Preliminary Report on Source Protection

Drumkeery Group Water Scheme

(Drumkeery Lough)

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1.0 Introduction

Source protection is the protection of raw water quality through measures that limit or eliminate the risk of water contamination. It is an increasingly important strategy for the protection and maintenance of drinking water sources. Source protection should be the first barrier in a multi-barrier approach to providing safe drinking water. In its simplest form, source protection emphasises prevention rather than cure in relation to water quality. A clean water source will help in the long term provision of safe and cheap potable water. This approach involves managing any potential pollution in the raw water catchment area.

In Ireland, a limited number of studies have investigated the potential of source protection to improve water quality. The National Source Protection Pilot Project (NSPPP) at Churchill and Oram Group Water Scheme, Co. Monaghan (2005-2009), was established by the National Rural Water Monitoring Committee and was overseen by the National Centre for Freshwater Studies (NCFS) at Dundalk Institute of Technology. The objectives of the Pilot Project were to assess water quality within the Milltown Lake catchment, identify sources of contamination and implement remediation measures to protect and enhance water quality in the lake. The project represents a model of best practice for the implementation of source protection in Ireland and was designed for replication by other group water schemes around the country. It is in the interest of privately-sourced group water schemes to carry out assessments to determine the potential for nutrient enrichment and biological contamination (e.g. *Enterococcus* spp., *Escherichia coli*, *Cryptosporidium* spp.) of their water supplies, and to meet application conditions for a Water Services Licence under the Water Services Act (2007).

This report provides an overview of how Drumkeery Lough fits into the Water Framework Directive (WFD), the all-inclusive legal framework for raw water quality in the European Union. In addition to summarising issues highlighted in the wider Blackwater North Water Management Unit Action Plan, the report provides a physical site description of the Drumkeery Lough catchment, explaining how this is relevant to water quality. The potential impact of land use is discussed, while the available raw water quality data is evaluated. Based on the above information the major concerns relating to source protection are highlighted and recommendations are made as how best to manage these in the future.

2.0 Methods

Catchment delineation

The catchment outline was defined using the available contours on the OS Discovery Series (1:50,000) maps. A map of the stream network and other water bodies was available in GIS format (Table 1). This allowed the various streams flowing into the lake to be identified. These maps were complemented by use of old 6 inch to 1 mile (scale) maps of the area

available at www.osi.ie. Those maps were particularly useful in defining direction of flow in small streams. The results were cross-referenced with the Blackwater North, Water Management Unit, generated as part of the Water Framework Directive.

Catchment description

Various national data sets (Table 1) relating to soils, geology, land cover etc. were accessed in GIS format and the appropriate sections clipped to the catchment area of Drumkeery Lough. This allowed for the potential impacts of these factors to be analysed.

Table1. Data sets used to describe the catchment.

Dataset	Source	Description
Corine	EPA Ireland	Image of land cover based on satellite imagery
Soils	Teagasc*	Irish Forestry Service soil types. Similar to great soils map
Subsoils	Teagasc*	Parent material is the material from which soils are formed
Bedrock Geology	GSI	Map of Irish bedrock
Aquifer Bedrock	GSI	Information of quality of aquifers
Aquifer Vulnerability	GSI	Information on connectivity between contaminants and aquifers
Streams/Lakes/Rivers	EPA Ireland	National data sets

*Soils and Subsoils data generated by Teagasc with co-operation of the Forest Service, EPA and GSI. Project completed May 2006.

Water Quality Data

Water quality data relating to Drumkeery Lough and its catchment were collated from a number of sources. Cavan County Council monitored Drumkeery Lough and this report analysed results from 2007 to 2011. This data provided a comprehensive insight into water quality based on four sampling trips per year. Similar data was available from the design contract for the water treatment plant. Much of that data was presented by T.J. O'Connor and Associates, Consulting Engineers, who sampled the lake on 11 occasions between 2002 and 2003 (see appendix). The maximum values for each parameter in this design contract are important for the GWS. The water treatment plant was designed to treat water of this quality and departures from this may be the responsibility of the scheme, not the operator.

Weekly analysis of raw water was also carried out by Veolia Water, treatment plant service provider, since February 2006 and this data is discussed below.

The parameters of relevance to source protection, from the above mentioned data, were discussed in detail. The data was also interpreted to highlight potential water quality issues in Drumkeery Lough and their potential causes and impacts.

Some data on the inflow and outflow streams to Drumkeery Lough was also available. This data was obtained from Cavan County Council and will be discussed below.

3.0 Overview of Drumkeery Lough and the Water Framework Directive (WFD)

Under the Water Framework Directive, the island of Ireland has been divided into 8 river basin districts, 2 of which are international. Drumkeery Lough and its catchment lie within the Eastern River Basin District. Under the WFD each RBD is subdivided into water management units. Drumkeery Lough and its catchment are part of the Blackwater North Water Management Unit (www.erbd.ie).

Within this water management unit many issues have been highlighted as causing pollution. These included, agriculture, waste water treatment plants (WWTP), industrial discharges and un-sewered properties (septic tanks). This information gives an overview of potential pollution in the Drumkeery Lough Catchment. As there are no WWTP or large industry in the Drumkeery Lough catchment this report will focus mainly on agriculture and un-sewered properties as potential pollution sources.

The River Basin Management Plan for the area described biological quality in Drumkeery Lough and Skeagh Lough Upper as poor status and set a deadline of 2015 for achieving improvements to good status.

4.0 Physical Site Description

Catchment location and outline

Drumkeery Lough is located approximately three kilometres north west of Bailieborough in Co. Cavan. The lake itself is 10.4 ha in area and drains an area of 9.4 km^2 (including lakes) (Figure 1). The lake consists of two basins. The smaller basin (to the west) is known locally as Crocknaheckna Lough which was previously the abstraction point for Vale GWS. The OS, 1:50,000 series, map of the area shows one main inflow to Drumkeery Lough. This stream links Skeagh Lough Upper to Drumkeery Lough and enters the lake at N 657 999. Skeagh

Lough Upper is a larger lake with an area of 61 ha. Drumkeery Lough also has one outflow that is visible on the same OS map and it leaves the lake at H 662 002. This stream drains to the south and discharges into Castle Lough. A number of smaller inflow streams were identified by viewing historical maps of the catchment (6 inch maps). Seven such inflow streams were identified and are included in Figure 1. One of these streams appears to link Lisgar Lough (H665 018) to Drumkeery Lough.

Drumkeery Lough is located at 139m above sea level and has steep slopes approaching the northern and southern shores. The entire catchment is characterised by these steeply sloping hills typical of this drumlin type landscape. Skeagh Lough Upper is also located amongst steeply sloping hills.

There are a number of third class roads throughout the catchment. The OS map of the area indicates that the catchment contains many single dwelling houses.

Bedrock geology

The Drumkeery Lough Catchment is underlain by Silurian metasediments and volcanics (Figure 2). These rocks were laid down during the Silurian period which represents the time period between approximately 444 million years ago and 416 million years ago. The metasedimentary rocks represent sedimentary rocks which have been altered through metamorphism. The volcanic rocks were formed from magma. These rock types do not contain large fissuring or cracking and are unlikely to support large aquifers

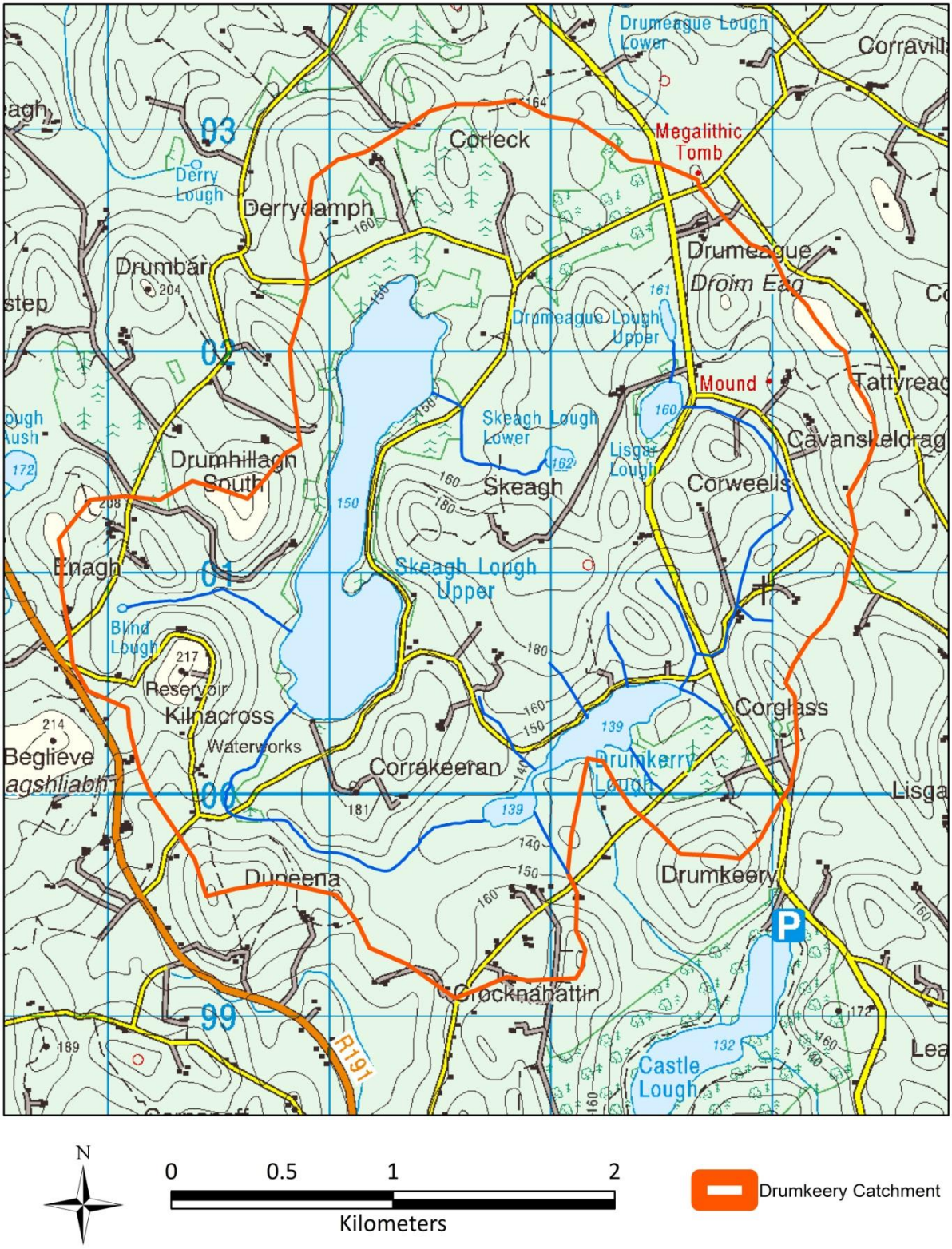


Figure 1. Ordnance Survey map showing the catchment outline

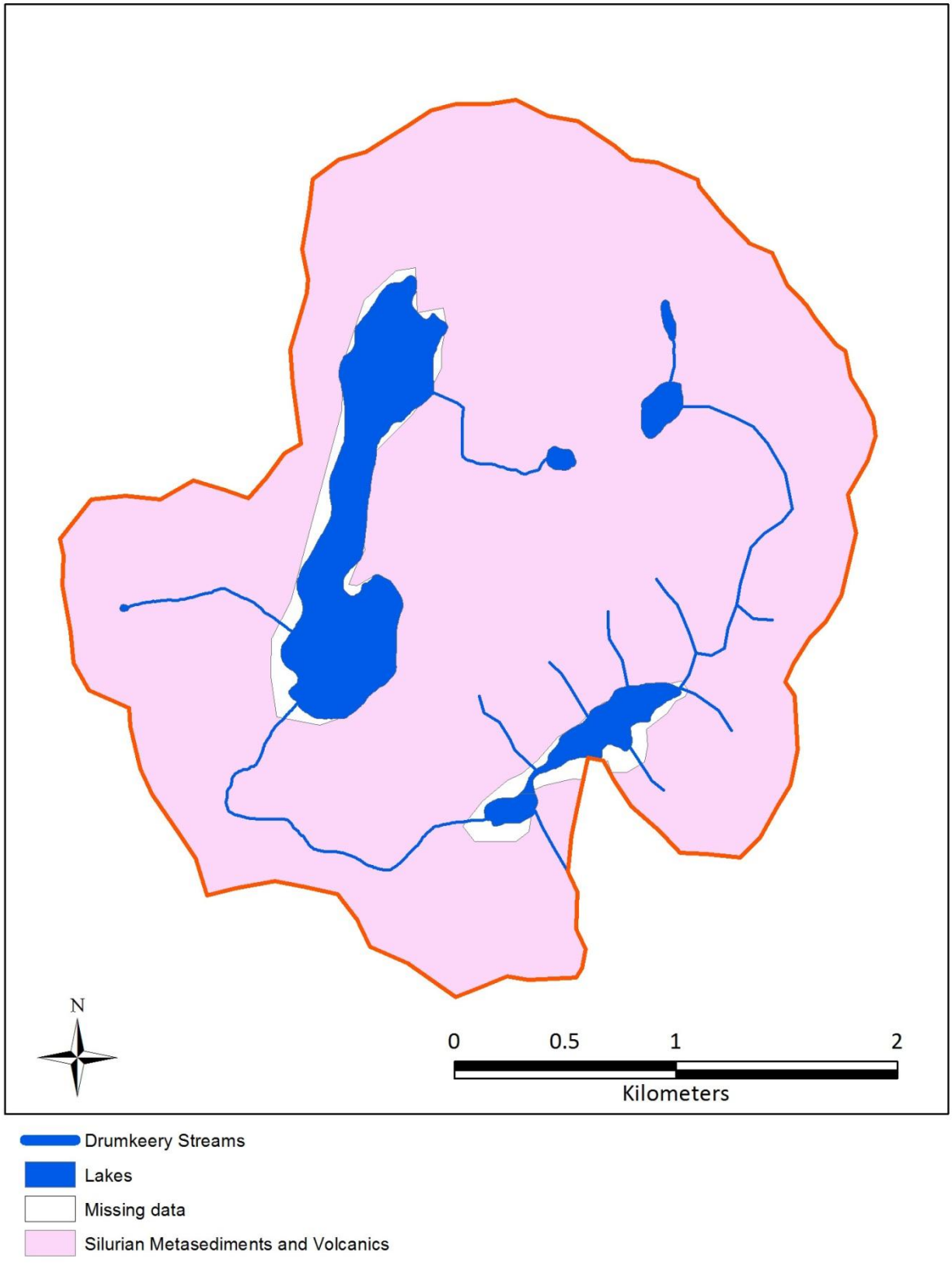


Figure 2. Bedrock geology in the Drumkeery Lough catchment

Aquifer Bedrock

The aquifers in the Drumkeery Lough catchment were described as poor aquifers (Figure 3). This is a reflection of the bedrock geology described above and means that the area is unlikely to support any large aquifers (<100m^3/day). Storage capacity, recharge acceptance, and base flow contributions are all likely to be low in this area. This suggests that during dry periods, stream levels will be very low and lake retention time will be high. This will make Drumkeery Lough particularly susceptible to pollution events during dry weather conditions.

Aquifer Vulnerability

The vulnerability of groundwater refers to the likelihood of surface contaminants reaching the groundwater store (Figure 4). The vulnerability of groundwater depends on: (i) the time of travel of infiltrating water (and contaminants); (ii) the relative quantity of contaminants that can reach the groundwater; and (iii) the contaminant attenuation capacity of the geological materials through which the water and contaminants infiltrate.

Groundwater vulnerability varies greatly throughout the catchment with areas ranging from low to extreme vulnerability present. Overall, moderate classification dominates the catchment. This classification includes large areas of the catchment including the lands around Skeagh Lough Upper. Groundwater in the area surrounding Drumkeery Lough is less well protected by the overlying soils. Most of the land bordering the lake was described as extremely vulnerable. This means there is little barrier to pollution moving between the soil surface and local groundwater.

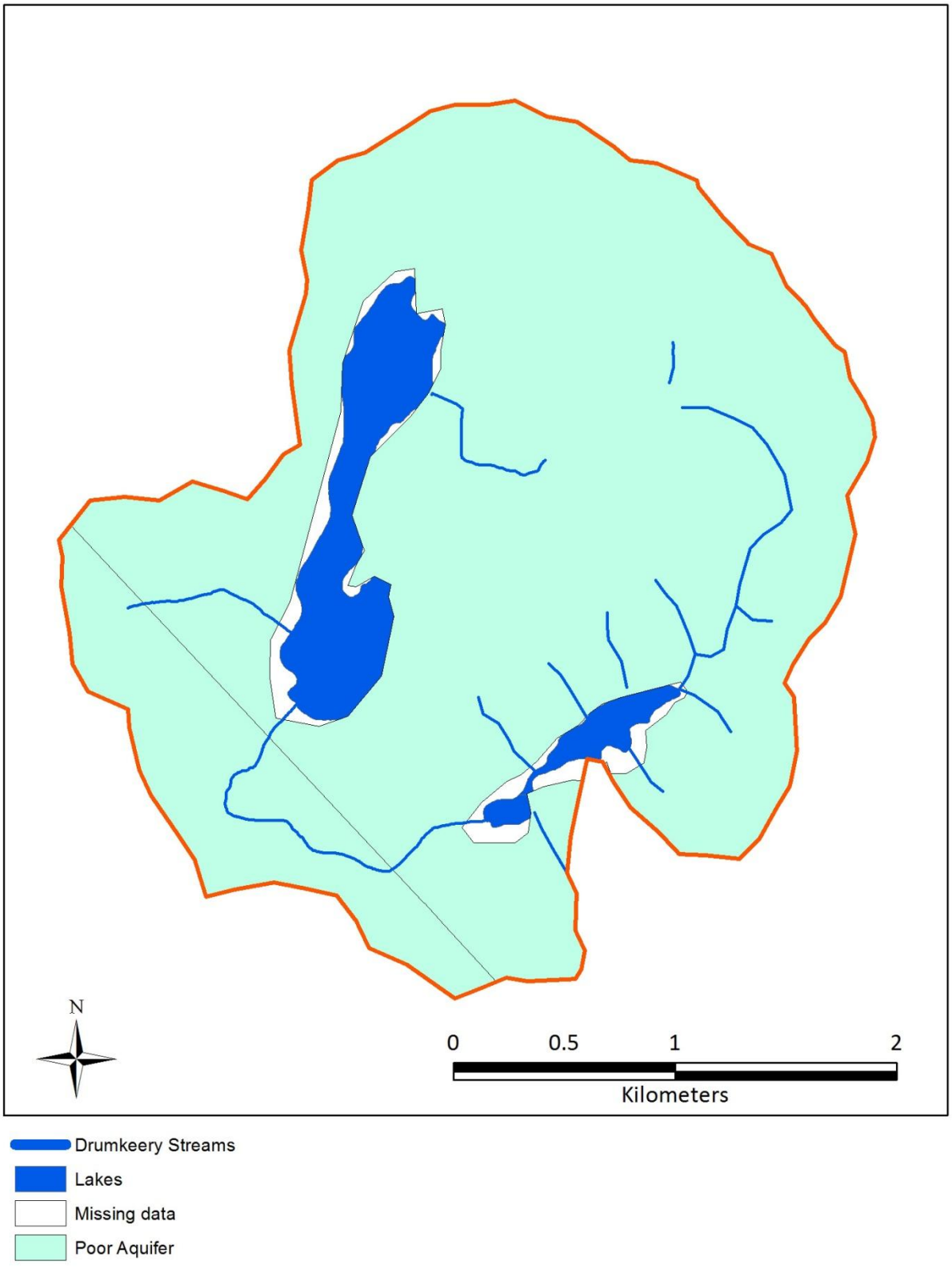


Figure 3. Aquifers present in the Drumkeery Lough catchment

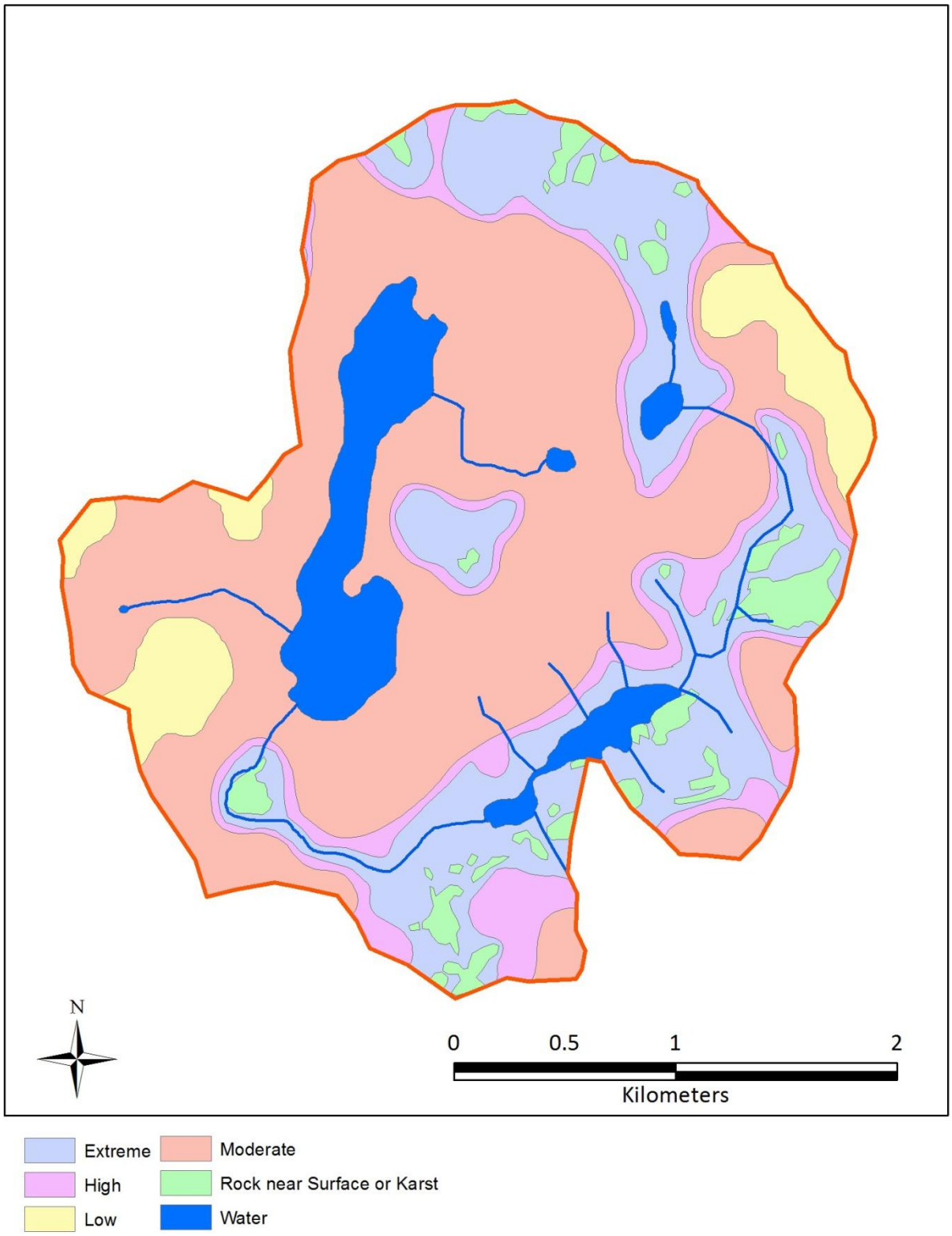


Figure 4. Groundwater vulnerability in the Drumkeery Lough catchment

Subsoils

Subsoils within the catchment are dominated by sandstone and shale dominated till (Figure 5). Till subsoils were generally deposited by glaciers after the last ice age. These soils are often tightly packed and contain particles of varying sizes. Depending on the depth of these tills and their drainage characteristics they may give rise to different top soils. There were also areas of alluvium, rock and cut peat in the catchment. Peat subsoils will have poor drainage while rock at or near the ground surface is indicative of thin unproductive soils. The peat soils present were generally located in the northern section of the catchment, including areas around the north of Skeagh Lough Upper, Lisgar Lough and Drumeague Lough Upper. The area north of Drumkeery Lough contained sandstone and shale tills while cut bogs and rock bordered the lake to the south and west.

Table 2. Subsoils in the catchment and map codes

Subsoil Description	Map code
Till type	
Sandstone and shale till (Lower Palaeozoic)	TLPSsS
Alluvium	
Alluvium undifferentiated	A
Peat	
Cut-over peat	Cut
Other categories	
Bedrock at surface	Rck

Soils

Soils in the Drumkeery Lough catchment are dominated by the class AminPD soils (Figure 6). This category consists of gley soils. Gley soils have impeded drainage and have a poor physical condition. These conditions are unsuitable for cultivation or intensive grassland farming. If combined with steep slopes, these soils are likely to lead to overland flow of water during periods of rainfall. Cut peats are also present in the catchment. As described above, these soils are located around the smaller loughs in the north of the catchment, bordering Skeagh Lough Upper and to the south of Drumkeery Lough. As well as having very poor drainage, peat soils also have an inability to retain phosphorus so any fertiliser added to these soils is likely to be lost to local water courses. Alluvium (Aluvmin) soils were also present in small areas of the catchment. These soils consist of material deposited by flowing water. For this reason they are located along the course of existing streams. Alluvium soils are located along the stream which links Lisgar Lough to Drumkeery Lough. The remainder of the soils in the catchment consist of Amin SRPT and Amin SW. These groups represent poor quality soils that are either rocky or peaty in nature.

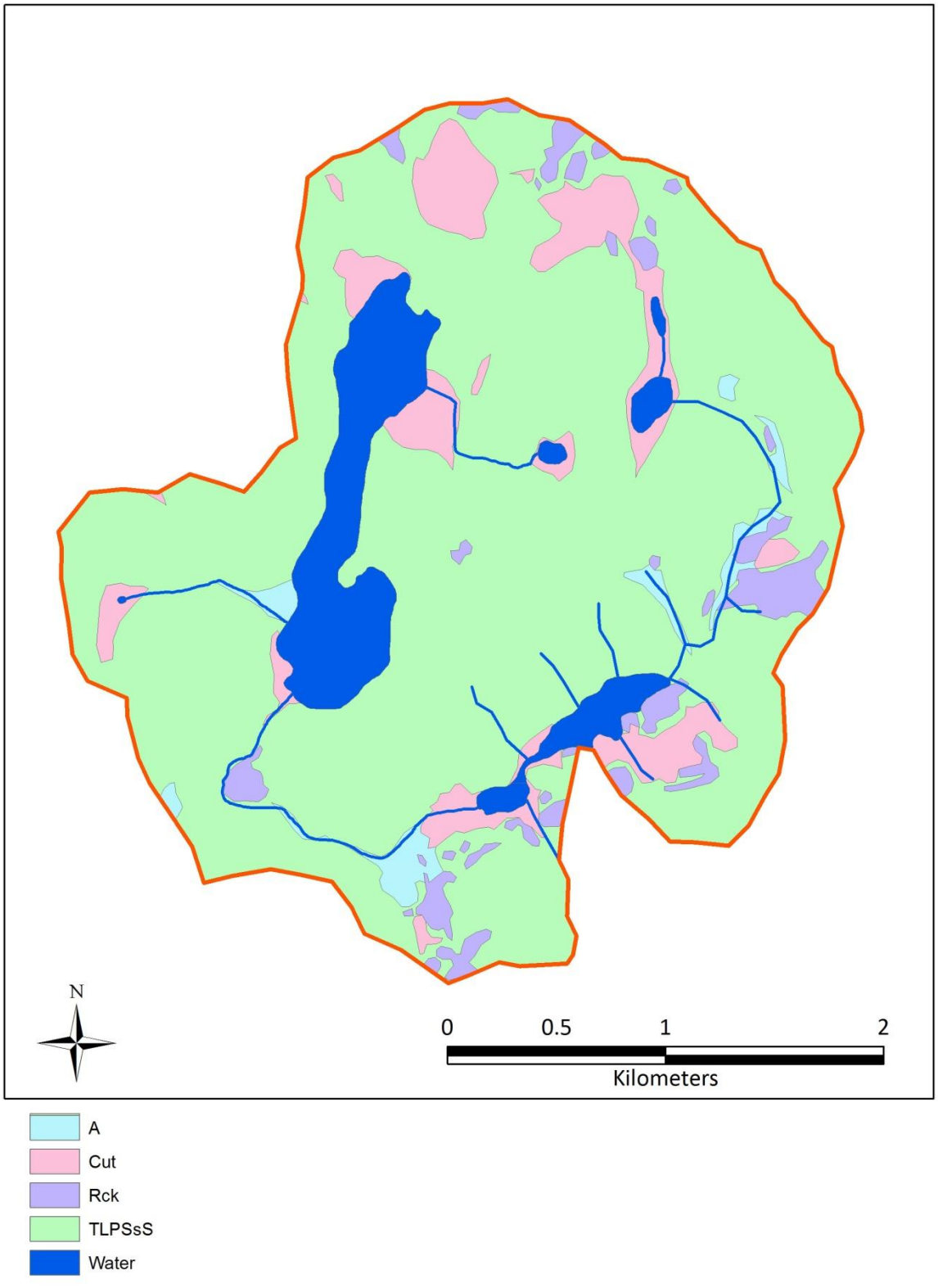


Figure 5. Subsoils present in the Drumkeery Lough catchment. See Table 2 for subsoils descriptions

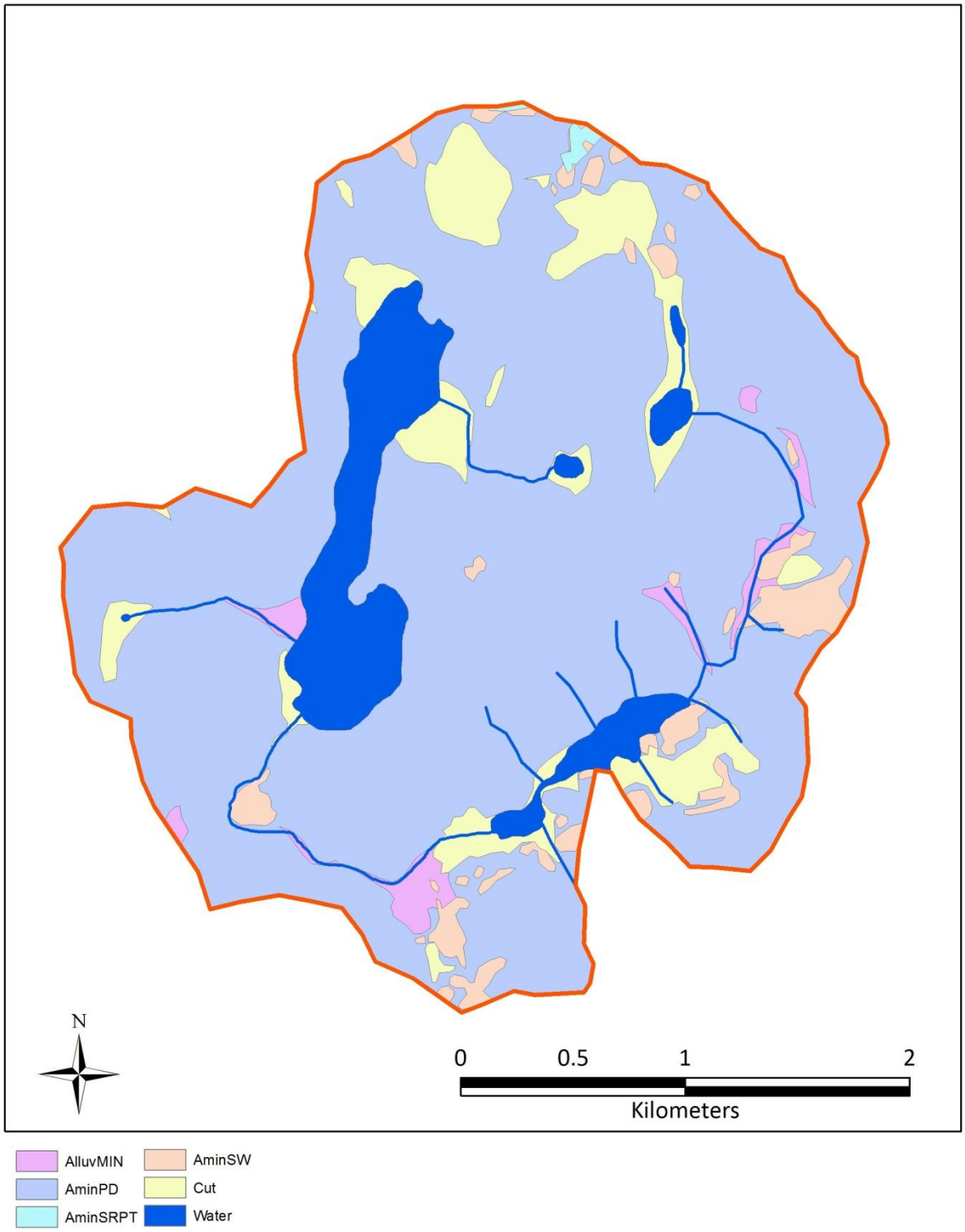


Figure 6. Soils present in the Drumkeery Lough catchment (See Table 3 for soil descriptions)

Table 3. Soils in the catchment

IFS Soil Description	IFS_soil	IFS Code	Included Great Soil Groups
Shallow well drained mineral			
Derived from mainly non-calcareous parent materials	AminSW	21	Lithosols Regosols
Deep poorly drained mineral			
Derived from mainly non-calcareous parent materials	AminPD	31	Surface water Gleys Groundwater Gleys
Alluviums			
Mineral alluvium	AlluvMIN	51	Variable
Peats			
Cutaway/cut-over peat	Cut	65	Basin Peats Blanket Peats
Shallow, lithosolic-podzolic type soils potentially with peaty topsoil			
Predominantly shallow soils derived from non-calcareous rock or gravels with/without peaty surface horizon	AminSRPT	43	Podzols (Peaty) Lithosols Peats

Slope and run-off

The slope of lands leading to a waterbody is an important determinant of the rate at which water and pollutants move into the lake by overland and subsurface flows. Slope will ultimately affect the quantity of nutrients and pathogens entering the lake and, hence, its water quality. Steep slopes are vulnerable to surface run-off, particularly if combined with poor draining soils.

The impact of these slopes could only be assessed in a more detailed study where the interaction between soils, land use and slope were considered together. However, some useful interpretation can be made from viewing the OS map of the area. In general, the catchment is characterised by areas of steep slopes leading towards the various waterbodies. This is typical of the drumlin type landscape of Counties Monaghan and Cavan. Of particular note were the slopes leading to the western shore of Skeagh Lough Upper. Three hills along this shore had slopes in excess of 10% (estimated) leading towards the lake. These hills were located at H 648 020, H 646 014 and H 644 005. The latter two hills may also have an impact on the stream linking Blind Lough to Skeagh Lough Upper.

The stream linking Skeagh Lough Upper to Drumkeery Lough also flows through an area of steeply sloping land. This may increase the potential for pollution in this part of the catchment.

Drumkeery Lough itself is also located in a depression between steeply sloping hills. Slopes are particularly high leading towards the north shore of the lake. Similar to Skeagh Lough Upper above, it is likely that the slopes surrounding Drumkeery Lough are greater than 10% in many areas.

5.0 Land use within the catchment

Corine

Corine land cover data gives some insight into land use within the Drumkeery Lough catchment. This satellite derived image, describes the catchment as being mainly covered in pastures with a small area to the north of Skeagh Lough Upper containing natural vegetation and transitional woodland (Figure 7).

A further insight into agricultural practice and intensity was shown when improved and unimproved pastures were separated (Figure 8). This figure suggests that approximately half of the pastures were improved while about half were non-improved. The improved areas may indicate more intensive agriculture where land had been drained and managed more intensively.

Forestry

Forestry plantations present threats to water quality both during planting and early growing stages and during felling. Water quality can be affected by activities such as ground preparation, fertilisation, thinning, felling and construction of forestry roads. The application of fertilisers to young standing stock to enhance growth can lead to excessive phosphorous availability, thereby increasing P volumes in run-off from planted land. During the felling process, sediment loss, siltation and nutrient release can also occur. In addition, exposure of un-vegetated soil can lead to run-off of P in soil suspension. Construction of forestry roads causes disturbance, erosion and compaction of the soil surface, resulting in sedimentation and nutrient run-off.

The Corine land cover data set only identifies transitional woodland in the catchment. Viewing aerial photographs of the area (www.osi.ie) and the OS map of the area also highlight additional scrub/transitional woodland to the south of Drumkeery Lough. It is unlikely that this land poses a pollution threat to the lakes, due to its non intensive nature but this should be confirmed by the GWS staff.

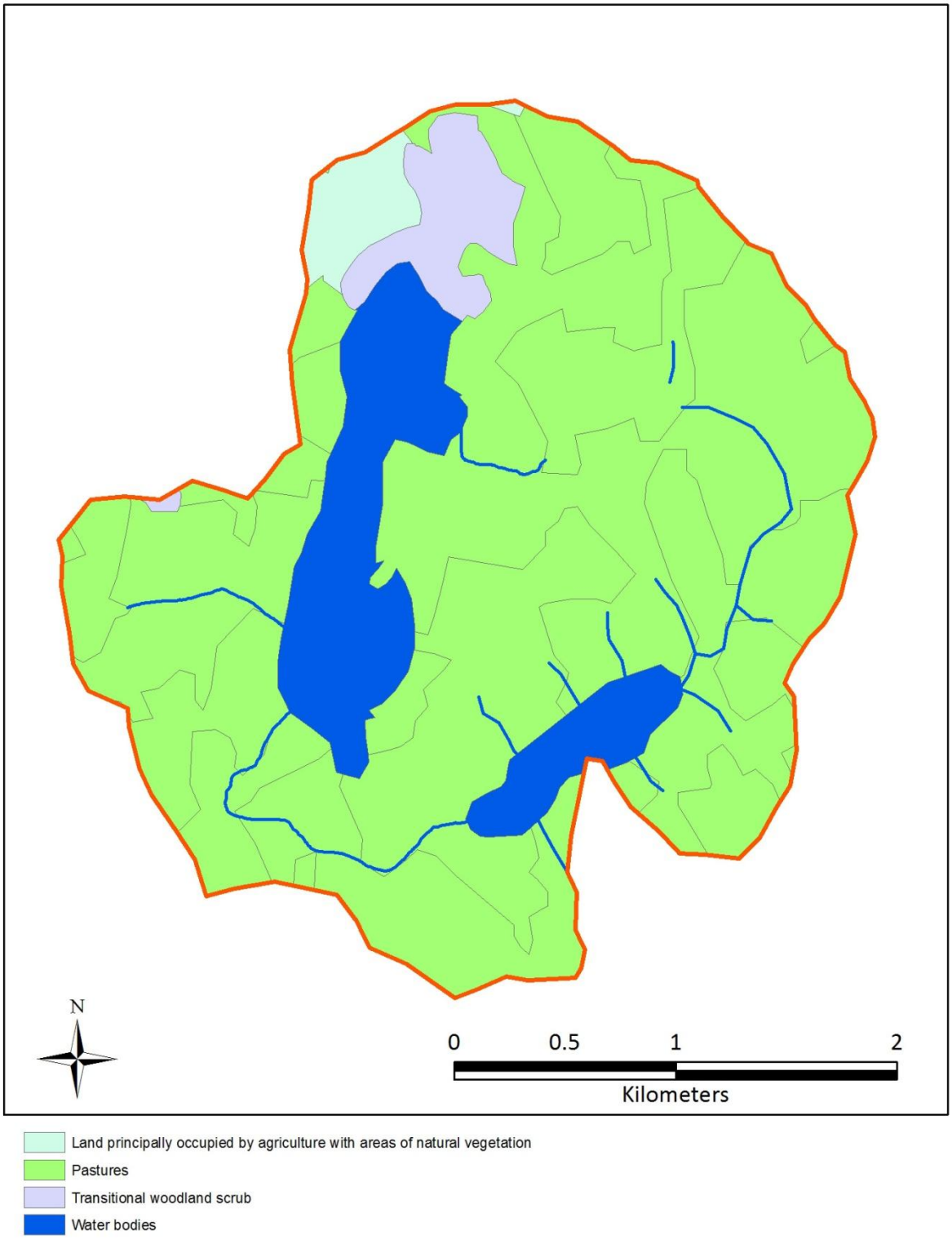


Figure 7. Corine land cover classification of the Drumkeery Lough catchment

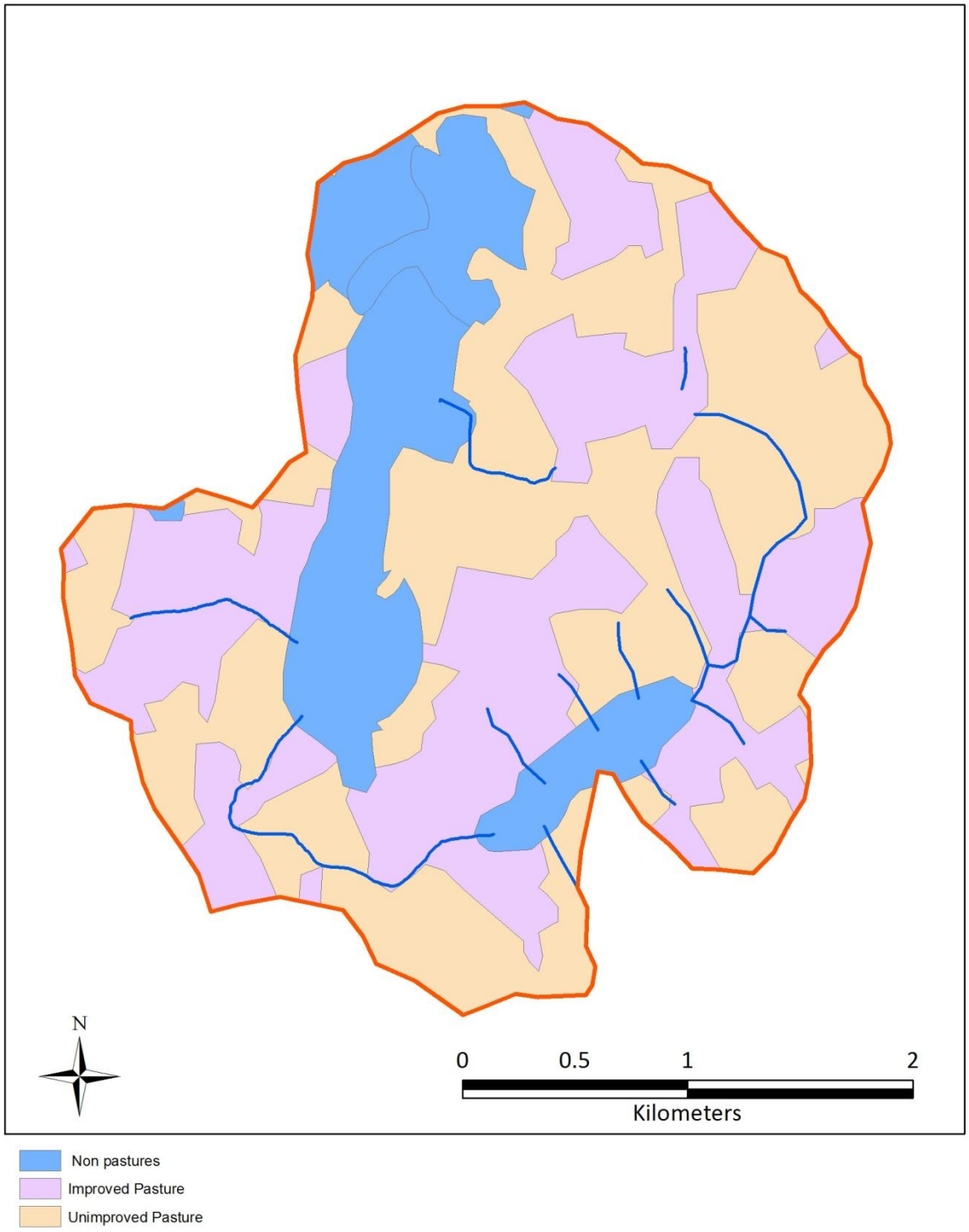


Figure 8. Corine land cover showing both improved and unimproved pastures

Integrated Pollution Prevention Control (IPPC) licenses

There are currently no IPPC licensed facilities in the Drumkeery Lough catchment. Previously, Anthony Fay, Crocknahattin, Bailieborough, Co Cavan had an IPPC licence (P0304-01) for intensive agriculture but this license has been surrendered (www.epa.ie).

Rural Housing and on-site waste water treatment plants

The location of rural houses in the Drumkeery Lough catchment was estimated by viewing the Ordnance Survey map of the area. While houses cannot be differentiated from other buildings, some insight into the location of houses and associated on-site waste water treatment plants (usually septic tanks) was gained.

Clusters of houses have been identified at the following locations throughout the catchment; near Crocknahattin (N 657 994), near Killnacross (H 645 001), at Cavanskeldragh (H 673 017) and approximately 350m north east of Drumkeery Lough (H 668 008). Some of these areas are close to Drumkeery Lough and its inflowing streams and can be used later to help in the interpretation of water quality data.

5.1 Overall interpretation of catchment and land use

Drumkeery Lough is located approximately 3km north west of Bailieborough in Co. Cavan. The lake is 10.4 ha in area and drains a catchment of 9.4 km^2. This includes Skeagh Lough which is upstream of Drumkeery Lough. The landscape in this area is characterised by steeply sloping drumlin hills. The effect of this is that there are steeply sloping hills surrounding the lakes and approaching the streams in this catchment.

The bedrock in the catchment consists of Silurian metasediments and volcanics. These rocks are unlikely to support very large aquifers. The lack of major aquifers means that streams will run low during dry periods and lake retention time will be high. This means that pollution prevention is highly important as contamination may affect the lake for long periods.

Subsoils in the catchment are dominated by sandstone and shale tills with gley soils being the dominant topsoil type. Some other soil types are also present throughout the catchment with peat present near many streams and lakes. Most of the soils in the catchment are poorly draining and not suitable for intensive agriculture (particularly tillage). This was reflected in the dominance of grassland based agriculture in the area.

There are several potential issues associated with grassland agriculture. Nutrients from agriculture (mainly nitrogen and phosphorus) play an important role in eutrophication of waterbodies. These nutrients can come directly from animal defecation, the application of

organic manures and the application of artificial fertilisers. If the pathways between these nutrient sources and waterways are not interrupted, such nutrients can have a detrimental impact on water quality. There are several factors effecting the movement of these nutrients from the land to water and they include; closeness between manure/fertiliser application and the receiving water, the degree of slope on the land, the permeability of the soil and the amount of rainfall interacting with the nutrients.

Direct cattle access to streams while grazing is another potential pollution risk. Cattle in streams can add nutrients and microbiological contaminants directly to the stream or lake through defecation. Cattle access will damage stream beds and banks, increasing erosion. Such erosion will add further nutrients, sediment and particulate matter to the waterbody, all of which impact on water quality entering the treatment plant.

Microbiological contamination, including E. coli and *Cryptosporidium* spp. can also be related to animal wastes and the closer such materials come to water the greater the risk of contamination. In the past *Cryptosporidium* outbreaks have been related to animal defecation, particularly from calves.

The presence of grassland based agriculture on land that has poor drainage and steep slopes makes waterbodies in this catchment susceptible to pollution. Management of agriculture will be central to the recommendations made later.

Certain parts of the catchment were also highlighted as containing rural houses. The presence of septic tanks in these areas may also pose a threat to water quality. Septic tanks can add both nutrients and microbiological contamination to water and the potential for pollution will be addressed in the recommendations below.

6.0 Raw water Quality

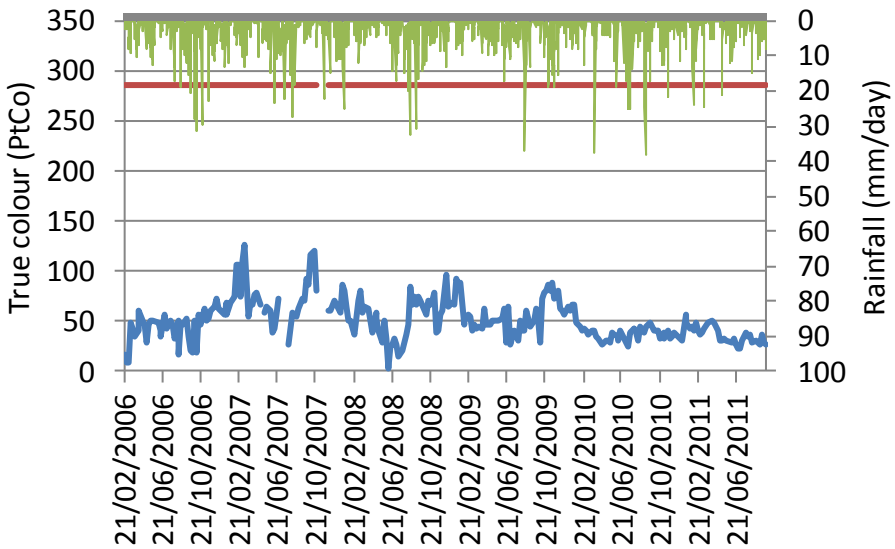
6.1 Lake Water Quality

Colour

Natural colour reflects the presence of organic molecules originating from humic matter such as peat, leaves and branches. A coloured water supply does not pose high health risks in itself but can react with chlorine in the treatment plant to create trihalomethanes and add significantly to the cost of treatment. For this reason high levels of colour should be avoided where possible. Colour is a parameter that varies greatly depending on quantities of precipitation and run-off, leading to spikes in results. Results may be presented as apparent colour (from an unfiltered sample) or true colour (filtered sample) in results. Colour in Irish Lakes ranged between 5 mg/L PtCo to 134 mg/L PtCo in a series of lakes presented by Irvine *et al.* (2001). The Surface Water Regulations (1989) specify a recommended value of 20 PtCo/hazen for A1 waters (true colour).

True colour

Figure 9. Raw water true colour from Drumkeery Lough (based on Veolia Water data). Red line represents the max allowable value for true colour based on the design contract (primary axis). Green bars represent daily rainfall at the Armagh Observatory.



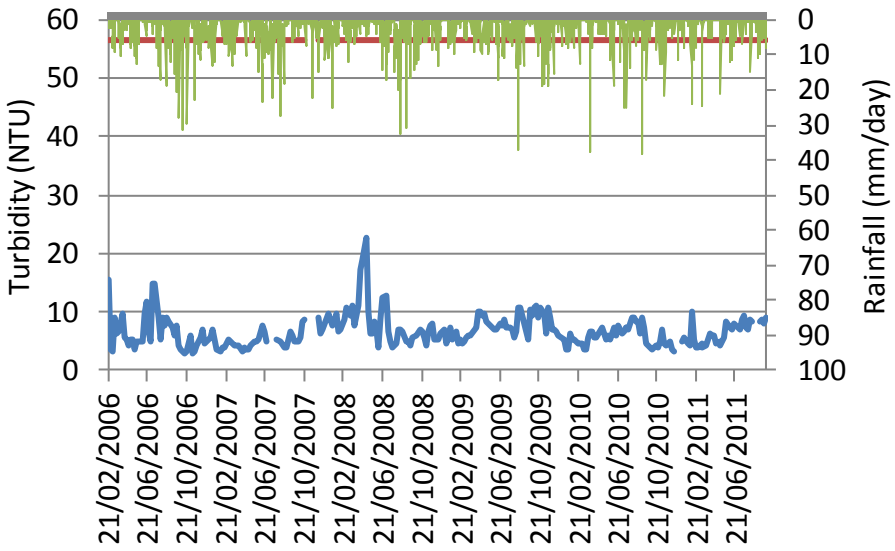
Weekly monitoring of colour, carried out by Veolia Water, showed how this parameter can change greatly in Drumkeery Lough (Figure 9). True colour ranged between 3 mg/L PtCo (9th June 2008) to 127 mg/L PtCo (13th March 2007) in the available data. The average value between 2006 and 2011 for true colour was 50.5 mg/L PtCo. While this value places Drumkeery Lough in the middle of the range of lakes described above, the colour concentration was more than double the recommended value for A1 waters in the Surface

Water Regulations (1989). While rainfall undoubtedly affected colour in Drumkeery Lough the relationship was not particularly clear from the available data.

Turbidity

Turbidity in water consists of very finely divided particles (too small to be removed by normal filtration). Their origin may include clay particles, algae, silt, sewage solids and organic or biological sludges. High levels of turbidity in the raw water supply can interfere with the ability of the treatment plant to provide safe drinking water. The following units are often used to present Turbidity: JTU (Jackson Turbidity Units), FTU (Formazin Turbidity Units) and NTU (Nephalometric Turbidity Units). These three units can be interpreted to mean the same thing.

Figure 10 Raw water turbidity from Drumkeery Lough (based on Veolia Water data). Red line represents the max allowable value for true colour based on the design contract (primary axis). Green bars represent daily rainfall at the Armagh Observatory.



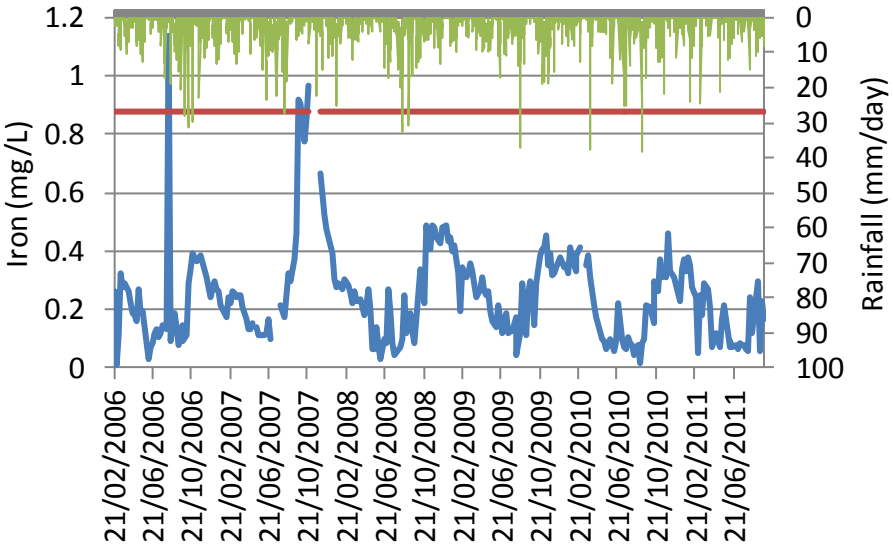
Turbidity results from the weekly monitoring carried out by Veolia Water varied greatly. Values ranged between 2.95 NTU (17th October 2006) to 22.6 NTU (30th April 2008). The average value between 2006 and 2011 was 6.7 NTU. While there were undoubtedly several factors affecting turbidity in Drumkeery Lough, several of the higher values were recorded during periods of low rainfall (Figure 10). For example, the maximum value described above, was preceded by 2 weeks of generally dry weather (< 1.6mm rainfall per day). Similarly, a peak in turbidity on 10th July 2006 was preceded by 2 weeks of dry weather < 1mm per day) except or one day with 4mm of rainfall. While rainfall may affect turbidity during certain periods, it is likely that algal blooms also contribute to peaks.

Iron

Iron (Fe) is present in rocks and soils in an insoluble form but can become soluble when water passes through ground formations. Large amounts of iron in water do not normally have harmful effects for users but can be aesthetically unpleasing by causing colour changes or turbidity (due to oxidation of soluble ferrous to insoluble ferric). This can lead to staining of laundry, discolouration of vegetables following cooking, and taste problems. Under the Surface Water Regulations (1989) the recommended concentration of Fe in Class A1 waters is 0.2 mg/L.

Results for iron concentration in raw water show a distinct pattern each year (Figure 11). In general, iron concentrations are lower in summer and higher in winter. Each year, iron concentrations increase in approximately October, remain higher for the winter and decline again in February/March the following year. Between 2006 and 2011 iron concentrations ranged between 0.011 mg/L (27th February 2006) and 1.14mg/L (09th August 2006). During the entire period the average iron concentration was 0.25mg/L. This value was in excess of the recommended value for iron in the Surface Water Regulations (1989).

Figure 11. Raw water iron concentration from Drumkeery Lough (based on Veolia Water data). Red line represents the max allowable value for true colour based on the design contract (primary axis). Green bars represent daily rainfall at the Armagh Observatory (secondary axis).



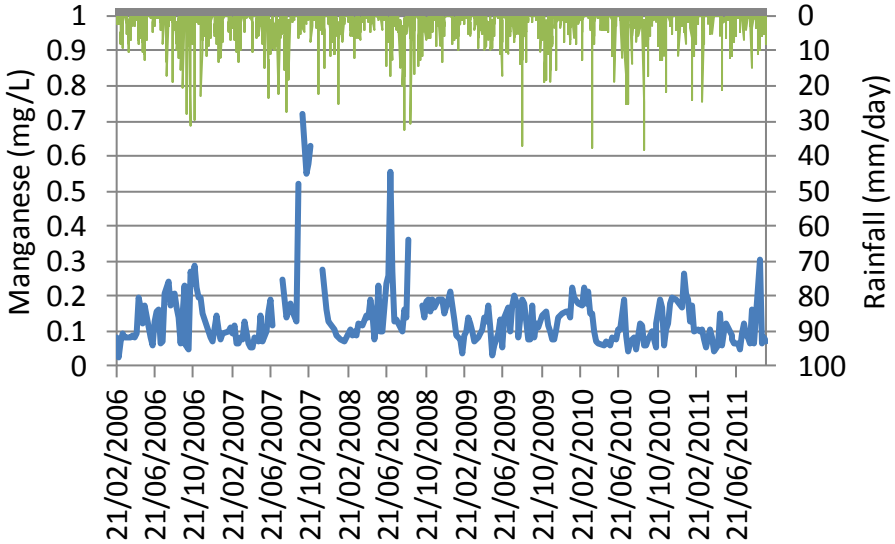
Manganese

Manganese (Mn) is found in soils and groundwater. It is generally not considered to be harmful to humans but can cause more severe staining problems than iron and adversely affect taste, and in large volumes, block pipes. Under the Surface Water Regulations (1989) the recommended value for Mn in Class A1 waters is 0.05 mg/L.

Raw water manganese concentrations in Drumkeery Lough ranged between 0.027mg/L (27th February 2006) to 0.722 mg/L (2nd October2007). The average manganese concentration between 2006 and 2011 was 0.137mg/L. This value was more than double the recommended value (for A1 waters) for manganese under the Surface Water Regulations (1989).

While a trend in the Mn data (Figure 12) was not as obvious as that described above for iron, there was a relationships between iron and manganese. A simple statistical analysis (Spearman's rho correlation) showed that the two datasets were positively correlated (0.44, $p<0.001$). This is to be expected as iron and manganese come from similar sources and are delivered by similar mechanisms.

Figure 12. Raw water manganese concentration from Drumkeery Lough (based on Veolia Water data). Red line represents the max allowable value for true colour based on the design contract (primary axis). Green bars represent daily rainfall at the Armagh Observatory (secondary axis).

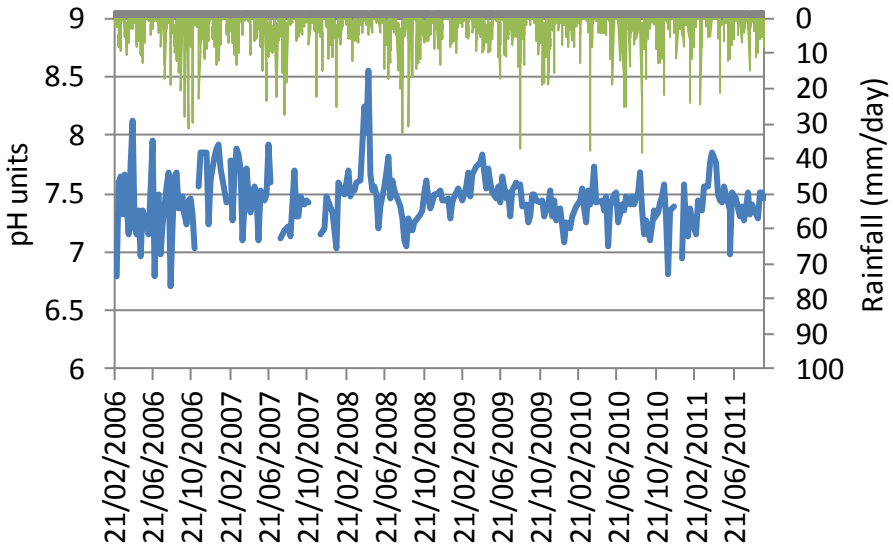


pH

The pH value of water is generally only of concern if it is extremely low or high, indicating extreme acidity or alkalinity, respectively, which in turn may have consequences for odour or taste, lead to corrosion in distribution systems, or affect fish survival. Water generally lies in the range of 6.5-8.0. The Surface Water Regulations (1989) recommend a range of 5.5-8.5 for Class A1 waters.

pH values in Drumkeery Lough were within the recommended ranges for A1 waters under the Surface Water Regulations (1989) on all but one sampling date (30th April 2008). Interestingly, the highest annual pH value was recorded in April of 2008, 2009, 2010 and 2011 (Figure 13). This may be caused by an increase in algal abundance at this time each year as increased photosynthesis can increase pH.

Figure 13. Raw water pH from Drumkeery Lough (based on Veolia Water data). Green bars represent daily rainfall at the Armagh Observatory (secondary axis).



Alkalinity

Alkalinity is a measure of a waters capacity to neutralise acids. High alkalinity is said to provide buffering against pH change. The alkalinity of water is mainly associated with bicarbonates in catchment soils. There is little known sanitary significance to alkalinity, but increased levels can be indicative of eutrophication and photosynthesis.

Average alkalinity in Drumkeery Lough was 46.1mg/L $CaCO_3$.

6.2 Important parameters for source protection

The parameters below present additional data available from Drumkeery Lough (Appendix A). Much of this data was obtained from Cavan County Council. Additionally, samples were presented by T.J. O'Connor and Associates, Consulting Engineers as part of the design contract for the GWS treatment plant (2002-2003). Many of these parameters give greater insight into raw water quality and the impact of human activities on water quality.

Eutrophication and Trophic Status (Note)

Eutrophic means well nourished and eutrophication is the process where pristine waterbodies become more eutrophic through the addition of nutrients (primarily N and P). These additional nutrients trigger a series of events causing excessive plant and algal growth. The process may culminate in oxygen depletion in waters, fish kills and problems with the treatment of the water for drinking. Waterbodies suffer from differing degrees of eutrophication, termed trophic status. Lakes are often characterised on the following scale; oligotrophic (low in nutrients and algal growth), mesotrophic (moderately productive, less clean than oligotrophic) and eutrophic (high levels of nutrients and algal growth, poor water quality). Sub categories are sometimes referred to and the term hypertrophic is used to describe lakes suffering from excessive eutrophication. Determination of trophic status is often made based on algal abundance (chlorophyll-a) or total phosphorus concentration (the most important nutrient in this process).

Total phosphorus

Phosphorus occurs widely in nature but most phosphorus in water is added through anthropogenic activities. Human and animal wastes contain large amounts of phosphorus and therefore agriculture and waste water treatment plants are major sources. Artificial fertilisers used in agriculture and forestry add further phosphorus to the environment, much of which is lost to watercourses. Phosphorus, and to a lesser extent nitrogen are the main nutrients involved in eutrophication. The negative impacts of eutrophication on water quality may include a loss of biological diversity and of desirable species, increased macrophyte growth, the development of algal scums as well as a general deterioration in water quality. Eutrophication is the largest threat to Irish water quality and is of central importance to drinking water sources. Specific to drinking water sources, increased algal abundance can lead to problems in treatment plants and decomposing algae can produce toxins and cause taste and odour problems. The management of phosphorus loading is central to the long term viability of many drinking water sources.

Annual mean total phosphorus concentration from Drumkeery Lough ranged between 29.5μg/L and 100 μg/L (Table 4). Trophic status for the lake, based on these results, ranged between mesotrophic and hypertrophic. These results suggest that there are large supplies

of phosphorus to Drumkeery Lough. Given the correct growth conditions, these phosphorus loads are likely to lead to excessive algal abundance within Drumkeery Lough. The maximum total phosphorus concentration that was presented in the design contract for the treatment plant was 386 µg/L (May 2003).

Skeagh Lough, upstream of Drumkeery Lough was monitored once annually between 2006-2010 (not 2007) for ortho phosphate. These samples were generally taken during winter and the maximum value in any sample was 10 µg/L P.

Table 4. Average total phosphorus data from Drumkeery Lough between 2002 and 2011. The number of samples taken in each year is indicated in brackets after the concentration. Trophic status is based on the OECD system described below (Table 6).

Date	**Total phosphorus (µg/L as P)** (n=no. of samples)	**Trophic Status**
2002/2003	100 (n=9)	Hypertrophic
2007	29.5 (n=4)	Mesotrophic
2008	65.48 (n=5)	Eutrophic
2009	48.2 (n=4)	Eutrophic
2010	43.7 (n=4)	Eutrophic
2011	100 (n=4)	Hypertrophic

Chlororphyll

Chlorophyll is a very important parameter in lake water quality. It is used as an indicator of overall algal abundance within a lake. The presence of algae can be problematic for treatment processes within the water treatment plant and can also lead to taste and odour problems in treated water. Generally chlorophyll values are highest in summer when weather is warmer and light availability is high.

Table 5. Average chlorophyll data from Drumkeery Lough between 2002 and 2011. The number of samples taken in each year is indicated in brackets after the concentration. Trophic status is based on the OECD system described below.

Date	**Chlorophyll mg/m^3** (n=no. of samples)	**Trophic Status**
2002/2003	19.9 (n=11)	Eutrophic
2007	20.5 (n=4)	Eutrophic
2008	20.4 (n=5)	Eutrophic
2009	26 (n=4)	Hypertrophic
2010	21 (n=4)	Eutrophic
2011	63.3 (n=4)	Hypertrophic

Mean chlorophyll concentrations from Drumkeery Lough were available from 2002/2003 (baseline assessment) and annually between 2007 and 2011. These values ranged between 19.9 mg/m^3 in 2002/2003 and 63.3 mg/m^3 (Table 5). Similar to total phosphorus above, trophic classifications can be made based on chlorophyll. The values from Drumkeery Lough equated to trophic classifications of eutrophic and hypertrophic between 2003 and 2011 (Table 5). These are the two worst categories in the OECD lake classification scheme and indicate that the lake is significantly impacted by algal growth (Table 6). Such high algal concentrations are likely to cause difficulty in the treatment process.

The maximum chlorophyll value presented in the design contract for the water treatment plant was 40.6 mg/m^3 (September 2002**)**

Skeagh Lough, upstream of Drumkeery Lough, was monitored for chlorophyll in 2006 (4 mg/m^3), 2008 (22 mg/m^3), 2009 (10 mg/m^3) and 2010 (16 mg/m^3). These samples were taken in winter (November and December) and were elevated for this time of year.

Table 6. OECD Lake classification scheme

Lake Category	Total P (µg L^{-1})	Chlorophyll (mg m^{-3})		Transparency (m)	
	Mean	Mean	Max.	Mean	Min.
Ultra-Oligotrophic	<4	< 1.0	<2.5	> 1 2	>6
Oligotrophic	<10	<2.5	<8.0	>6	> 3
Mesotrophic	10-35	2.5-8	8-25	6-3	3-1.5
Eutrophic	35-100	8-25	25-75	3-1.5	1.5-0.7
Hypertrophic	>100	>25	>75	< 1.5	<0.7

Nitrogen

Nitrogen is a key nutrient for plant growth (including algae) and together with phosphorus is central to the development of eutrophication. Nitrogen gas makes up approximately 78% of the Earth's atmosphere. As Nitrogen gas is not available to plants it is converted into different forms through the nitrogen cycle. Because of this, different forms of nitrogen are presented in water analysis. Nitrite, nitrate and ammonium are commonly analysed in water. Nitrate is the most common form of nitrogen in rivers and lakes. It usually originates from human or animal wastes or from the application of artificial fertilisers to agricultural lands. Nitrite is an intermediate form of nitrogen between ammonium and nitrate and normally only accounts for a couple of % of nitrogen in water. Nitrite and nitrate are often presented together as Total Oxidised Nitrogen.

Ammonium is also a precursor to nitrite and nitrate in the nitrogen cycle. As human and animal wastes are the most likely source of ammonium, high concentrations can be indicative of pollution from these sources. Ammonium is present in natural waters but if it is found in excess of 0.1mg/L N, it is seen as an indication of human waste or industrial contamination. Due to the potential link between high ammonia concentrations and human waste, it is an important parameter to monitor at a drinking water source.

Total Oxidised Nitrogen (TON)

TON is the sum of nitrite and nitrate and was measured by Cavan County Council between 2007 and 2011. TON data from Drumkeery Lough was also available from the design contact for the GWS water treatment plant. Similar to other parameters TON concentration varied significantly between sampling dates. However, the maximum concentration recorded in any individual sample was 1.15mg/L (N). which was well below the threshold value set out in the Surface Water Regulations (1989) of 11.3 mg/L (nitrate). While these values were not in excess of the above threshold they should be monitored closely as nitrogen also plays an important role in eutrophication.

Ammonium

Ammonium concentrations in Drumkeery Lough ranged between 0.016mg/L (N) and 2.01mg/L (N) between 2002 and 2011. During this period, the average concentration was 0.20mg/L. On several occasions ammonium was in excess of the 0.155 mg/L (as N) threshold outlined in the Surface Water Regulations (1989). This may indicate that human or animal waste is entering the lake and this should be considered when implementing source protection measures.

Conductivity

Conductivity quantifies the ability of water to conduct an electrical current and is an indicator of the mineral salt content of water. Conductivity in itself has no direct health or sanitary significance The Surface Water Regulations (1989) specify a limit of 1000 µS/cm at 20 °C for Class A1 waters.

Conductivity in Drumkeery Lough ranged between 113 µS/cm and 174 µS/cm between 2002 and 2011. The average value from the available data was 143 µS/cm. All of these values were within the limit for A1 waters under the Surface Water Regulations (1989).

Dissolved oxygen (DO)

DO is an important parameter for fish survival. Generally, when water quality is suitable for fish survival, it meets the quality requirements for most other functions. Under the Surface Water Regulations (1989), Class A1 waters must have a DO saturation level of > 60%.

DO saturation is dependent on water temperature with warmer waters containing less oxygen. This concept, combined with low water levels can make waters particularly vulnerable to organic pollution during summer. DO saturation and concentration are also effected by photosynthesis. Increased eutrophication and photosynthesis leads to very high oxygen concentration in waters during daylight hours. While such high concentrations are not a problem they may be indicative of oxygen depletion at night when respiration takes over from photosynthesis.

All DO saturation data from Drumkeery Lough was in excess of the 60% saturation required by A1 waters under the Surface Water Regulations (1989). Based on the available data (2002-2011), DO saturation ranged between 69.8% saturation and 108% saturation.

BOD

Unpolluted water is saturated with dissolved oxygen (DO). When organic pollution enters a waterbody, bacteria break it down, using available oxygen and thus reducing DO levels. BOD is a measure of the oxygen demand required to break down organic waste. BOD is the amount of dissolved oxygen taken up by bacteria degrading organic material in the dark at 20°C over five days. Under the Surface Water Regulations (1989) the recommended value for BOD in Class A1 waters is 5 mg/L O2.

The only BOD data available of relevance to this study was for Skeagh Lough. One sample was taken in 2006, 2008, 2009 and 2010. The maximum value from these samples was 3mg/L BOD, which was below the 5mg/L threshold mentioned above.

Coliforms

Faecal coliforms (e.g. *E. coli*) originate in either human or animal wastes. Total coliforms include faecal and soil-borne coliforms. Coliforms are used as an indicator of pathogenic organisms within a waterbody. Under the Surface Water Regulations (1989), A1 waters should not exceed 5,000 total coliforms per 100ml or 1,000 faecal coliforms.

Data on coliforms from Drumkeery Lough was only available from the design contract for the drinking water plant (1999-2003). During this period, 25 samples for total and faecal coliforms were taken. All results were <100 coliforms per 100 ml except for two samples. Samples on 7th September 1999 (440 faecal, 1600 total coliforms) and 23rd May 2003 (>300 faecal, >300 total coliforms) were indicative of some human or animal water entering the lake. These results are not a cause for alarm but the lack of sampling in more recent years means this type of pollution cannot be quantified.

6.2 Stream water quality

Data was available from two stream sites near Drumkeery Lough. One was located on the inflow stream to Drumkeery Lough (site code 0100) and another on the outflow (site code 0400, just upstream on Castle Lough).

Q ratings

The Q value system describes the relationship between water quality and the macroinvertebrate community in numerical terms. Q5 waters have high diversity of macroinvertebrates and good water quality, while Q1 have little or no macroinvertebrate diversity and bad water quality.

The most recent data for the upstream site was Q4, which indicated good status according to the Water Framework Directive. The downstream site had Q 2/3 water quality, indicating poor status according to the Water Framework Directive (Table 7).

Table 7. Q-value data from stream sites upstream and downstream of Drumkeery Lough. Data from Cavan County Council 2011.

Station Number	Station Location	Q'94	Q'97	Q'00	Q'03	Q'06	Q'09
0100	Br downstream of Skeagh Lough (upstream of Drumkeery Lough)	3	3	4	-	-	-
0400	Upstream of Castle Lough (downstream of Drumkeery Lough)	3	3	2/3	2/3	2/3	-

Molybdate reactive phosphorus (MRP)

MRP values were also available from the two stream sites. In all but one year, MRP concentration was higher at the downstream site (Table 8). This suggests that there is a source of phosphorus between the two sites leading to the deterioration in water quality.

Table 8. Mean molybdate reactive phosphorus (MRP µg P/L) data from stream sites upstream and downstream of Drumkeery Lough. Data from Cavan County Council 2011.

Station	1999	2000	2001	2002	2003	2004	2005	2006
0100	NM	NM	18	11	14	15	**15***	14
0400	12	21	40	10	23	19	24	20

6.3 Overall interpretation of Water Quality

When analysing water quality, the general quality of water was considered but also the limits set out in the design contract for the drinking water treatment plant. While certain parameters complied with the design contract they were still indicative of poor general water quality. The design contract limits were based on sampling carried out in 2002/2003 and certain parameters were poor then and have shown no sign of improvement since.

Colour and turbidity varied greatly in the weekly Veolia Water data. While exceedences of the design contract did not occur, these parameters were indicative of stained raw water. Colour for example was above the threshold of A1 waters in the Surface Water Regulations (1989). Similarly, turbidity ranged over the annual cycle. Changes in turbidity were likely driven by weather patterns and algal biomass within the lake. The potential role played by algae was indicated by high colour and turbidity values during dry summer periods.

Eutrophication is the over-enrichment of waters with nutrients, leading to increased algal biomass. Phosphorus is the main limiting nutrient in this process and efforts to control eutrophication must concentrate on this element. The data available from Drumkeery Lough suggested that phosphorus levels were high in the lake and this led to high levels of algal biomass.

Total phosphorus levels in excess of 20 µg/L are widely acknowledged as causing excessive algal growth. Nearly all recorded values were in excess of this threshold. Lake classifications based on total phosphorus categorised Drumkeery Lough between eutrophic and hypertrophic. These classifications suggested algal growth would be a problem in Drumkeery Lough. As sampling generally focused on the growing season (April to October) the exact timing of phosphorus loading to the lake is hard to establish. However, based on knowledge of similar catchments, it's likely that sufficient nutrients are delivered to the lake, all year round, to drive algal growth. In addition to this, when high rainfall events coincide with high soil nutrient concentrations (after slurry or fertiliser application) additional loads are delivered to Drumkeery Lough.

Chlorophyll levels (an indicator of algal growth) back up the suggestion above, that algal levels were likely to be high in Drumkeery Lough. Chlorophyll values in the lake were very high and categorised the lake between eutrophic and hypertrophic between 2002/2003 and 2011. Such high algal levels are likely to cause challenges for the treatment of this water for drinking purposes.

Nitrogen concentrations were not in breach of the Surface Water Regulations (1989) but several values indicated deteriorated quality form an environmental perspective. Ammonium was present in certain samples in excess of 0.1mg/L which may indicate human or animal waste entering the lake. This adds to the suggestion above that agricultural runoff

is likely to play an important role in this catchment. This was added to further by occasionally elevated microbiological results (coliforms).

The exact source of contamination to Drumkeery Lough cannot be defined in this study. However, it is safe to say that a certain proportion of nutrient loading is delivered from Skeagh Lough, upstream. The limited data available from that lake shows it to be in an impacted state (Appendix B) and the lakes are clearly linked. Additionally, data available from stream sites in the location gave some insight into the source of contamination. The fact that the site downstream of Drumkeery Lough had worse quality that the one upstream suggests there was a significant pollution source between the two sites. This means that not all problems are due to pollution in Skeagh Lough upstream, but are likely added to by land use practices near Drumkeery Lough.

Several of the recommendations will focus on the management of the problems outlined in this section. Usually, the implementation of source protection measures will impact several parameters positively. For example, reducing the impact of cattle access would reduce nutrient loads, micro bacterial levels and sediment transfer.

7.0 Recommendations

Put source protection on the agenda

Within many GWS's the importance of source protection is often underestimated or neglected. It is recommended that source protection be installed as an item on the agenda at all GWS meetings (AGM, committee meetings etc.). This will ensure that important issues within the catchment are discussed and addressed as appropriate. For example, the findings of this report should be discussed as a starting point. Issues around public awareness, installation of source protection measures and potential pollution within the catchment should also be discussed.

Reporting of potential pollution issues

The GWS should encourage committee members and people with connections to the scheme to report potential pollution issues. Members should be able to call the scheme staff to report pollution incidents in confidence. The scheme staff can then decide how to proceed with the investigation, either dealing with the problem themselves or passing relevant information on to the County Council where there is evidence of deliberate and/or serious pollution. A pollution reporting form could be distributed to members where they can record the relevant details and return them to the scheme staff by post. Providing the reporter's personal details should not be compulsory.

Develop a protocol for dealing with offenders

The committee should agree a protocol for dealing with potential pollution incidences. From the moment the staff receive knowledge, there should be a procedure in place. The protocol should reflect the seriousness of individual issues with some being dealt with by the scheme and more serious incidences being reported directly to the appropriate authority. The protocol should set out if oral communication or written communication is suitable and at what point incidences are passed on to the authorities. Having a protocol in place ensures that all complaints are dealt with in an agreed and equitable way

It is recommended that this protocol should, in the first instance, rely on personal contact to resolve any issues amicably and by agreement. However, if the offender chooses not to respond to personal contacts from either a committee member or member of staff, the County Council Environment Section should be consulted.

Agriculture and farmyard management

Until specific areas of the catchment are highlighted as being problematic some general recommendations can be put into practice.

(a) Create a database of all farms and landowners within the catchment.

(b) Make committee and staff members aware of potential problems caused by agriculture and the relevant rules and regulations relating to spreading of fertiliser and manure (See section 5.1 of this report).

There are strict regulations relating to the land spreading of manures and fertilisers, European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2010. It is in the interest of the GWS that these regulations are adhered to.

These regulations are available online (www.irishstatutebook.ie) but here are some important points to remember;

- Artificial fertiliser cannot be spread within 2m of any watercourse. This will include all lakes, inflowing streams and drains within the catchment.
- Organic fertilisers cannot be spread within 200m of the abstraction point of the GWS. As Drumkeery Lough is used as a drinking water abstraction point for volumes in excess of $100m^3$ per day the 200m exclusion zone applies.
- Organic fertiliser cannot be spread within 20m of any lake shore.

- Organic fertilisers cannot be spread within 5m of any surface waters. This will apply to all the inflowing streams within the Drumkeery Lough catchment. This distance may be reduced to 3m for open drains.
- Organic fertiliser or soiled water shall not be applied to land within 10m of any surface waters where the land has an average incline greater than 10% towards the water.

Also, fertilisers (including manure) shall not be applied to land when:

- the land is waterlogged.
- the land is flooded or likely to flood.
- the land is frozen or snow-covered.
- heavy rain is forecast within 48 hours.
- the ground slopes steeply and where - taking into account factors such as proximity to bodies of waters, soil condition, ground cover and rainfall- there is significant risk of causing water pollution.

(c) To increase compliance, the scheme should meet with farmers reminding them of their legal obligations and the benefits to the scheme of complying with this code of good agricultural practice.

Farmyard management (Note)

As part of the NSPPP a survey of 126 farms in Monaghan was carried out. The most common faults encountered were;

A lack of guttering on sheds which allowed the mixing of clean rainwater and effluent on the farmyard.

Lack of sufficient slurry storage.

Out-wintering of cattle leading to soil poaching and erosion, giving a high potential for runoff.

(d) Soil nutrient analysis and nutrient management planning.

This is dealt with under the future work section below but some recommendations from the NSPPP should be considered here;

- Farmers should only apply organic and inorganic fertiliser on lands for which nutrient management plans have been completed.
- Nutrient management plans should be completed every 4-5 years for all farms.
- Field slope should be considered when generating nutrient management plans, not just soil nutrient status.

- Issues relating to soil nutrient status should be communicated with farmers both orally and in writing.

The section below on future work will highlight how farms bordering streams and the abstraction lake should be prioritised. Also the potential of cost sharing will be discussed.

(e) It was discussed earlier how cattle access to streams and lakes can lead to pollution. The NSPPP made recommendations relating to cattle access which are relevant to this catchment.

- The NSPPP recommended that cattle should be excluded from all waterways. Exclusion fencing is one way of achieving this objective but alteration of management practices could also be applied. For example, fields bordering streams could be prioritised for silage instead of grazing.

Septic Tanks

(a) Generate a list of householders within the catchment who have septic tanks.

(b) Meet all households that have septic tanks and advise them of the correct maintenance of septic tanks and the potential pollution threats.

The recommendations from the NSPPP suggest that education should be provided to householders regarding the correct care and maintenance of their on-site waste water treatment systems (OSWTS's). Several OSWTS's in that study were shown to suffer from ponding, backing up and several were never emptied.

Also, septic tank inspections are due to commence around the country in the coming years according to Phil Hogan T.D. However, if certain septic tanks are suspected to be causing pollution to water it may be possible to get these tanks inspected by Cavan County Council as a priority.

7.1 Future work

1. Identify and sample all inflowing streams

The available data shows that Drumkeery Lough is in an impacted state. However, the exact sources of contamination are unclear.

A number of small streams flowing into Drumkeery Lough were identified earlier (Figure 1). These were identified from historic maps and the areas need to be walked to confirm the stream locations and size. Ideally this should be done during wet weather.

When streams are identified, a sampling programme should be put in place to monitor water quality. This will highlight parts of the catchment in need of remediation measures.

The exact frequency and location of sampling sites can be discussed later. The following parameters should be included in the sampling programme; ammonium, nitrate, nitrite, total phosphorus, molybdate reactive phosphorus (MRP), total coliforms and faecal coliforms. Probe readings such as dissolved oxygen, conductivity and total dissolved solids could also be included.

2. Identify livestock access and congregation points.

It is recommended to carry out a walkover survey of the lakes and streams to highlight areas where cattle access and livestock congregation points are causing pollution (at feeders, gates, drinkers etc.). These areas act as livestock congregation points which may lead to soil poaching. Such areas that are close to streams and lakes act as pollution sources. Such areas should be identified and actions taken to relocate these congregation points. For example, moving a feeder away from a stream will reduce the risk of pollution to the stream. Such a survey would highlight fields where fencing is needed and prioritise particular areas for remediation works. This survey would also identify suitable areas for the location of alternative livestock drinkers.

While such a programme would not be cheap, certain perks could be offered by the GWS to landowners. Also, by prioritising the worst areas, investment can be made in a targeted way. Also, certain agricultural schemes may offer funding for the required work.

Some of these issues could also be addressed by altering management practices. Fields bordering streams and lakes could be prioritised for silage cutting instead of grazing thus reducing cattle access to streams.

3. Soil nutrient analysis

The implementation of soil nutrient analysis throughout the catchment would be a valuable initiative. Soils with high nutrient status are most likely to result in losses to nearby waterways. If soils have sufficient nutrient content, farmers could save money by not applying extra fertilisers to fields. Knowledge of soil nutrient status will allow farmers to match fertiliser application to crop needs. This analysis would be beneficial to both the GWS and the farmers and therefore costs could be shared.

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Appendix A. Raw data from Drumkeery Lough. Data a= Design Contract, Data b= EPA/Cavan County Council. NH_4^+ = Ammonium. Chl=Chlorophyll. DO=dissolved oxygen. TON=total oxidised nitrogen. Fe=iron. Mn=manganese. Highest values from design contract are highlighted in yellow.

Date	Data	NH_4^+	Chl	Colour	DO	pH	TON	Total P	Ortho-P	Faecal Coli.	Total Coli.	Fe	Mn
		(N) (mg/l)	mg/m^3	Hazen	% sat.		(N) (mg/l)	(P) (ug/l)	(P) (ug/l)	no. /100ml	no. /100ml	mg/L	mg/l
29/07/99	a					7.9	0.03		390	19	20	0.636	0.193
07/09/99	a	0.16		71		6.9	0.06			440	1600	0.040	0.010
Nov 00	a	<0.2		106		7.2	1.02			0	0	0.436	0.107
Dec 00	a	<0.2		239		7.1	0.72			0	3	0.045	<.00003
Jan 01	a	<0.2		79		7.0	0.80			0	0	0.123	0.013
Feb 01	a	<0.2		69		7.2	0.81			0	0	0.112	0.003
May 01	a	<0.2		70		7.8	$<0.45NO_2$/ $<0.012NO_3$			6	9	0.002	0.001
June 01	a	0.22		79		7.2	$<0.45NO_2$/ $<0.012\ NO_3$			4	18	0.017	<.00003
July 01	a	<0.2		67		7.4	$<0.45NO_2$/ $<0.012\ NO_3$			0	0	0.005	0.000
Aug 01	a	<0.1		53		7.6	$<0.5NO_2$/ $<0.010\ NO_3$			0	10	<0.00009	0.000
Sep 01	a	<0.1		84		7.8	$<0.5NO_2$/ $0.026\ NO_3$			3	12	<0.00010	0.001
Oct 01	a	0.14		98		7.6	$<0.5\ NO_2$/ $<0.010\ NO_3$			1	4	0.001	0.003
Nov 01	a	<0.1		41		7.6	$<0.10NO_2$/ $0.029\ NO_3$			18	24	0.031	0.000

Appendix A continued													
Date	**Data**	**NH_4^+**	**Chl**	**Colour**	**DO**	**pH**	**TON**	**Total P**	**Ortho-P**	**Faecal Coli.**	**Total Coli.**	**Fe**	**Mn**
		(N) (mg/l)	mg/m^3	Hazen	% sat.		(N) (mg/l)	(P) (ug/l)	(P) (ug/l)	no. /100ml	no. /100ml	mg/L	mg/l
20/11/02	a	0.04		54		6.7	1.04			10	21	0.690	0.031
06/09/02	a	<0.12	40.6	57	9.4	7.6	<0.09/ 0.024 NO_3	59	24	0	2	0.200	0.210
09/10/02	a	<0.12	17.3	46	7.8	8.0	<0.09NO_2/ 0.031	71		1	10	0.190	0.162
26/11/02	a	2.01	26.4	65	8.6	7.3	0.66	64	42	13	19	0.430	0.141
04/12/02	a	0.16	17.5	75	9.0	7.2	0.81	118	54	12	36	0.512	0.133
27/01/03	a	<0.02	5.0	61	8.8	7.3	0.84	51	8	8	81	0.281	0.074
25/02/03	a	0.07	18.3	49	10.2	7.3	1.15	54	25	8	18	0.737	0.164
21/03/03	a	0.23	11.0	54	11.8	7.2	0.87	37	20	1	32	0.218	0.068
09/04/03	a	0.06	23.6	50	12.1	7.6	0.33	58	6	3	3	0.083	0.019
23/05/03	a	0.26	4.4	55	9.9	7.2	0.54	386	46	>300	300	0.089	0.057
18/06/03	a	0.17	31.1	65		7.3				0	3	0.169	0.019
17/07/03	a	0.11	23.5	68		7.4				7	62	0.049	0.017
18/04/07	b	<0.01	8.0	35		7.5	0.52	23					
12/07/07	b	<0.01	34.0	44		7.5	<0.04	14					
05/09/07	b	0.02	22.0	66		8.1	<0.04	43					
17/10/07	b	0.21	18.0	70		7.5	0.09	38					
08/04/08	b	<0.01	24.0	42		7.7	0.19	56.8					
22/04/08	b	<0.01	40.0	26				95.9					
28/07/08	b	<0.01	10.0	33		7.4	<0.04	30.7					
25/08/08	b	0.16	22.0	76		7.4	0.19	96.1					
30/10/08	b	0.16	6.0	69		7.5	0.31	47.9					
30/04/09	b	<0.01	80.0	36		8.1	0.13	51.8					
27/08/09	b	<0.01	16.0	67		7.7	0.08	18.2					
25/11/09	b	0.07	6.0	55	83.0	7.9	0.38	67					
09/12/09	b	0.12	<2	65		6.9	0.42	55.8					

Appendix A continued													
Date	**Data**	**NH_4^+**	**Chl**	**Colour**	**DO**	**pH**	**TON**	**Total P**	**Ortho-P**	**Faecal Coli.**	**Total Coli.**	**Fe**	**Mn**
		(N) (mg/l)	mg/m^3	Hazen	% sat.		(N) (mg/l)	(P) (ug/l)	(P) (ug/l)	no. /100ml	no. /100ml	mg/L	mg/l
29/04/10	b	0.05	24.0	46	69.8	6.8	0.04	38.1					
19/08/10	b	0.02	10.0	31	92.1	7.9	<0.04	35.1					
07/10/10	b	0.08	30.0	65		7.6	0.19	44.3					
08/11/10	b	0.18	20.0	68	82.4	7.7	0.41	57.4					
28/04/11	b	<0.02	14.0	50	106.2	8.0	0.04	38					
28/07/11	b	<0.02	22.0	42		8.8	<0.01	46					
15/09/11	b	0.04	207.0	164		8.2	0.09	233					
03/11/11	b	0.13	10.0	126	82.2	7.3	0.56	83.7					

Appendix B Data from Skeagh Lough Upper. Data provided by Cavan County Council

Lake	Date	Chlorophyll	Colour	Faecal Coli	Total Coli	Fe	Mn	Nitrates	Nitrites	Ortho-P (P) (mg/l)	pH
		mg/m^3	Hazen	no./ 100 mls	no./ 100 mls	mg/l	mg/l	(NO3) (mg/l)	(N) (mg/l)	(P) (mg/l)	
Skeagh	13/12/2006	4	49	142	770			3.17	0.045	<0.01	7.48
Skeagh	19/11/2008	22	48	45	200			0.141		0.01	7.38
Skeagh	16/12/2010	16	106	1	21	<0.05		0.193		<0.01	7.62
Skeagh	17/12/2009	10	64	14	25			0.392		<0.01	7.49