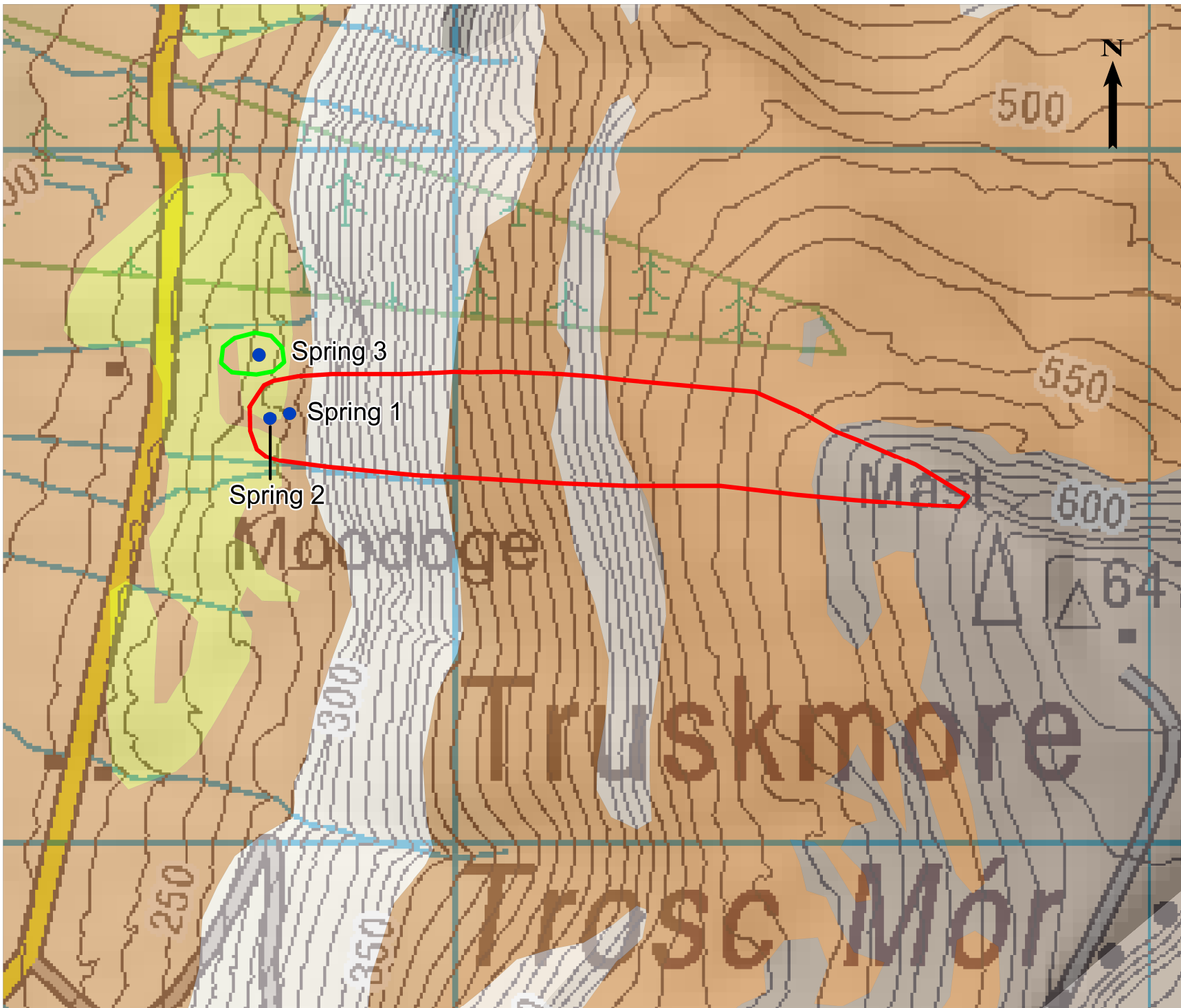
Stage:

Client:
Ballinrillick Group Water Scheme

Scale: 1:10,000 @ A4

surveyed	drawn ST	checked	date 18/11/15
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Revisions: Rev A



Legend:

- Spring Location
- Groundwater ZOC
- Surface water ZOC (Catchment)

Subsoils

- Peat
- Karst Rock
- Rock Exposed
- Scree
- Shales & Sandstones Till (Namurian)

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Title:
Figure 3 Subsoils

Drawing No: 130_3

Project:
Zone of Contribution Delineation

Stage:

Client:
Ballinrillick Group Water Scheme

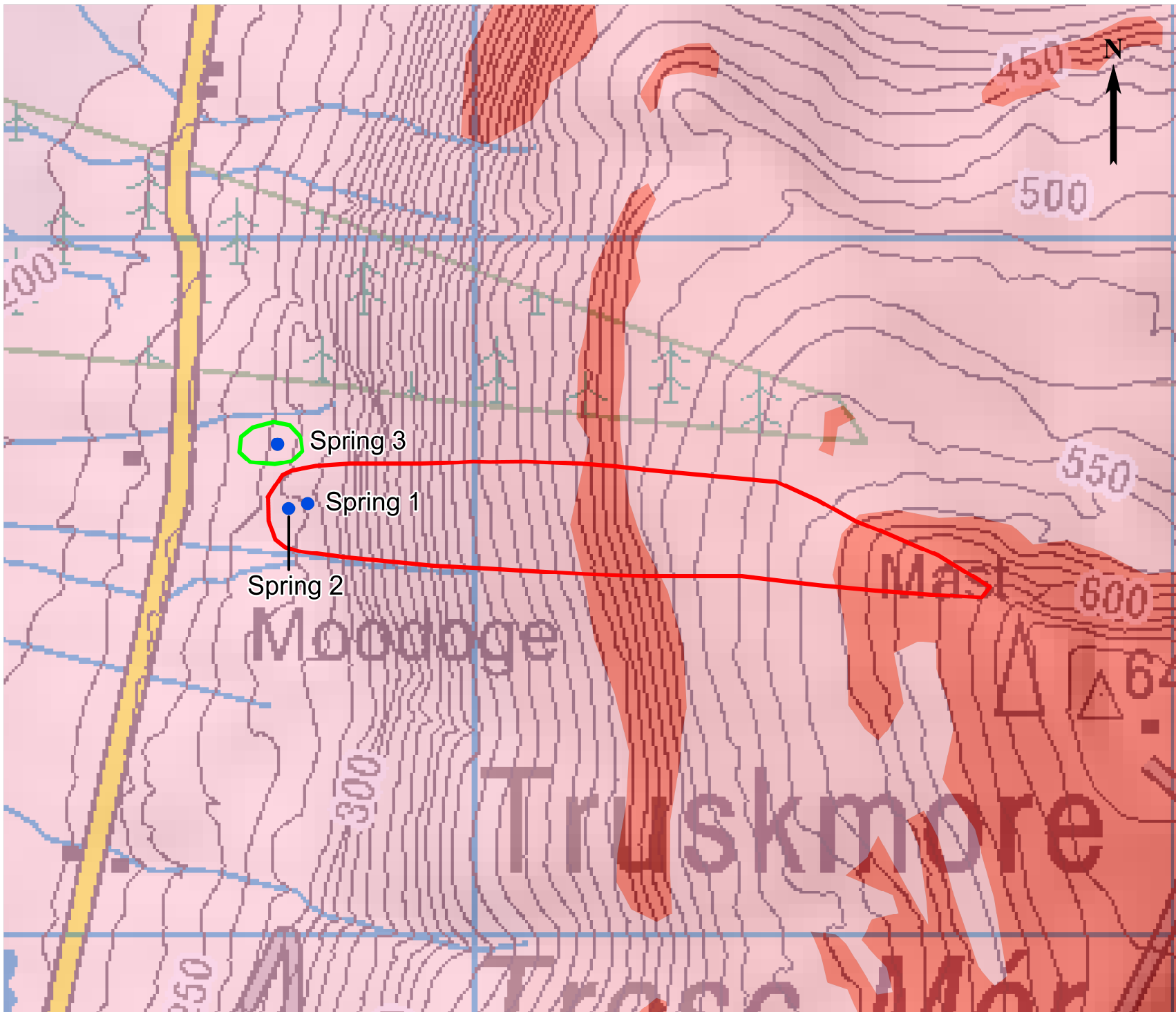
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surveyed	drawn ST	checked	date 03/02/16
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Legend:

● Spring Location

□ Groundwater ZOC

□ Surface Water ZOC (Catchment)

Groundwater Vulnerability

■ Rock at or near surface or Karst
■ Extreme

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Title:
Figure 4 Groundwater Vulnerability

Drawing No: 130_4

Project:
Zone of Contribution Delineation

Stage:

Client:
Ballinrillick Group Water Scheme

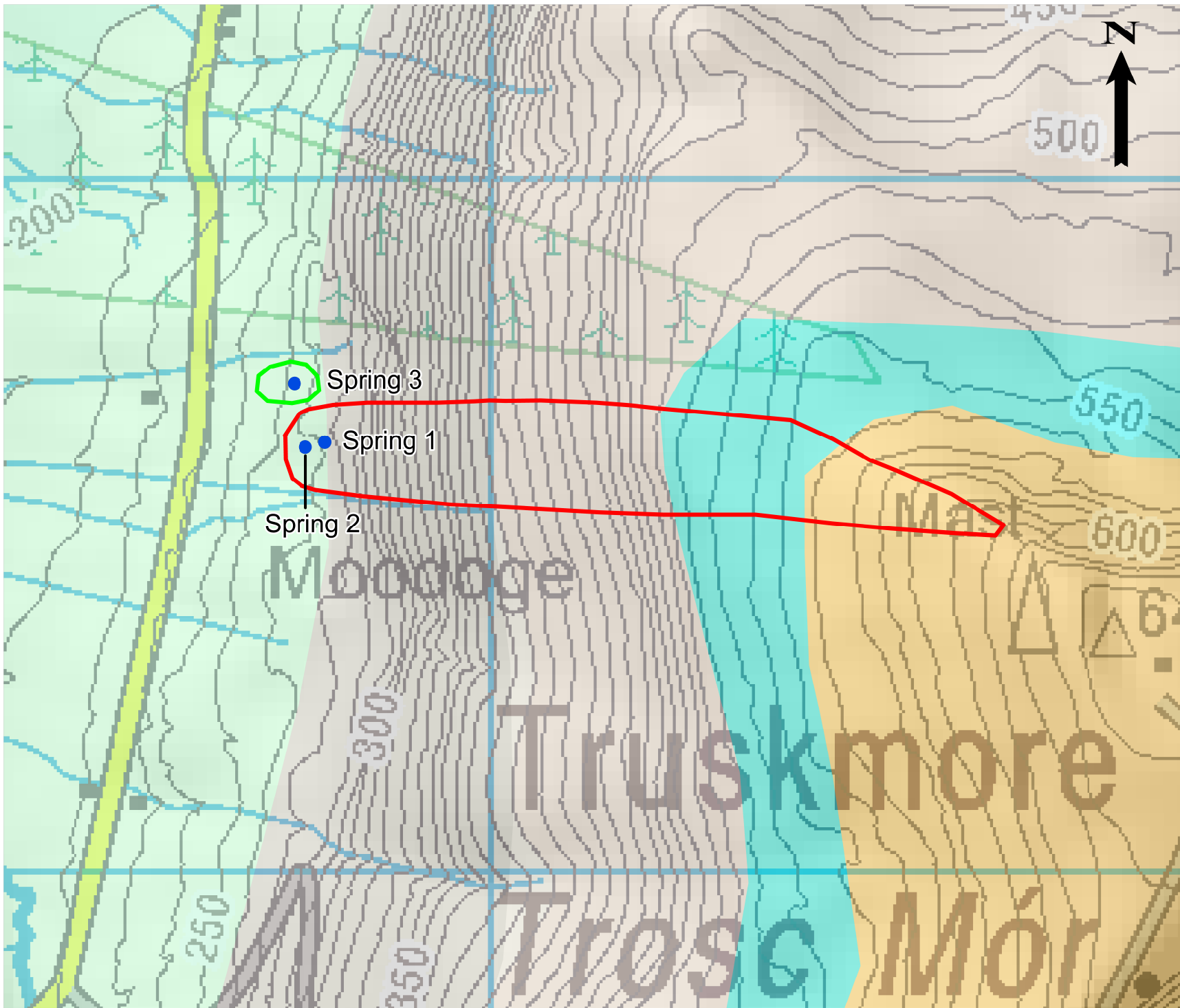
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surveyed	drawn ST	checked	date 02/02/16
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Legend:

- Spring Location
- Groundwater ZOC
- Surface Water ZOC (Catchment)

Geological Rock Units

- Dinantian Sandstones
- Dinantian Mixed Sandsts, Shales & Limestones
- Dinantian Pure Bedded Limestones
- Dinantian Upper Impure Limestones
- Dinantian Shales & Limestones

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Title:
Figure 5 Bedrock Units

Drawing No: 130_5

Project:
Zone of Contribution Delineation

Stage:

Client:
Ballinrillick Group Water Scheme

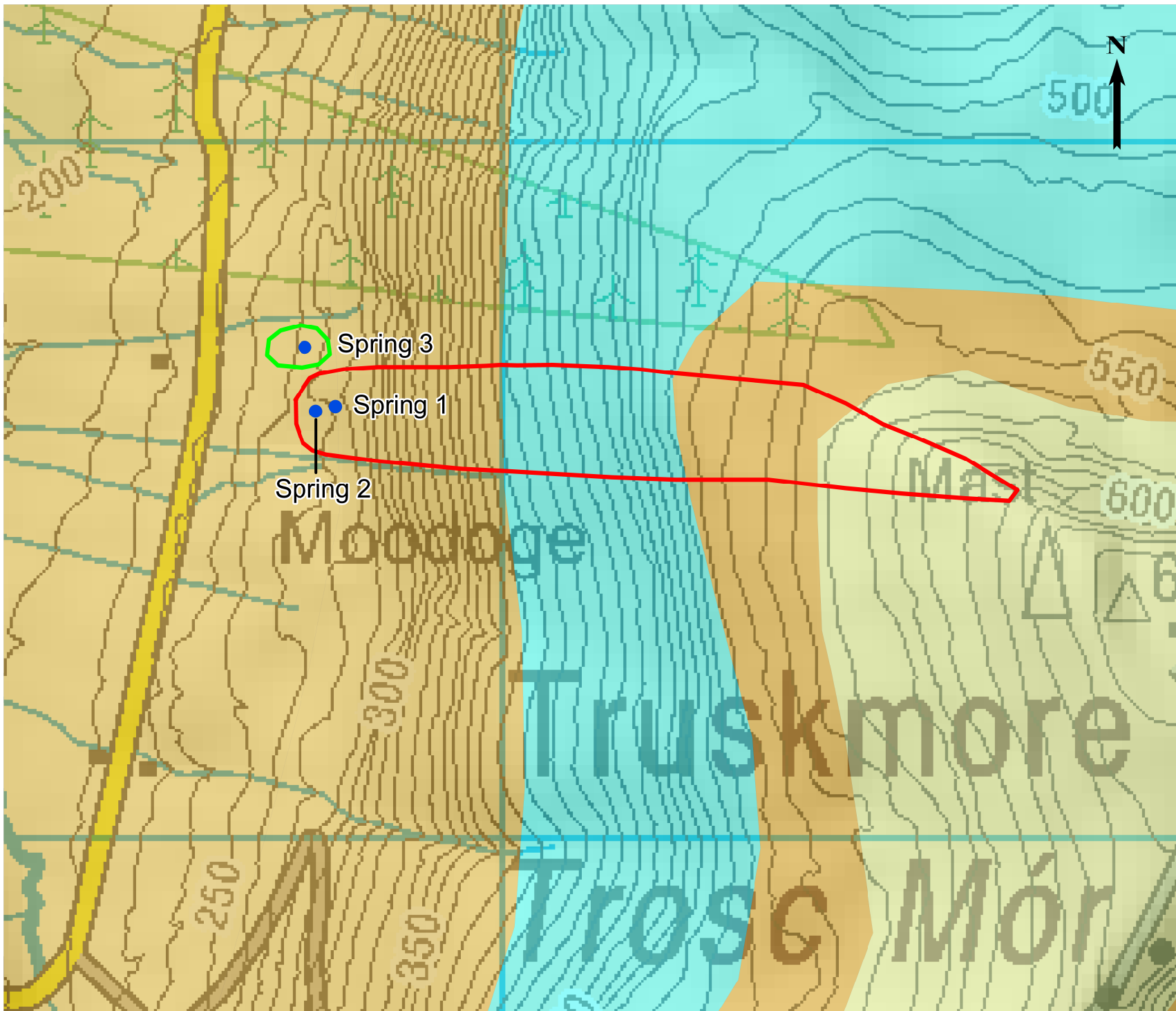
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surveyed	drawn	checked	date
	ST		02/02/16

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Legend:

● Spring Location

□ Groundwater ZOC

□ Surface Water ZOC (Catchment)

Bedrock Aquifer Type & Productivity

- Local - Generally Moderately Productive
- Local - Moderately Productive in Local Zones
- Regional - Karstified (conduit)

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Title:
Figure 6 Aquifer Type and Productivity

Drawing No: 130_6

Project:
Zone of Contribution Delineation

Stage:

Client:
Ballinrillick Group Water Scheme

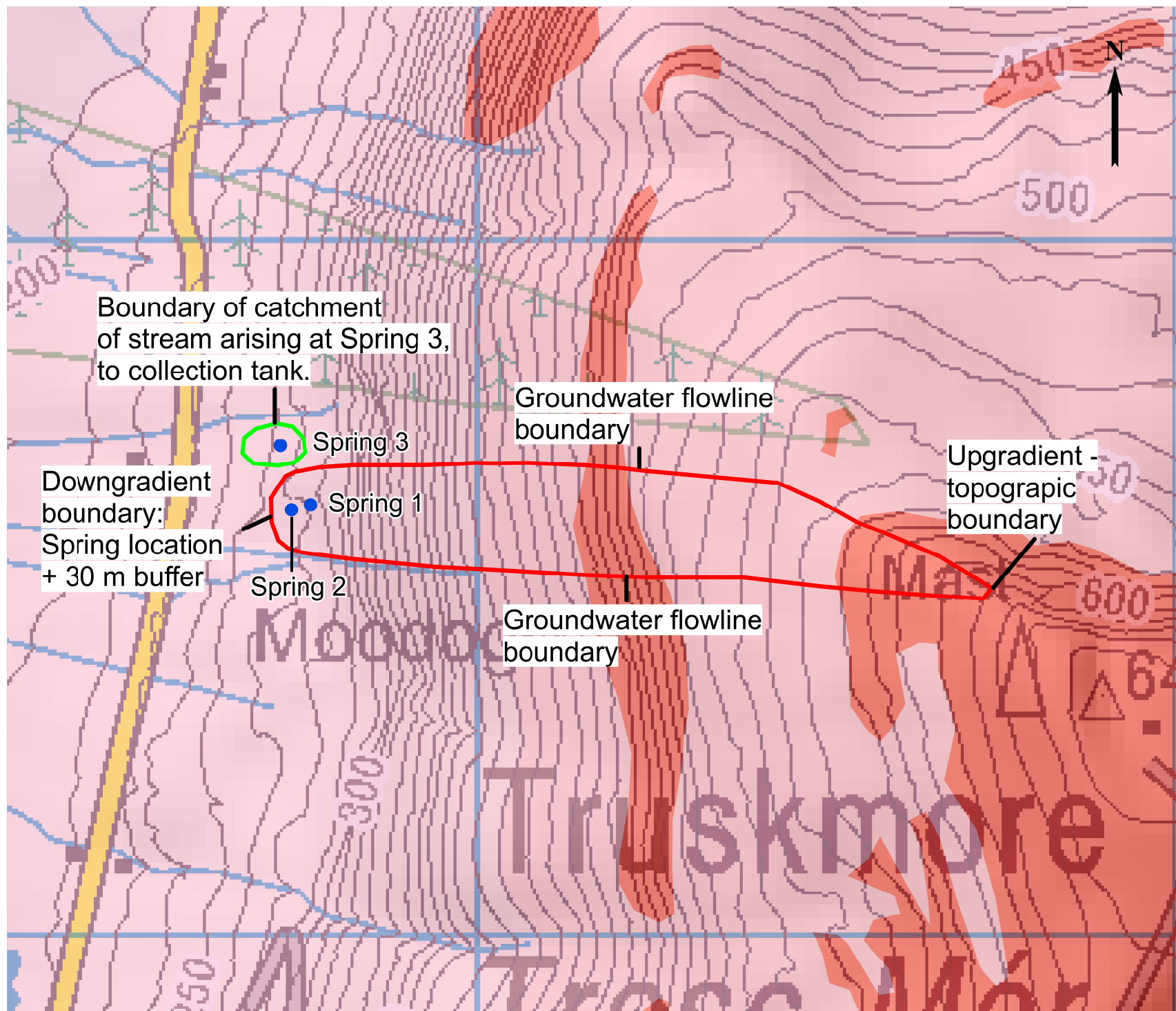
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surveyed	drawn ST	checked	date 02/02/16
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Legend:

● Spring Location

□ Groundwater ZOC

□ Surface Water ZOC (Catchment)

Groundwater Vulnerability

■ Rock at or near surface or Karst
■ Extreme

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Title:
Figure 7 ZOC Boundary Types

Drawing No: 130_7

Project:
Zone of Contribution Delineation

Stage:

Client:
Ballinrillick Group Water Scheme

Scale: 1:7,500 @ A4

surveyed	drawn ST	checked	date 05/02/16
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Revisions:	Rev B
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Appendix 1

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: **Extreme**, **High**, **Moderate** and **Low**, 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 below.

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 <u>only</u>)
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 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 2

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 Hunter Williams et al (2013), which is based on Guidance Document GW5 (Groundwater Working Group 2005).

Table 1. Recharge coefficients for different hydrogeological settings.

Groundwater vulnerability category	Hydrogeological setting		Recharge coefficient (RC)		
			Min (%)	Inner Range	Max (%)
Extreme (X or E)	1.i	Areas where rock is at ground surface	30	80-90	100
	1.ii	Sand/gravel overlain by 'well drained' soil	50	80-90	100
	1.iii	Sand/gravel overlain by 'poorly drained' (gley) soil	15	35-50	70
	1.iv	Till overlain by 'well drained' soil	45	50-70	80
	1.v	Till overlain by 'poorly drained' (gley) soil	5	15-30	50
	1.vi	Sand/ gravel aquifer where the water table is ≤ 3 m below surface	50	80-90	100
	1.vii	Peat	1	15-30	50
High (H)	2.i	Sand/gravel aquifer, overlain by 'well drained' soil	50	80-90	100
	2.ii	High permeability subsoil (sand/gravel) overlain by 'well drained' soil	50	80-90	100
	2.iii	High permeability subsoil (sand/gravel) overlain by 'poorly drained' soil	15	35-50	70
	2.iv	Sand/gravel aquifer, overlain by 'poorly drained' soil	15	35-50	70
	2.v	Moderate permeability subsoil overlain by 'well drained' soil	35	50-70	80
	2.vi	Moderate permeability subsoil overlain by 'poorly drained' (gley) soil	10	15-30	50
	2.vii	Low permeability subsoil	1	20-30	40
	2.viii	Peat	1	5-15	20
Moderate (M)	3.i	Moderate permeability subsoil and overlain by 'well drained' soil	35	50-70	80
	3.ii	Moderate permeability subsoil and overlain by 'poorly drained' (gley) soil	10	15-30	50
	3.iii	Low permeability subsoil	1	10-20	30
	3.iv	Peat	1	3-5	10
Low (L)	4.i	Low permeability subsoil	1	5-10	20
	4.ii	Basin peat	1	3-5	10

The recharge coefficients in this table are summarised in a paper by Hunter Williams *et al.* (2013) in the Quarterly Journal of Engineering Geology and Hydrogeology. Aquifer recharge acceptance capacity is generally limited in LI aquifers (200 mm/yr) and PI and Pul aquifers (100 mm/yr). Made ground has recharge coefficient of 20%.

Appendix 3

Water quality results

- Results of analyses
-

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **SO001**, BALLINTRILLICK

Padraic McGowan

Amorset

Manorhamilton

Co Leitrim

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **SO001**, BALLINTRILLICK, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	20 Hazen	4 NTU	1500 µS/cm	6.0 to 9.0	0.23 mgN/l	11.3 mgN/l	0.03 mgN/l	200 µg/l	200 µg/l	50 µg/l	0 per 100 ml	0 per 100 ml
NOV2000	87	1.23	171.7	6.8	0.364	0.443		<0.7	50	11	0	
DEC2000	121	1.42	167.3	6.9	0.157	18.163		<0.7	11	<0.03	3	
JAN2001	139	3.08	154.6	7.0	0.461	4.886		<0.7	25	<0.03	16	
FEB2001	378	9.57	161.4	7.2	0.400	1.329		<0.7	14	<0.03	5	
JUN2001	24	0.525	125.9	7.79	0.01	0.218	0.003	21	11	<6	395	322
JUL2001	7	0.22	320.0	7.80	0.020	0.650	0.002	11	6	<6	31	31
AUG2001	3	0.183	285	7.85	0.007	0.411	0.003	9	6	<6	21	21
SEP2001	13	0.43	276	7.85	0.008	0.309	0.0002	16	15	6	48	48
OCT2001	13	0.38	277	7.94	0.005	0.347	<0.0002	15	8	<6	207	111
NOV2001	6	0.271	282	8.07	0.005	0.365	0.002	5	8	<6	10	8

Results of Raw and Treated Water Monthly Check Monitoring by Coffey Water, DBO Contractor

Coffey ID	Lab ID	Sample Description	Test Name	Result	Units
387	A	02/09/2015			
523	617682	Treated Water 14461-360	Clostridium Perfringens in Water	0	cfu/100ml
524		Treated Water 14461-360	Colilert (Ecoli)	0	MPN/100ml
525		Treated Water 14461-360	Colilert (Total Coliforms)	0	MPN/100ml
526		Treated Water 14461-360	Colour, apparent	<4	mg/l Pt Co
527		Treated Water 14461-360	pH	7.7	pH Units
528		Treated Water 14461-360	Turbidity	<0.2	N.T.U.
529		Treated Water 14461-360			
530	617681	Raw Water 14461-359	Clostridium Perfringens in Water	0	cfu/100ml
531		Raw Water 14461-359	Colilert (Ecoli)	22	MPN/100ml
532		Raw Water 14461-359	Colilert (Total Coliforms)	36	MPN/100ml
533		Raw Water 14461-359	Colour, apparent	<4	mg/l Pt Co
534		Raw Water 14461-359	pH	7.6	pH Units
535		Raw Water 14461-359	Turbidity	0.4	N.T.U.
536		Raw Water 14461-359			
793	A	12/08/2015			
1018	612800	Treated Water 14461-358	Clostridium Perfringens in Water	0	cfu/100ml
1019		Treated Water 14461-358	Colilert (Ecoli)	0	MPN/100ml
1020		Treated Water 14461-358	Colilert (Total Coliforms)	0	MPN/100ml
1021		Treated Water 14461-358	Colour, apparent	11.4	mg/l Pt Co
1022		Treated Water 14461-358	pH	7.8	pH Units
1023		Treated Water 14461-358	Turbidity	0.4	N.T.U.
1024		Treated Water 14461-358			
1025	612799	Raw Water 14461-357	Clostridium Perfringens in Water	0	cfu/100ml
1026		Raw Water 14461-357	Colilert (Ecoli)	78	MPN/100ml
1027		Raw Water 14461-357	Colilert (Total Coliforms)	118	MPN/100ml
1028		Raw Water 14461-357	Colour, apparent	31.5	mg/l Pt Co
1029		Raw Water 14461-357	pH	7.7	pH Units
1030		Raw Water 14461-357	Turbidity	0.8	N.T.U.
1031		Raw Water 14461-357			
1810	A	01/07/2015			
1881	604592	Treated Water 14461-356	Clostridium Perfringens in Water	0	cfu/100ml
1882		Treated Water 14461-356	Colilert (Ecoli)	0	MPN/100ml
1883		Treated Water 14461-356	Colilert (Total Coliforms)	0	MPN/100ml
1884		Treated Water 14461-356	Colour, apparent	8.1	mg/l Pt Co
1885		Treated Water 14461-356	pH	7.9	pH Units
1886		Treated Water 14461-356	Turbidity	0.3	N.T.U.
1887		Treated Water 14461-356			
1888	604591	Raw Water 14461-355	Clostridium Perfringens in Water	0	cfu/100ml
1889		Raw Water 14461-355	Colilert (Ecoli)	0	MPN/100ml
1890		Raw Water 14461-355	Colilert (Total Coliforms)	22	MPN/100ml
1891		Raw Water 14461-355	Colour, apparent	8.8	mg/l Pt Co

1892		Raw Water 14461-355	pH	7.9	pH Units
1893		Raw Water 14461-355	Turbidity	1.1	N.T.U.
1894		Raw Water 14461-355			
2453	A	10/06/2015			
2524	599995	Treated Water 14461-354	Clostridium Perfringens in Water	0	cfu/100ml
2525		Treated Water 14461-354	Colilert (Ecoli)	0	MPN/100ml
2526		Treated Water 14461-354	Colilert (Total Coliforms)	0	MPN/100ml
2527		Treated Water 14461-354	Colour, apparent	5.4	mg/l Pt Co
2528		Treated Water 14461-354	pH	7.9	pH Units
2529		Treated Water 14461-354	Turbidity	0.4	N.T.U.
2530		Treated Water 14461-354			
2531	599994	Raw Water 14461-353	Clostridium Perfringens in Water	0	cfu/100ml
2532		Raw Water 14461-353	Colilert (Ecoli)	0	MPN/100ml
2533		Raw Water 14461-353	Colilert (Total Coliforms)	78	MPN/100ml
2534		Raw Water 14461-353	Colour, apparent	11.0	mg/l Pt Co
2535		Raw Water 14461-353	pH	7.8	pH Units
2536		Raw Water 14461-353	Turbidity	1.5	N.T.U.
2537		Raw Water 14461-353			
2944	A	13/05/2015			
3015	593667	Treated Water 14461-352	Clostridium Perfringens in Water	0	cfu/100ml
3016		Treated Water 14461-352	Colilert (Ecoli)	0	MPN/100ml
3017		Treated Water 14461-352	Colilert (Total Coliforms)	0	MPN/100ml
3018		Treated Water 14461-352	Colour, apparent	5.2	mg/l Pt Co
3019		Treated Water 14461-352	pH	7.7	pH Units
3020		Treated Water 14461-352	Turbidity	0.2	N.T.U.
3021		Treated Water 14461-352			
3022	593666	Raw Water 14461-351	Clostridium Perfringens in Water	2	cfu/100ml
3023		Raw Water 14461-351	Colilert (Ecoli)	2	MPN/100ml
3024		Raw Water 14461-351	Colilert (Total Coliforms)	109	MPN/100ml
3025		Raw Water 14461-351	Colour, apparent	17.7	mg/l Pt Co
3026		Raw Water 14461-351	pH	7.7	pH Units
3027		Raw Water 14461-351	Turbidity	1.7	N.T.U.
3028		Raw Water 14461-351			
3671	A	15/04/2015			
3892	587798	Treated Water 14461-350	Clostridium Perfringens in Water	0	cfu/100ml
3893		Treated Water 14461-350	Colilert (Ecoli)	0	MPN/100ml
3894		Treated Water 14461-350	Colilert (Total Coliforms)	0	MPN/100ml
3895		Treated Water 14461-350	Colour, apparent	5.8	mg/l Pt Co
3896		Treated Water 14461-350	pH	7.8	pH Units
3897		Treated Water 14461-350	Turbidity	0.3	N.T.U.
3898		Treated Water 14461-350			
3899	587797	Raw Water 14461-349	Clostridium Perfringens in Water	0	cfu/100ml
3900		Raw Water 14461-349	Colilert (Ecoli)	0	MPN/100ml
3901		Raw Water 14461-349	Colilert (Total Coliforms)	>201	MPN/100ml
3902		Raw Water 14461-349	Colour, apparent	17.1	mg/l Pt Co
3903		Raw Water 14461-349	pH	7.8	pH Units
3904		Raw Water 14461-349	Turbidity	6.3	N.T.U.

3905		Raw Water 14461-349			
4567	A	11/03/2015			
4803	580870	Treated Water 14461-348	Clostridium Perfringens in Water	0	cfu/100ml
4804		Treated Water 14461-348	Colilert (Ecoli)	0	MPN/100ml
4805		Treated Water 14461-348	Colilert (Total Coliforms)	0	MPN/100ml
4806		Treated Water 14461-348	Colour, apparent	<4	mg/l Pt Co
4807		Treated Water 14461-348	pH	8.0	pH Units
4808		Treated Water 14461-348	Turbidity	0.2	N.T.U.
4809		Treated Water 14461-348			
4810	580869	Raw Water 14461-347	Clostridium Perfringens in Water	0	cfu/100ml
4811		Raw Water 14461-347	Colilert (Ecoli)	0	MPN/100ml
4812		Raw Water 14461-347	Colilert (Total Coliforms)	14	MPN/100ml
4813		Raw Water 14461-347	Colour, apparent	4	mg/l Pt Co
4814		Raw Water 14461-347	pH	8.1	pH Units
4815		Raw Water 14461-347	Turbidity	0.5	N.T.U.
4816		Raw Water 14461-347			
5324	A	11/02/2015			
5709	573545	Treated Water 14461-346	Clostridium Perfringens in Water	0	cfu/100ml
5710		Treated Water 14461-346	Colilert (Ecoli)	0	MPN/100ml
5711		Treated Water 14461-346	Colilert (Total Coliforms)	0	MPN/100ml
5712		Treated Water 14461-346	Colour, apparent	<4	mg/l Pt Co
5713		Treated Water 14461-346	pH	7.8	pH Units
5714		Treated Water 14461-346	Turbidity	0.4	N.T.U.
5715		Treated Water 14461-346			
5716	573544	Raw Water 14461-345	Clostridium Perfringens in Water	0	cfu/100ml
5717		Raw Water 14461-345	Colilert (Ecoli)	2	MPN/100ml
5718		Raw Water 14461-345	Colilert (Total Coliforms)	12	MPN/100ml
5719		Raw Water 14461-345	Colour, apparent	5.6	mg/l Pt Co
5720		Raw Water 14461-345	pH	7.8	pH Units
5721		Raw Water 14461-345	Turbidity	1.2	N.T.U.
5722		Raw Water 14461-345			
6319	A	07/01/2015			
6390	566405	Treated Water 14461-344	Clostridium Perfringens in Water	0	cfu/100ml
6391		Treated Water 14461-344	Colilert (Ecoli)	0	MPN/100ml
6392		Treated Water 14461-344	Colilert (Total Coliforms)	0	MPN/100ml
6393		Treated Water 14461-344	Colour, apparent	<4	mg/l Pt Co
6394		Treated Water 14461-344	pH	7.9	pH Units
6395		Treated Water 14461-344	Turbidity	0.3	N.T.U.
6396		Treated Water 14461-344			
6397	566404	Raw Water 14461-343	Clostridium Perfringens in Water	26	cfu/100ml
6398		Raw Water 14461-343	Colilert (Ecoli)	101	MPN/100ml
6399		Raw Water 14461-343	Colilert (Total Coliforms)	101	MPN/100ml
6400		Raw Water 14461-343	Colour, apparent	10.3	mg/l Pt Co
6401		Raw Water 14461-343	pH	7.8	pH Units
6402		Raw Water 14461-343	Turbidity	0.3	N.T.U.
6403		Raw Water 14461-343			
6856	A	03/12/2014			

6942	561054	Treated Water 14461-342	Clostridium Perfringens in Water	0	cfu/100ml
6943		Treated Water 14461-342	Colilert (Ecoli)	0	MPN/100ml
6944		Treated Water 14461-342	Colilert (Total Coliforms)	0	MPN/100ml
6945		Treated Water 14461-342	Colour, apparent	<4	mg/l Pt Co
6946		Treated Water 14461-342	pH	7.6	pH Units
6947		Treated Water 14461-342	Turbidity	0.2	N.T.U.
6948		Treated Water 14461-342			
6949	561053	Raw Water 14461-341	Clostridium Perfringens in Water	0	cfu/100ml
6950		Raw Water 14461-341	Colilert (Ecoli)	10	MPN/100ml
6951		Raw Water 14461-341	Colilert (Total Coliforms)	29	MPN/100ml
6952		Raw Water 14461-341	Colour, apparent	10.6	mg/l Pt Co
6953		Raw Water 14461-341	pH	7.3	pH Units
6954		Raw Water 14461-341	Turbidity	0.7	N.T.U.
6955		Raw Water 14461-341			
7853	A	05/11/2014			
7926	554026	Treated Water 14461-340	Clostridium Perfringens in Water	0	cfu/100ml
7927		Treated Water 14461-340	Colilert (Ecoli)	0	MPN/100ml
7928		Treated Water 14461-340	Colilert (Total Coliforms)	0	MPN/100ml
7929		Treated Water 14461-340	Colour, apparent	11.6	mg/l Pt Co
7930		Treated Water 14461-340	pH	7.8	pH Units
7931		Treated Water 14461-340	Turbidity	0.5	N.T.U.
7932		Treated Water 14461-340			
7933	554025	Raw Water 14461-339	Clostridium Perfringens in Water	0	cfu/100ml
7934		Raw Water 14461-339	Colilert (Ecoli)	201	MPN/100ml
7935		Raw Water 14461-339	Colilert (Total Coliforms)	>201	MPN/100ml
7936		Raw Water 14461-339	Colour, apparent	18.6	mg/l Pt Co
7937		Raw Water 14461-339	pH	7.9	pH Units
7938		Raw Water 14461-339	Turbidity	0.5	N.T.U.
7939		Raw Water 14461-339			
8455	A	08/10/2014			
8670	547840	Treated Water 14461-338	Clostridium Perfringens in Water	0	cfu/100ml
8671		Treated Water 14461-338	Colilert (Ecoli)	0	MPN/100ml
8672		Treated Water 14461-338	Colilert (Total Coliforms)	0	MPN/100ml
8673		Treated Water 14461-338	Colour, apparent	9.1	mg/l Pt Co
8674		Treated Water 14461-338	pH	7.7	pH Units
8675		Treated Water 14461-338	Turbidity	0.8	N.T.U.
8676		Treated Water 14461-338			
8677	547839	Raw Water 14461-337	Clostridium Perfringens in Water	3	cfu/100ml
8678		Raw Water 14461-337	Colilert (Ecoli)	45	MPN/100ml
8679		Raw Water 14461-337	Colilert (Total Coliforms)	109	MPN/100ml
8680		Raw Water 14461-337	Colour, apparent	18.6	mg/l Pt Co
8681		Raw Water 14461-337	pH	7.7	pH Units
8682		Raw Water 14461-337	Turbidity	1.0	N.T.U.
8683		Raw Water 14461-337			
9394	A	03/09/2014			
9465	540765	Treated Water 14461-336	Clostridium Perfringens in Water	0	cfu/100ml
9466		Treated Water 14461-336	Colilert (Ecoli)	0	MPN/100ml

9467		Treated Water 14461-336	Colilert (Total Coliforms)	0	MPN/100ml
9468		Treated Water 14461-336	Colour, apparent	5.0	mg/l Pt Co
9469		Treated Water 14461-336	pH	7.69	pH Units
9470		Treated Water 14461-336	Turbidity	0.3	N.T.U.
9471		Treated Water 14461-336			
9472	540764	Raw Water 14461-335	Clostridium Perfringens in Water	0	cfu/100ml
9473		Raw Water 14461-335	Colilert (Ecoli)	89	MPN/100ml
9474		Raw Water 14461-335	Colilert (Total Coliforms)	>201	MPN/100ml
9475		Raw Water 14461-335	Colour, apparent	6.5	mg/l Pt Co
9476		Raw Water 14461-335	pH	7.9	pH Units
9477		Raw Water 14461-335	Turbidity	0.4	N.T.U.
9478		Raw Water 14461-335			
9719	A	13/08/2014			
9924	535661	Treated Water 14461-334	Clostridium Perfringens in Water	0	cfu/100ml
9925		Treated Water 14461-334	Colilert (Ecoli)	0	MPN/100ml
9926		Treated Water 14461-334	Colilert (Total Coliforms)	0	MPN/100ml
9927		Treated Water 14461-334	Colour, apparent	<4	mg/l Pt Co
9928		Treated Water 14461-334	pH	7.8	pH Units
9929		Treated Water 14461-334	Turbidity	0.2	N.T.U.
9930		Treated Water 14461-334			
9931	535660	Raw Water 14461-333	Clostridium Perfringens in Water	0	cfu/100ml
9932		Raw Water 14461-333	Colilert (Ecoli)	70	MPN/100ml
9933		Raw Water 14461-333	Colilert (Total Coliforms)	101	MPN/100ml
9934		Raw Water 14461-333	Colour, apparent	<4	mg/l Pt Co
9935		Raw Water 14461-333	pH	7.6	pH Units
9936		Raw Water 14461-333	Turbidity	0.5	N.T.U.
9937		Raw Water 14461-333			
10994	A	02/07/2014			
11185	527112	Treated Water 14461-323	Clostridium Perfringens in Water	0	cfu/100ml
11186		Treated Water 14461-323	Colilert (Ecoli)	0	MPN/100ml
11187		Treated Water 14461-323	Colilert (Total Coliforms)	0	MPN/100ml
11188		Treated Water 14461-323	Colour, apparent	<4	mg/l Pt Co
11189		Treated Water 14461-323	pH	7.4	pH Units
11190		Treated Water 14461-323	Turbidity	<0.2	N.T.U.
11191		Treated Water 14461-323			
11199	527110	Treated Water 14461-332	Clostridium Perfringens in Water	0	cfu/100ml
11200		Treated Water 14461-332	Colilert (Ecoli)	0	MPN/100ml
11201		Treated Water 14461-332	Colilert (Total Coliforms)	0	MPN/100ml
11202		Treated Water 14461-332	Colour, apparent	<4	mg/l Pt Co
11203		Treated Water 14461-332	pH	7.9	pH Units
11204		Treated Water 14461-332	Turbidity	<0.2	N.T.U.
11205		Treated Water 14461-332			
11206	527109	Raw Water 14461-331	Clostridium Perfringens in Water	0	cfu/100ml
11207		Raw Water 14461-331	Colilert (Ecoli)	6	MPN/100ml
11208		Raw Water 14461-331	Colilert (Total Coliforms)	8	MPN/100ml
11209		Raw Water 14461-331	Colour, apparent	<4	mg/l Pt Co
11210		Raw Water 14461-331	pH	7.8	pH Units

11211		Raw Water 14461-331	Turbidity	0.2	N.T.U.
11212		Raw Water 14461-331			
11685	A	05/06/2014			
11782	521680	Treated Water 14461-330	Clostridium Perfringens in Water	0	cfu/100ml
11783		Treated Water 14461-330	Colilert (Ecoli)	0	MPN/100ml
11784		Treated Water 14461-330	Colilert (Total Coliforms)	0	MPN/100ml
11785		Treated Water 14461-330	Colour, apparent	<4	mg/l Pt Co
11786		Treated Water 14461-330	pH	7.6	pH Units
11787		Treated Water 14461-330	Turbidity	0.2	N.T.U.
11788		Treated Water 14461-330			
11789	521679	Raw Water 14461-329	Clostridium Perfringens in Water	0	cfu/100ml
11790		Raw Water 14461-329	Colilert (Ecoli)	3	MPN/100ml
11791		Raw Water 14461-329	Colilert (Total Coliforms)	8	MPN/100ml
11792		Raw Water 14461-329	Colour, apparent	6.8	mg/l Pt Co
11793		Raw Water 14461-329	pH	7.6	pH Units
11794		Raw Water 14461-329	Turbidity	0.6	N.T.U.
11795		Raw Water 14461-329			
12181	A	07/05/2014			
12254	515505	Treated Water 14461-328	Clostridium Perfringens in Water	0	cfu/100ml
12255		Treated Water 14461-328	Colilert (Ecoli)	0	MPN/100ml
12256		Treated Water 14461-328	Colilert (Total Coliforms)	0	MPN/100ml
12257		Treated Water 14461-328	Colour, apparent	<4	mg/l Pt Co
12258		Treated Water 14461-328	pH	7.4	pH Units
12259		Treated Water 14461-328	Turbidity	0.3	N.T.U.
12260		Treated Water 14461-328			
12261	515504	Raw Water 14461-327	Clostridium Perfringens in Water	0	cfu/100ml
12262		Raw Water 14461-327	Colilert (Ecoli)	0	MPN/100ml
12263		Raw Water 14461-327	Colilert (Total Coliforms)	22	MPN/100ml
12264		Raw Water 14461-327	Colour, apparent	4.5	mg/l Pt Co
12265		Raw Water 14461-327	pH	7.3	pH Units
12266		Raw Water 14461-327	Turbidity	0.4	N.T.U.
12267		Raw Water 14461-327			
12939	A	02/04/2014			
13010	508995	Treated Water 14461-326	Clostridium Perfringens in Water	0	cfu/100ml
13011		Treated Water 14461-326	Colilert (Ecoli)	0	MPN/100ml
13012		Treated Water 14461-326	Colilert (Total Coliforms)	0	MPN/100ml
13013		Treated Water 14461-326	Colour, apparent	<4	mg/l Pt Co
13014		Treated Water 14461-326	pH	6.9	pH Units
13015		Treated Water 14461-326	Turbidity	<0.2	N.T.U.
13016		Treated Water 14461-326			
13017	508994	Raw Water 14461-325	Clostridium Perfringens in Water	0	cfu/100ml
13018		Raw Water 14461-325	Colilert (Ecoli)	1	MPN/100ml
13019		Raw Water 14461-325	Colilert (Total Coliforms)	1	MPN/100ml
13020		Raw Water 14461-325	Colour, apparent	<4	mg/l Pt Co
13021		Raw Water 14461-325	pH	6.9	pH Units
13022		Raw Water 14461-325	Turbidity	0.3	N.T.U.
13023		Raw Water 14461-325			

13627	A	05/03/2014			
13832	503504	Treated Water 14461-324	Clostridium Perfringens in Water	0	cfu/100ml
13833		Treated Water 14461-324	Colilert (Ecoli)	0	MPN/100ml
13834		Treated Water 14461-324	Colilert (Total Coliforms)	0	MPN/100ml
13835		Treated Water 14461-324	Colour, apparent	<4	mg/l Pt Co
13836		Treated Water 14461-324	pH	7.6	pH Units
13837		Treated Water 14461-324	Turbidity	0.3	N.T.U.
13838		Treated Water 14461-324			
13839	503503	Raw Water 14461-323	Clostridium Perfringens in Water	0	cfu/100ml
13840		Raw Water 14461-323	Colilert (Ecoli)	5	MPN/100ml
13841		Raw Water 14461-323	Colilert (Total Coliforms)	6	MPN/100ml
13842		Raw Water 14461-323	Colour, apparent	8.2	mg/l Pt Co
13843		Raw Water 14461-323	pH	7.5	pH Units
13844		Raw Water 14461-323	Turbidity	0.7	N.T.U.
13845		Raw Water 14461-323			
14350	A	05/02/2014			
14421	498350	Treated Water 14461-322	Clostridium Perfringens in Water	0	cfu/100ml
14422		Treated Water 14461-322	Colilert (Ecoli)	0	MPN/100ml
14423		Treated Water 14461-322	Colilert (Total Coliforms)	0	MPN/100ml
14424		Treated Water 14461-322	Colour, apparent	5.0	mg/l Pt Co
14425		Treated Water 14461-322	pH	7.2	pH Units
14426		Treated Water 14461-322	Turbidity	0.5	N.T.U.
14427		Treated Water 14461-322			
14428	498349	Raw Water 14461-321	Clostridium Perfringens in Water	0	cfu/100ml
14429		Raw Water 14461-321	Colilert (Ecoli)	9	MPN/100ml
14430		Raw Water 14461-321	Colilert (Total Coliforms)	11	MPN/100ml
14431		Raw Water 14461-321	Colour, apparent	8.3	mg/l Pt Co
14432		Raw Water 14461-321	pH	7.1	pH Units
14433		Raw Water 14461-321	Turbidity	1.0	N.T.U.
14434		Raw Water 14461-321			
15326	A	08/01/2014			
15531	493077	Treated Water 14461-320	Clostridium Perfringens in Water	0	cfu/100ml
15532		Treated Water 14461-320	Colilert (Ecoli)	0	MPN/100ml
15533		Treated Water 14461-320	Colilert (Total Coliforms)	0	MPN/100ml
15534		Treated Water 14461-320	Colour, apparent	<4	mg/l Pt Co
15535		Treated Water 14461-320	pH	7.6	pH Units
15536		Treated Water 14461-320	Turbidity	<0.2	N.T.U.
15537		Treated Water 14461-320			
15538	493075	Raw Water 14461-319	Clostridium Perfringens in Water	0	cfu/100ml
15539		Raw Water 14461-319	Colilert (Ecoli)	2	MPN/100ml
15540		Raw Water 14461-319	Colilert (Total Coliforms)	15	MPN/100ml
15541		Raw Water 14461-319	Colour, apparent	7.8	mg/l Pt Co
15542		Raw Water 14461-319	pH	7.3	pH Units
15543		Raw Water 14461-319	Turbidity	0.9	N.T.U.
15544		Raw Water 14461-319			
15747	A	04/12/2013			
15818	487557	Treated Water 14461-318	Clostridium Perfringens in Water	0	cfu/100ml

15819		Treated Water 14461-318	Colilert (Ecoli)	0	MPN/100ml
15820		Treated Water 14461-318	Colilert (Total Coliforms)	0	MPN/100ml
15821		Treated Water 14461-318	Colour, apparent	<4	mg/l Pt Co
15822		Treated Water 14461-318	pH	7.7	pH Units
15823		Treated Water 14461-318	Turbidity	<0.2	N.T.U.
15824		Treated Water 14461-318			
15825	487556	Raw Water 14461-317	Clostridium Perfringens in Water	0	cfu/100ml
15826		Raw Water 14461-317	Colilert (Ecoli)	2	MPN/100ml
15827		Raw Water 14461-317	Colilert (Total Coliforms)	5	MPN/100ml
15828		Raw Water 14461-317	Colour, apparent	<4	mg/l Pt Co
15829		Raw Water 14461-317	pH	7.5	pH Units
15830		Raw Water 14461-317	Turbidity	0.3	N.T.U.
15831		Raw Water 14461-317			
16300	A	13/11/2013			
16523	482134	Raw Water 14461-315	Clostridium Perfringens in Water	79	cfu/100ml
16524		Raw Water 14461-315	Colilert (Ecoli)	10	MPN/100ml
16525		Raw Water 14461-315	Colilert (Total Coliforms)	>201	MPN/100ml
16526		Raw Water 14461-315	Colour, apparent	11.2	mg/l Pt Co
16527		Raw Water 14461-315	pH	7.3	pH Units
16528		Raw Water 14461-315	Turbidity	<0.2	N.T.U.
16529		Raw Water 14461-315			
17164	A	09/10/2013			
17371	474778	Treated Water 14461-314	Clostridium Perfringens in Water	0	cfu/100ml
17372		Treated Water 14461-314	Colilert (Ecoli)	0	MPN/100ml
17373		Treated Water 14461-314	Colilert (Total Coliforms)	0	MPN/100ml
17374		Treated Water 14461-314	Colour, apparent	<4	mg/l Pt Co
17375		Treated Water 14461-314	pH	7.3	pH Units
17376		Treated Water 14461-314	Turbidity	<0.2	N.T.U.
17377		Treated Water 14461-314			
17378	474772	Raw Water 14461-313	Clostridium Perfringens in Water	0	cfu/100ml
17379		Raw Water 14461-313	Colilert (Ecoli)	10	MPN/100ml
17380		Raw Water 14461-313	Colilert (Total Coliforms)	19	MPN/100ml
17381		Raw Water 14461-313	Colour, apparent	<4	mg/l Pt Co
17382		Raw Water 14461-313	pH	7.3	pH Units
17383		Raw Water 14461-313	Turbidity	<0.2	N.T.U.
17384		Raw Water 14461-313			
18215	A	04/09/2013			
18339	467010	Treated Water 14461-312	Clostridium Perfringens in Water	0	cfu/100ml
18340		Treated Water 14461-312	Colilert (Ecoli)	0	MPN/100ml
18341		Treated Water 14461-312	Colilert (Total Coliforms)	0	MPN/100ml
18342		Treated Water 14461-312	Colour, apparent	<4	mg/l Pt Co
18343		Treated Water 14461-312	pH	7.9	pH Units
18344		Treated Water 14461-312	Turbidity	0.2	N.T.U.
18345		Treated Water 14461-312			
18346	467006	Raw Water 14461-311	Clostridium Perfringens in Water	0	cfu/100ml
18347		Raw Water 14461-311	Colilert (Ecoli)	9	MPN/100ml
18348		Raw Water 14461-311	Colilert (Total Coliforms)	12	MPN/100ml

18349		Raw Water 14461-311	Colour, apparent	10.7	mg/l Pt Co
18350		Raw Water 14461-311	pH	7.8	pH Units
18351		Raw Water 14461-311	Turbidity	0.3	N.T.U.
18352		Raw Water 14461-311			
18721	A	07/08/2013			
18928	460611	Treated Water 14461-310	Clostridium Perfringens in Water	0	cfu/100ml
18929		Treated Water 14461-310	Colilert (Ecoli)	0	MPN/100ml
18930		Treated Water 14461-310	Colilert (Total Coliforms)	0	MPN/100ml
18931		Treated Water 14461-310	Colour, apparent	4.1	mg/l Pt Co
18932		Treated Water 14461-310	pH	7.8	pH Units
18933		Treated Water 14461-310	Turbidity	0.3	N.T.U.
18934		Treated Water 14461-310			
18935	460610	Raw Water 14461-309	Clostridium Perfringens in Water	0	cfu/100ml
18936		Raw Water 14461-309	Colilert (Ecoli)	59	MPN/100ml
18937		Raw Water 14461-309	Colilert (Total Coliforms)	130	MPN/100ml
18938		Raw Water 14461-309	Colour, apparent	4.9	mg/l Pt Co
18939		Raw Water 14461-309	pH	7.7	pH Units
18940		Raw Water 14461-309	Turbidity	0.4	N.T.U.
18941		Raw Water 14461-309			
19696	A	03/07/2013			
19901	453564	Treated Water 14461-308	Clostridium Perfringens in Water	0	cfu/100ml
19902		Treated Water 14461-308	Colilert (Ecoli)	0	MPN/100ml
19903		Treated Water 14461-308	Colilert (Total Coliforms)	0	MPN/100ml
19904		Treated Water 14461-308	Colour, apparent	<4	mg/l Pt Co
19905		Treated Water 14461-308	pH	8.0	pH Units
19906		Treated Water 14461-308	Turbidity	0.3	N.T.U.
19907		Treated Water 14461-308			
19908	453562	Raw Water 14461-307	Clostridium Perfringens in Water	0	cfu/100ml
19909		Raw Water 14461-307	Colilert (Ecoli)	6	MPN/100ml
19910		Raw Water 14461-307	Colilert (Total Coliforms)	8	MPN/100ml
19911		Raw Water 14461-307	Colour, apparent	<4	mg/l Pt Co
19912		Raw Water 14461-307	pH	8.0	pH Units
19913		Raw Water 14461-307	Turbidity	0.3	N.T.U.
19914		Raw Water 14461-307			
19982	A	12/06/2013			
20187	449295	Treated Water 14461-306	Clostridium Perfringens in Water	0	cfu/100ml
20188		Treated Water 14461-306	Colilert (Ecoli)	0	MPN/100ml
20189		Treated Water 14461-306	Colilert (Total Coliforms)	0	MPN/100ml
20190		Treated Water 14461-306	Colour, apparent	<4	mg/l Pt Co
20191		Treated Water 14461-306	pH	7.9	pH Units
20192		Treated Water 14461-306	Turbidity	<0.2	N.T.U.
20193		Treated Water 14461-306			
20194	449294	Raw Water 14461-305	Clostridium Perfringens in Water	0	cfu/100ml
20195		Raw Water 14461-305	Colilert (Ecoli)	0	MPN/100ml
20196		Raw Water 14461-305	Colilert (Total Coliforms)	1	MPN/100ml
20197		Raw Water 14461-305	Colour, apparent	<4	mg/l Pt Co
20198		Raw Water 14461-305	pH	7.8	pH Units

20199		Raw Water 14461-305	Turbidity	0.2	N.T.U.
20200		Raw Water 14461-305			
20671	A	15/05/2013			
21009	443597	Treated Water 14461-304	Clostridium Perfringens in Water	0	cfu/100ml
21010		Treated Water 14461-304	Colilert (Ecoli)	0	MPN/100ml
21011		Treated Water 14461-304	Colilert (Total Coliforms)	0	MPN/100ml
21012		Treated Water 14461-304	Colour, apparent	5.5	mg/l Pt Co
21013		Treated Water 14461-304	pH	7.9	pH Units
21014		Treated Water 14461-304	Turbidity	0.3	N.T.U.
21015		Treated Water 14461-304			
21016	443596	Raw Water 14461-303	Clostridium Perfringens in Water	0	cfu/100ml
21017		Raw Water 14461-303	Colilert (Ecoli)	3	MPN/100ml
21018		Raw Water 14461-303	Colilert (Total Coliforms)	4	MPN/100ml
21019		Raw Water 14461-303	Colour, apparent	5.5	mg/l Pt Co
21020		Raw Water 14461-303	pH	7.8	pH Units
21021		Raw Water 14461-303	Turbidity	0.5	N.T.U.
21022		Raw Water 14461-303			
21861	A	03/04/2013			
22088	435357	Treated Water 14461-302	Clostridium Perfringens in Water	0	cfu/100ml
22089		Treated Water 14461-302	Colilert (Ecoli)	0	MPN/100ml
22090		Treated Water 14461-302	Colilert (Total Coliforms)	0	MPN/100ml
22091		Treated Water 14461-302	Colour, apparent	<4	mg/l Pt Co
22092		Treated Water 14461-302	pH	8.0	pH Units
22093		Treated Water 14461-302	Turbidity	<0.2	N.T.U.
22094		Treated Water 14461-302			
22095	435356	Raw Water 14461-301	Clostridium Perfringens in Water	1	cfu/100ml
22096		Raw Water 14461-301	Colilert (Ecoli)	0	MPN/100ml
22097		Raw Water 14461-301	Colilert (Total Coliforms)	0	MPN/100ml
22098		Raw Water 14461-301	Colour, apparent	<4	mg/l Pt Co
22099		Raw Water 14461-301	pH	7.8	pH Units
22100		Raw Water 14461-301	Turbidity	0.2	N.T.U.
22101		Raw Water 14461-301			
22420	A	06/03/2013			
22625	429847	Treated Water 14461-300	Clostridium Perfringens in Water	0	cfu/100ml
22626		Treated Water 14461-300	Colilert (Ecoli)	0	MPN/100ml
22627		Treated Water 14461-300	Colilert (Total Coliforms)	0	MPN/100ml
22628		Treated Water 14461-300	Colour, apparent	<4	mg/l Pt Co
22629		Treated Water 14461-300	pH	8.0	pH Units
22630		Treated Water 14461-300	Turbidity	<0.2	N.T.U.
22631		Treated Water 14461-300			
22632	429846	Raw Water 14461-299	Clostridium Perfringens in Water	0	cfu/100ml
22633		Raw Water 14461-299	Colilert (Ecoli)	0	MPN/100ml
22634		Raw Water 14461-299	Colilert (Total Coliforms)	0	MPN/100ml
22635		Raw Water 14461-299	Colour, apparent	<4	mg/l Pt Co
22636		Raw Water 14461-299	pH	7.9	pH Units
22637		Raw Water 14461-299	Turbidity	<0.2	N.T.U.
22638		Raw Water 14461-299			

23234	A	06/02/2013			
23305	424397	Treated Water 14461-298	Clostridium Perfringens in Water	0	cfu/100ml
23306		Treated Water 14461-298	Colilert (Ecoli)	0	MPN/100ml
23307		Treated Water 14461-298	Colilert (Total Coliforms)	0	MPN/100ml
23308		Treated Water 14461-298	Colour, apparent	4	mg/l Pt Co
23309		Treated Water 14461-298	pH	7.8	pH Units
23310		Treated Water 14461-298	Turbidity	0.3	N.T.U.
23311		Treated Water 14461-298			
23312	424396	Raw Water 14461-297	Clostridium Perfringens in Water	1	cfu/100ml
23313		Raw Water 14461-297	Colilert (Ecoli)	0	MPN/100ml
23314		Raw Water 14461-297	Colilert (Total Coliforms)	1	MPN/100ml
23315		Raw Water 14461-297	Colour, apparent	5.4	mg/l Pt Co
23316		Raw Water 14461-297	pH	7.6	pH Units
23317		Raw Water 14461-297	Turbidity	0.4	N.T.U.
23318		Raw Water 14461-297			
23754	A	09/01/2013			
23963	419154	Treated Water 14461-296	Clostridium Perfringens in Water	0	cfu/100ml
23964		Treated Water 14461-296	Colilert (Ecoli)	0	MPN/100ml
23965		Treated Water 14461-296	Colilert (Total Coliforms)	0	MPN/100ml
23966		Treated Water 14461-296	Colour, apparent	<4	mg/l Pt Co
23967		Treated Water 14461-296	pH	7.8	pH Units
23968		Treated Water 14461-296	Turbidity	0.2	N.T.U.
23969		Treated Water 14461-296			
23970	419153	Raw Water 14461-295	Clostridium Perfringens in Water	6	cfu/100ml
23971		Raw Water 14461-295	Colilert (Ecoli)	>201	MPN/100ml
23972		Raw Water 14461-295	Colilert (Total Coliforms)	>201	MPN/100ml
23973		Raw Water 14461-295	Colour, apparent	33.8	mg/l Pt Co
23974		Raw Water 14461-295	pH	7.6	pH Units
23975		Raw Water 14461-295	Turbidity	1.5	N.T.U.
23976		Raw Water 14461-295			

CERTIFICATE OF ANALYSIS

Client : Edmund Kelly
Ballinrillick GWS
Ballinrillick
Co.Sligo

Report No. : 267338
Date of Receipt : 29/07/2015
Start Date of Analysis : 29/07/2015
Date of Report : 15/09/2015
Order Number :
Sample taken by : CLS

Lab No	Sample Description	Test	*	Result	Units
610350	Ballinrillick. Raw Water. 29/07/15	BOD	R	<1	mg/l
		COD	R	<10	mg/l
		Turbidity	R	0.5	N.T.U.
		pH	R	7.6	pH Units
		Conductivity @20C	R	234	uS/cm
		Alkalinity, total	R	124	mg/l CaCO3
		Nitrite as N	R	<0.005	mg/l
		Sodium, total	R	8	mg/l
		Chloride	R	11.8	mg/l
		Ammonium as NH4	R	<0.01	mg/l
		Nitrate as NO3	R	1.38	mg/l
		Dissolved Oxygen (%)	R	97	%Sat
		Potassium, total	R	0.8	mg/l
		Total Hardness (Kone)	R	126	mg/l CaCO3
		Magnesium, total	R	7	mg/l
		Colour, apparent	R	12.4	mg/l Pt Co
		Silica as Si O2 (reactive)	S	1.85	mg/l
		Sulphate	R	7.44	mg/l
		Fluoride	S	0.12	mg/l
		Orthophosphate as PO4-P	R	<0.01	mg/l
		Calcium, total	R	75	mg/l
		Aluminium, dissolved	R	3	ug/l
		Iron, dissolved	R	<10	ug/l
		Manganese, dissolved	R	<5	ug/l
		Copper, dissolved	R	<1	ug/l
		Lead, dissolved	R	<0.5	ug/l
		Chromium, dissolved	R	<0.5	ug/l
		Nickel, dissolved	R	<0.5	ug/l
		Cadmium, dissolved	R	<0.5	ug/l
		Arsenic, dissolved	R	<0.5	ug/l
		Zinc, dissolved	R	<5	ug/l
		Barium, dissolved	R	9	ug/l
		TOC	R	1.53	mg/L
		Clostridium Perfringens in Water	R	0	cfu/100ml
		Strontium, dissolved	R	252	ug/l
		E coli (Filtration) (Environmental Waters)	R	36	cfu/100ml
		Total Coliforms (Filtration) (Environmental Waters)	R	36	cfu/100ml



Approved by:

Barbara Lee

Barbara Lee
Environmental
Scientist

See below for test specifications and accreditation status.

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* Location of analysis: R=Ros Muc, M=MedPharma, S=Subcontracted.

It is recommended that water samples requiring microbiological analysis should be tested within 24 hours of sampling.

Test	Specification	CLS 17025 status	GMP/FDA ¹	ISO ²	Sub ³	Sub 17025 Status
BOD	CLS 12	Yes	No	Yes	No	No
COD	CLS 52	Yes	No	Yes	No	No
Turbidity	CLS 30	Yes	No	Yes	No	No
pH	CLS 26	Yes	No	Yes	No	No
Conductivity @20C	CLS 67	Yes	No	Yes	No	No
Alkalinity, total	CLS 54	No	No	Yes	No	No
Nitrite as N	Konelab CLS 37	Yes	No	Yes	No	No
Sodium, total	ICP-MS CLS129	Yes	No	Yes	No	No
Chloride	Konelab CLS 36	Yes	No	Yes	No	No
Ammonium as NH4	Konelab CLS 40	Yes	No	Yes	No	No
Nitrate as NO3	Konelab CLS 39	Yes	No	Yes	No	No
Dissolved Oxygen (%)	CLS 75	No	No	Yes	No	No
Potassium, total	ICP-MS CLS129	Yes	No	Yes	No	No
Total Hardness (Kone)	Konelab CLS 77	Yes	No	Yes	No	No
Magnesium, total	ICP-MS CLS129	Yes	No	Yes	No	No
Colour, apparent	CLS 29	Yes	No	Yes	No	No
Silica as Si O2 (reactive)	Spectroph.	No	No	N/A	Yes	No
Sulphate	Konelab CLS 88	Yes	No	Yes	No	No
Fluoride	ISE	No	No	N/A	Yes	Yes
Orthophosphate as PO4-P	Konelab CLS 35	Yes	No	Yes	No	No
Calcium, total	ICP-MS CLS129	Yes	No	Yes	No	No
Aluminium, dissolved	ICP-MS CLS129	Yes	No	Yes	No	No
Iron, dissolved	ICP-MS CLS 129	Yes	No	Yes	No	No
Manganese, dissolved	ICP-MS CLS129	Yes	No	Yes	No	No
Copper, dissolved	ICP-MS CLS 129	Yes	No	Yes	No	No
Lead, dissolved	ICP-MS CLS129	Yes	No	Yes	No	No
Chromium, dissolved	ICP-MS CLS 129	Yes	No	Yes	No	No
Nickel, dissolved	ICP-MS CLS129	Yes	No	Yes	No	No
Cadmium, dissolved	ICP-MS CLS129	Yes	No	Yes	No	No
Arsenic, dissolved	ICP-MS CLS129	Yes	No	Yes	No	No
Zinc, dissolved	ICP-MS CLS 129	Yes	No	Yes	No	No
Barium, dissolved	ICP-MS CLS129	Yes	No	Yes	No	No
TOC	CLS 150	Yes	No	Yes	No	No
Clostridium Perfringens in Water	CLS 43	Yes	No	Yes	No	No
Strontium, dissolved	ICP-MS CLS129	Yes	No	Yes	No	No
E coli (Filtration) (Environmental Waters)	CLS 16	Yes	No	Yes	No	No
Total Coliforms (Filtration) (Environmental Waters)	CLS 16	Yes	No	Yes	No	No

¹Analysis carried out in a GMP approved, FDA inspected facility (MedPharma site only).

²Laboratory Analysis, Sampling, Technical Backup, Training, Food Safety Program Auditing and Monitoring are all ISO 9001:2008 certified (Ros Muc site only).

³Subcontracted.

Lab No	Sample ID	Sample Condition on Receipt	Sampling Date
610350	Ballintrillick. Raw Water. 29/07/15	Good condition	29/07/2015

Appendix 4

Acronyms and Glossary

Acronyms

EPA – Environmental Protection Agency
DEHLG – Department of Environment Heritage and Local Government
EU – European Union
GSI – Geological Survey of Ireland
GWB – Groundwater Body
GWD – Groundwater Directive (European Union)
GWS – Group Water Scheme
IGI – Institute of Geologists of Ireland
IG – Irish National Grid Reference
m aOD – metres above Ordnance Datum
m bgl – metres below ground level
TVs – Threshold Values
UV – Ultra-Violet
ZOC – Zone of Contribution
WFD – Water Framework Directive

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.

Boulder Clay

See 'Till'

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.

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

Dolines, 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. The area of the groundwater system that has lower groundwater levels than other areas. Opposite of upgradient.

Enclosed Depression

See doline

Fissure

A natural crack in rock which allows rapid water movement.

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 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 (also known as 'Permeability')

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 Rock

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.

Metamorphic Rock

A rock made out of highly altered existing rock. Common types include marble, schist and quartzite.

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 (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 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.

Sedimentary Rock

A rock composed of sediments (sand, silt, clay, calcium carbonate fragments, shell fragments, etc.) that have been buried and lithified (cemented). Common types include sandstone, shale and limestone.

Soil (topsoil)

The uppermost layer of soil in which plants grow.

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 spring usually reflects a change in soil or rock type, or a change in slope.

Subsoil

Unlithified (uncemented) geological strata or materials beneath the topsoil and above bedrock. Common types include Till/Boulder Clay, sand/gravel and peat.

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 (also known as 'Sinkhole')

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 (also known as 'Boulder Clay')

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.

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.

Up-gradient

The direction of increasing groundwater levels, i.e. the direction from which groundwater is flowing. The area of the groundwater system that has higher groundwater levels than other areas. Opposite of down-gradient.

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. This is the level to which water naturally settles in the cracks, cavities and pore spaces underground. Above the water table, the spaces in the rock or sediments are air-filled. Below the water table, the spaces are filled with water.

Weathering

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

Well

A construction into the ground in order to access groundwater. Can be a dug well, which is generally shallow, with a diameter of a metre or more, or a borewell (see 'Borehole'), which is narrower in diameter and generally deeper.

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.

Appendix 5

Spring Discharge Estimate

Estimation of flows springs 1, 2 and 3 were carried out on 3/10/2015. There had been no rainfall for two weeks preceding this date.

Spring 1 velocity was measured inside the outflow pipe from the spring chamber and flow calculated using the velocity area method. Flow was estimated to be 86 m³/day.

Spring 2 flow was estimated by container fill time at the point where the piped flow discharges to a drain within the treatment compound. An additional 10% is estimated to flow around the pipe collection point and forms the start of a permanent watercourse. Total flow was estimated to be 67 m³/day.

Spring 3 flow was estimated by eye, due to the lack of a suitable reach in which to measure velocity. It was estimated to be of the order of 50 m³/day.