Preliminary Report on Source Protection

Killeen Group Water Scheme

County Mayo

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Executive Summary

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, emphasising prevention rather than cure in relation to raw water quality. The National Source Protection Pilot Project (2005-2009) overseen by the National Centre for Freshwater Studies (now the Centre for Freshwater and Environmental Studies) at Dundalk Institute of Technology represents a model for best practice for the implementation of source protection in Ireland and was designed for replication by group water schemes around the country.

This report provides a physical site description of the Killeen Group Water Scheme (GWS) catchment and explains the relevance to water quality (Section 4), discusses the potential impact of land use on raw water quality (Section 5), evaluates available relevant water quality data (Section 6) and provides recommendations to best manage concerns relating to source protection (Section 7).

Killeen Group Water Scheme is located within the Mweelrea/Sheefry/Erriff Complex Special Area of Conservation approximately 5 Km north of Killary Harbour in County Mayo. The scheme extracts its water from Lough Cunnel, a lake with a surface area of approximately 8 ha. Water flows into the lake from three mountain streams that flow from higher elevation to the south of the lake. A single outflow stream is located at the eastern edge of the lake which flows eastwards into Glencullin Lough. The catchment area of Lough Cunnel is small at approximately 13.7 km^2 and the lake is located at an elevation of approximately 210 m, with elevation rising to the south to a maximum elevation of approximately 340 m.

The poorly productive aquifer present in the catchment may deliver groundwater to both Lough Cunnel and the surface water streams within the catchment area through small shallow cracks and fissures in the bedrock. Such fissures can facilitate the potential delivery of contaminants into the surface water. However given the small area of the catchment and the predominance of bedrock at the surface, there are unlikely to be significant groundwater-surface water interactions, and limited contaminants present within either water source. Groundwater vulnerability is at the highest classification throughout the catchment due to the presence of bedrock at the surface in much of the catchment, and to the presence of peaty soils and subsoils. Soils are predominantly blanket peat or ‘mainly shallow, non-calcareous peaty mineral soils of undefined drainage’.

These peaty soils are acidic and are the likely reason for low pH values (more acidic) being the greatest water quality issue within the raw water supply (for those parameters monitored). Raw water pH was frequently below the Surface Water Regulations (1989) parametric range for Class A1 waters, and treated water pH was frequently below the minimum value outlined in the Drinking Water Regulations (2007 and 2014), resulting in caustic dosing of the raw water to achieve desirable drinking water pH. Given the naturally low pH of the peaty soils through which the surface waters of the catchment flow, there are limited catchment-level source protection management actions available to improve raw water pH.

Nitrate levels in the treated water (used as a proxy for raw water nitrate concentrations) are low as expected for water abstracted from an oligotrophic (low in nutrients) upland lake. Total Phosphorus has not been monitored within Lough Cunnel, but given the lake's location and the lack of likely nutrient sources within the catchment area, Total Phosphorus levels are likely to be low and frequent monitoring is not likely to be required.

Colour values in the raw water are high although it is not clear whether Apparent or True Colour has been monitored since January 2010, and clarification with AECOM is required on this issue. Trihalomethanes, a bi-product of the chlorination process that is particularly associated with raw water of high True Colour, are not at levels of concern; however monitoring timeframes should be aligned with late summer and early winter periods when colour values (and subsequently THM values) are likely to be at their highest.

Given the monitoring data available, the raw water quality within Lough Cunnel is good and the Ecological Status of the lake has been classified in the Carrownisky/Killary Water Management Unit Action Plan as high through extrapolation of regional data rather than based on true monitoring data. However, a number of key issues are recommended in Section 7.0 to be addressed in order to improve source protection and maintain high quality water supplies. The most urgent recommendations are:

1. Put source protection on the agenda

Within many group water schemes 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 Killeen GWS meetings (AGM, Committee meetings, etc.). This will ensure that important issues within the catchment are discussed and addressed as appropriate.

2. Engage with local farmers

Although the livestock densities present within the Killeen GWS catchment are low, it will be important to engage with local farmers to discuss source protection and ensure that such densities (in particular sheep densities on peatland soils) are kept low to reduce the potential of overgrazing (which can lead to soil erosion and subsequent sediment and turbidity issues in the raw water supply) and faecal contamination of Lough Cunnel.

3. Engage AECOM regarding raw water colour Trihalomethane monitoring

Clarification should be made with AECOM regarding whether it is Apparent Colour or True Colour that has been monitored since January 2010. True colour should be monitored to ensure compliance with the Surface Water Regulations (1989) parametric value for colour.

Although THM values recorded in the Killeen treated water have not been at levels of concern, the timing of the monitoring has not been aligned with the period when raw water colour values are typically highest: late summer through to early winter. It is therefore recommended that a once-off short-term THM monitoring programme (aligned with True Colour monitoring) should be initiated over the period from late summer through to early winter. Following this initial short term monitoring programme, subsequent THM monitoring should be undertaken on an annual basis when True Colour values are found to be highest.

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 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, County Monaghan (2005-2009) was established by the National Rural Water Monitoring Committee and was overseen by the National Centre for Freshwater Studies (now the Centre for Freshwater and Environmental Studies, CFES) 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 for 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-source group water schemes to carry out assessments to determine the potential for nutrient enrichment and biological contamination (e.g. *Enterococcus* species, *Escherichia coli, Cryptosporidium* species) of their water supplies, and to meet application conditions for a Water Services Licence under the Water Services Act (2007).

This report provides a physical site description of the Killeen Group Water Scheme (GWS) catchment and explains how this is relevant to water quality. The potential impact of land use is discussed and available raw water quality data is evaluated. Finally, major concerns relating to source protection are highlighted and recommendations are made as how best to manage these concerns in the future.

2.0 Methods

2.1 Catchment delineation and description

The outline of the catchment was defined using the available contours on the Map Genie ArcGIS basemaps available from Ordinance Survey Ireland and provided under license by the Geological Survey of Ireland. A number of national digital Geographical Information System Layers (GIS) were available from a various sources (Table 1), and were clipped to the catchment area of Killeen GWS. This allowed detailed descriptions of, for example, CORINE land cover, soils and geology, as well as illustrating the stream and water body network within the catchment.

Table 1: National GIS datasets used to describe the catchment

Dataset	Source	Description
Streams/Lakes/Rivers	EPA Ireland	Location of streams, lakes and rivers
CORINE	EPA Ireland	Image of land cover based on satellite imagery
Bedrock Geology	Geological Survey of Ireland (GSI)	Map (1:100,000 scale) of Irish bedrock geology)
Aquifer Bedrock	GSI	Information on the quality of groundwater aquifers
Aquifer Vulnerability	GSI	Information on the connectivity between contaminants and aquifers
Soils	GSI and Teagasc	Information on soil type
Subsoils	GSI and Teagasc	Information on subsoil type

2.2 Water Quality Data

Water quality data relating to the catchment area was provided by the National Federation of Group Water Schemes (NFGWS) from March 2009 to December 2103 in the form of Monthly Status Reports. From the data provided, raw water and treated water monitoring was undertaken by Earth Tech Ireland from March 2009 to November 2009 and by AECOM from November 2009 onwards.

Parameters relevant to source protection were taken from the Monthly Status Reports, analysed temporally and interpreted to highlight potential water quality issues in the Killeen GWS catchment and their potential causes and impacts.

3.0 Overview of the Killeen GWS catchment and the Water Framework Directive

Under the Water Framework Directive, the island of Ireland is divided into eight River Basin Districts (RBDs), two of which are international with boundaries shared by the Republic of Ireland and Northern Ireland. Killeen GWS abstraction point and its catchment lie within the Western River Basin District (WERBD). Each RBD is subdivided into Water Management Units (WMU), and the Killeen GWS catchment is included within the Carrownisky/Killary Water Management Unit for the WERBD. An action plan for this WMU is available from http://www.wfdireland.ie/docs/.

The WMU action plan presents an overview of water quality, information relating to potential causes of pollution and actions required to improve water quality to 'good' status (the overarching objective of the WFD is to achieve 'good' status for all water bodies).

In the Carrownisky/Killary WMU Action Plan, rivers within the WMU were predominately classed as high to good status with only a 'small number' of the 57 rivers present in the WMU classed as poor status. Of the 12 lakes situated within the WMU, most are classed as high to good with one lake classed as moderate status. The Carrownisky/Killary WMU Action Plan attributes 90 % of the Total Phosphorus (TP) load to diffuse sources, with agriculture accounting for over 80 % of TP. A total of 964 on-site waste water treatment systems are located within the WMU, with 629 systems being located within river water body boundaries with the remainder lying between the boundaries and the seashore.

Lough Cunnel, from which Killeen GWS abstracts its water, has not been monitored as part of the EPA's Water Framework Lake Water Quality Monitoring Programme; however its overall ecological status has been extrapolated from regional data and classified in the Carrownisky/Killary WMU Action Plan as high.

4.0 Physical Site Description

4.1 Catchment location and outline

Killeen Group Water Scheme is located approximately 5 Km north of Killary Harbour in County Mayo. The scheme extracts its water from Lough Cunnel which has a surface area of approximately 8 ha (Figure 1 and Figure 2). Water flows into the lake from three mountain streams that flow from higher elevation to the south of the lake. A single outflow stream is located at the eastern edge of the lake which flows eastwards into Glencullin Lough.

Lough Cunnel and its catchment are located within the Mweelrea/Sheefry/Erriff Complex Special Area of Conservation, a large hilly area that covers areas from Killary Harbour to the Erriff River. The Mweelrea/Sheefry/Erriff Complex is an extremely large site containing a wide range of habitats, including many that are listed on Annex I of the EU Habitats Directive, of which five are given priority status, i.e. blanket bog, petrifying springs, lagoons, machair and decalcified dune heath. The site supports populations of rare and threatened plants (mosses, liverworts, stoneworts, ferns and flowering plants) and animals (invertebrates, fish, birds and mammals). The upland areas of the Sheefry Hills are dominated by blanket bogs, heath and acid grassland.

The Group Water Scheme abstraction point (Figure 2) is located on the north-western shore of Lough Cunnel. The catchment area of Lough Cunnel is small at approximately 1.37 km^2. The lake is located at an elevation of approximately 210 m, with elevation rising to the south to a maximum elevation of approximately 340 m.

4.2 Bedrock geology

The bedrock underlying the Killeen GWS catchment is comprised of three sandstone-dominated formations (Figure 3): the Glenummera Formation, consisting of green-grey slate and sandstone, is present in the south of the catchment; the Derrylea formation, consisting of sandstone, mudrock, conglomerate and tuff(a soft, porous rock usually formed through the compaction of volcanic ash) is present in the centre of the catchment underlying much of Lough Cunnel; and the Sheefry Formation, consisting of mudrock, sandstone and tuff, is present in the far north of the catchment.

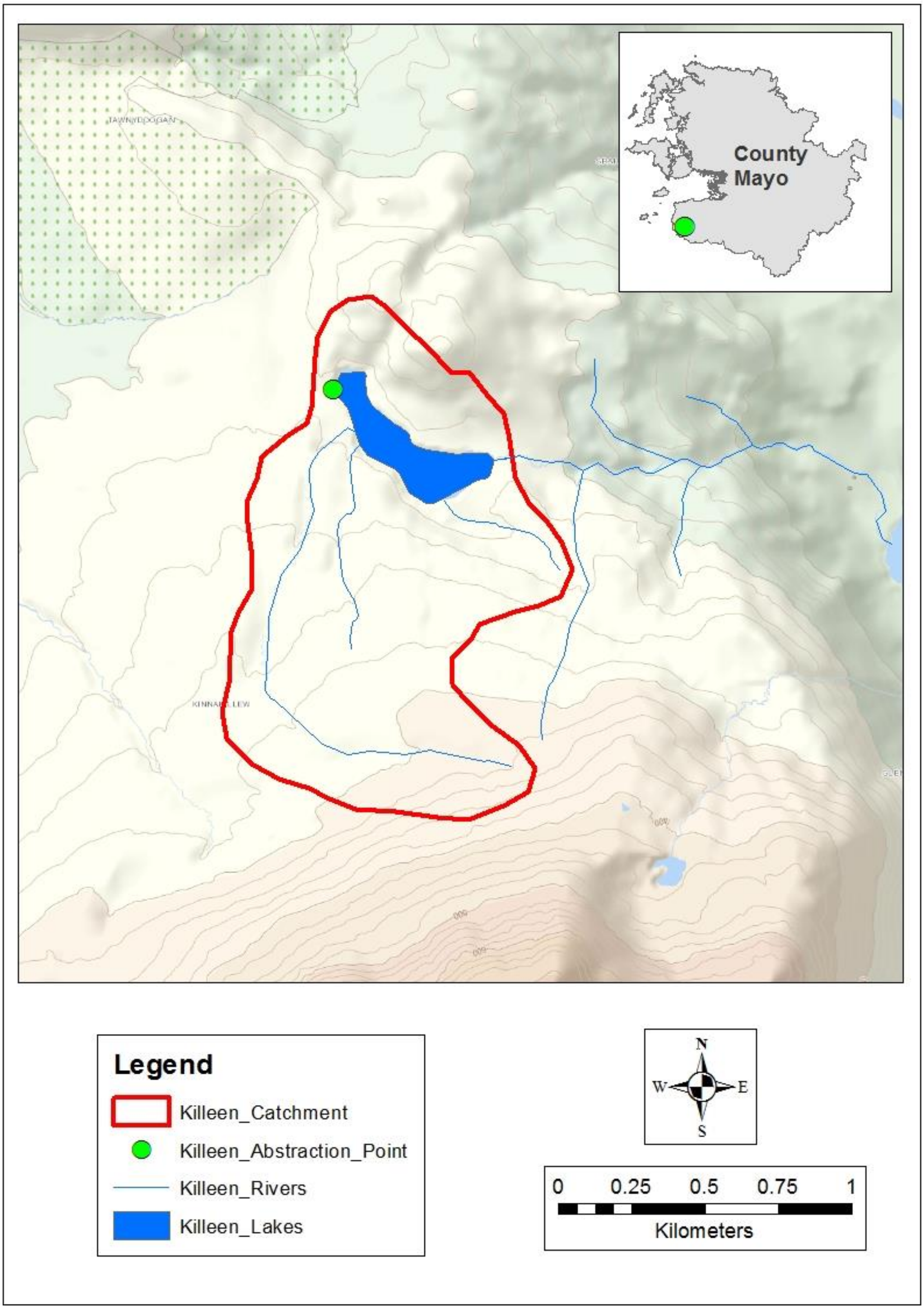

Figure 1: Surface water catchment area for the Killeen GWS.

Figure 2: Lough Cunnel facing south-east. The abstraction point is located at the end of the pontoon in the foreground.

4.3 Bedrock aquifers

An aquifer is an underground body of permeable rock or sand/gravel that yields water in sufficient quantities for use. The whole of the Killeen GWS catchment area is classed as a 'Poor aquifer with bedrock which is generally unproductive except for local zones' (Figure 4). Such aquifers are generally considered as unproductive (i.e. groundwater wells produce low yields), yet are mapped as covering approximately two-thirds of the total land area of Ireland. They are not regarded as important sources of water for public water supply, but are believed to be important with regard to delivering water (and associated pollutants) to rivers and lakes via shallow groundwater pathways (EPA, 2010).

4.4 Groundwater vulnerability

Groundwater vulnerability refers to the likelihood of surface water contaminants reaching the groundwater store. The vulnerability of groundwater is dependent on three components: 1). the time of travel of infiltrating water (and contaminants); 2). the relative quantity of contaminants that can reach the groundwater; and 3). the contaminant attenuation capacity of the geological materials through which the water and contaminants infiltrate.

The majority of the Killeen catchment is classified as having the two highest groundwater vulnerability classifications: E (Rock at/near surface or karst); and Extreme (Figure 5). A small area in the west of the catchment is classified as High groundwater vulnerability. The vulnerability of

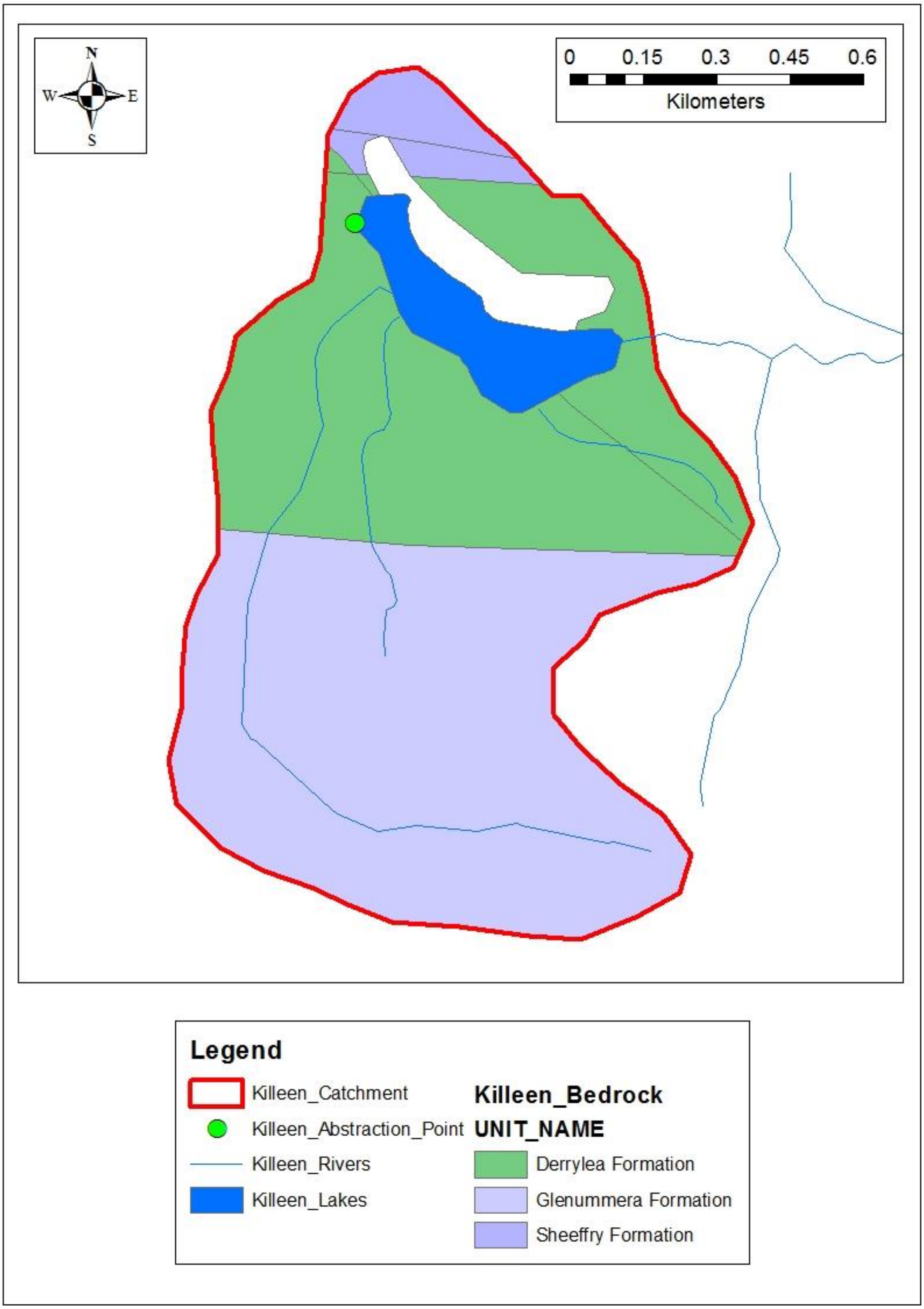

Figure 3: Bedrock geology within the Killeen GWS catchment.

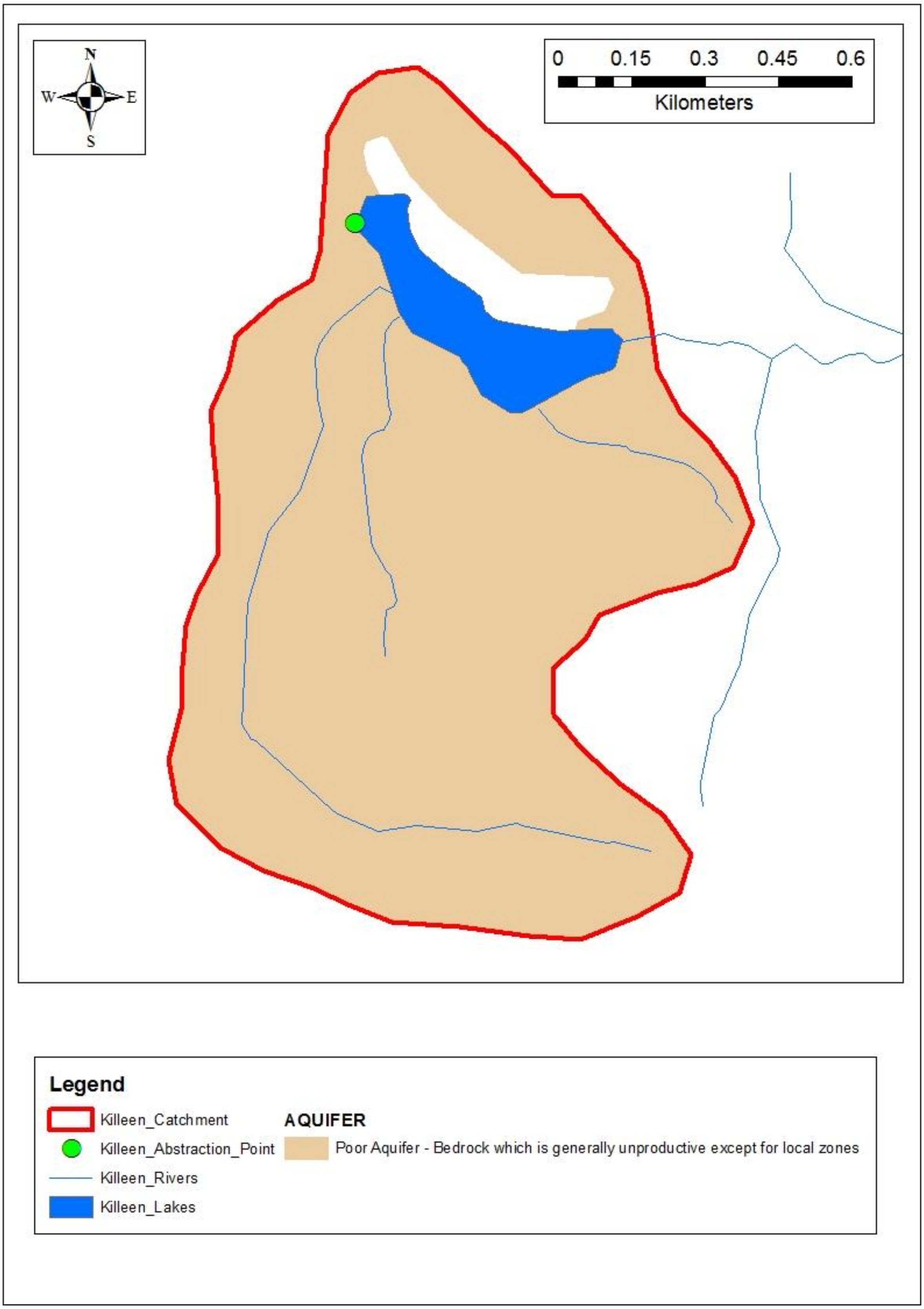

Figure 4: Aquifer types present within the Killeen GWS catchment.

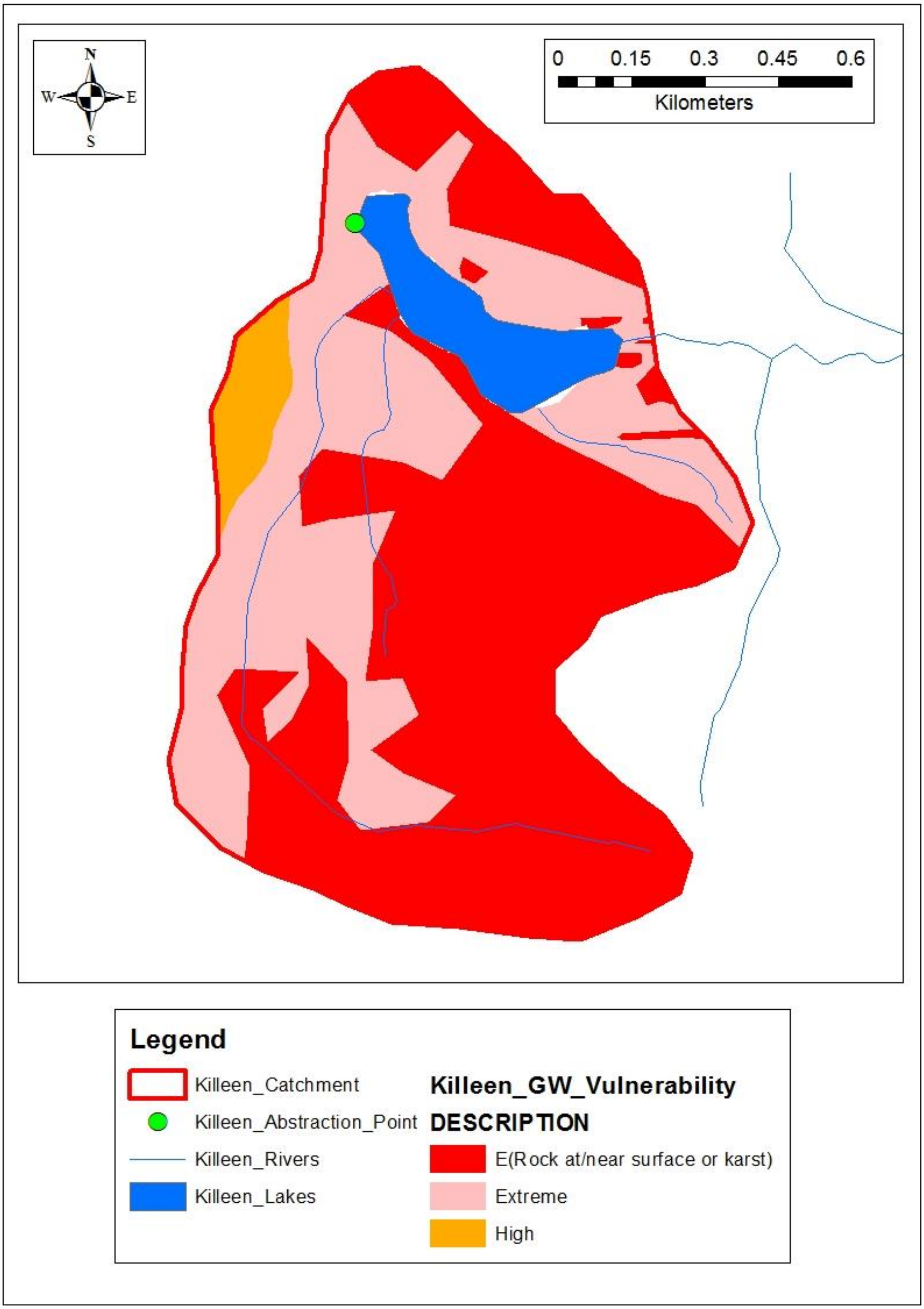

Figure 5: Groundwater vulnerability within the Killeen GWS catchment.

groundwater is affected by the permeability of the overlying subsoils and soils and the interactions with surface water and groundwater.

4.5 Subsoils

Subsoils lie between the bedrock and soils and are the most important feature in influencing the groundwater vulnerability to pollution as they act as a protective filtering layer, the effectiveness of which depends on their type, permeability and thickness.

As a result of its mountainous location the Killeen GWS catchment subsoils are classified as either bedrock outcrops or subcrops or blanket peat (Figure 6). Blanket peat subsoils are present in the western region of the catchment and in the immediate vicinity of Lough Cunnel. Bedrock outcrops/subcrops are present throughout the south, east and far north of the catchment.

4.6 Soils

Two different soil types are present within the Killeen GWS catchment: mainly shallow, non-calcareous peaty mineral soils of undefined drainage located in the south, east and far north of the catchment; and blanket peat soils present in the west of the catchment and in the immediate vicinity of Lough Cunnel (Figure 7). These soil types are typical of upland environments.

4.7 Slope and run-off

The slope of the land leading to a water body is an important determinant of the rate at which water and pollutants move into the lake by overland and groundwater flows. Slope can affect the quantity of contaminants entering a water body and thus can influence the quality of the water body. Steep slopes are vulnerable to surface water run-off, particularly if combined with poor draining soils. Soil erosion can also be a problem if vegetation cover is sparse, particularly as a result of overgrazing.

The highest elevation of approximately 340 m occurs in the south of the catchment, with elevation reducing sharply towards Lough Cunnel at an elevation of approximately 210 m. Further south of the catchment, elevation extends over 700 m.

The exact impact of the slopes within the Killeen GWS catchment could only be assessed in a more detailed study, but the potential interactions between the geology, soils, land use and slope will be discussed in more detail below.

The slope of the land also influences groundwater flow directions and water table gradients. Groundwater gradients (the amount of slope of the water table) are determined by the amount of rainfall replenishing the groundwater, and the ability of the aquifer to transmit the groundwater. Poor aquifers tend to have the steepest gradients and regionally important aquifers tend to have the flattest gradients, all other things being equal.

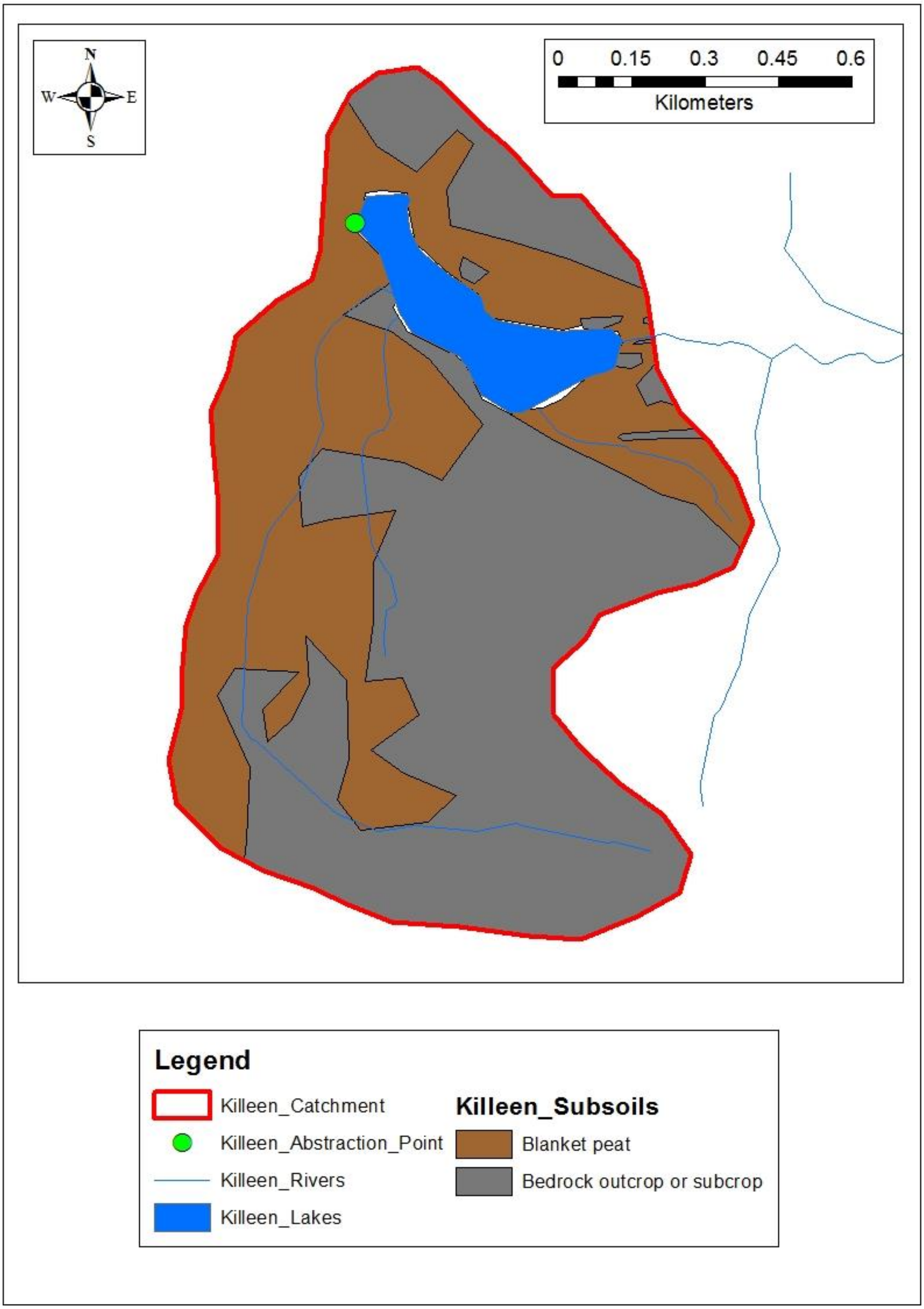

Figure 6: Subsoil deposits within the Killeen GWS catchment.

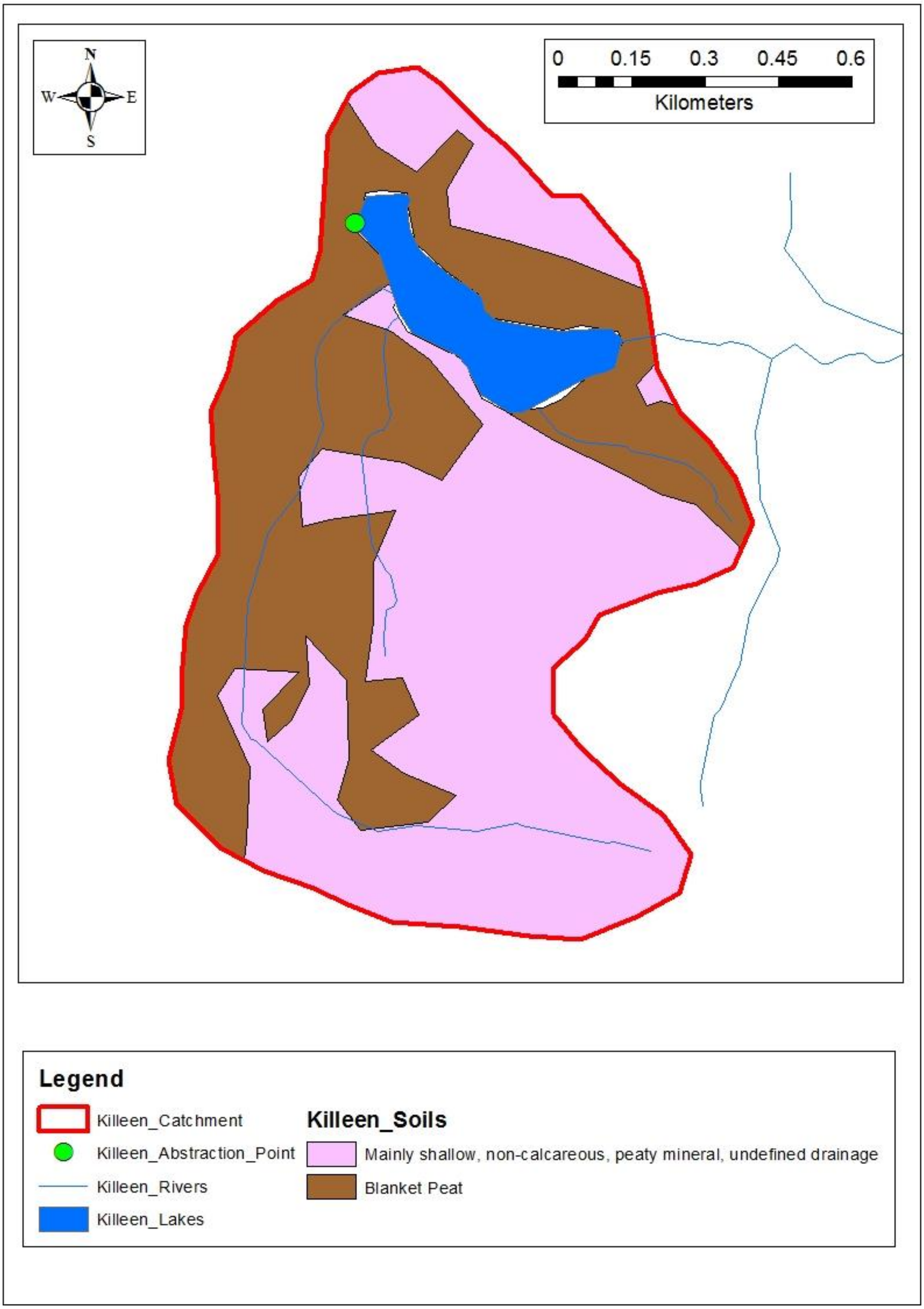

Figure 7: Soil types present within the Killeen GWS catchment.

5.0 Land use within the catchment

5.1 CORINE Land Cover

CORINE land cover is a map of the European environmental landscape based on the interpretation of satellite images (remote sensing). CORINE stands for 'Coordination of Information on the Environment' and the project has resulted in a Europe wide cataloguing of land cover into 44 standard classes. Importantly, land cover is defined as the observed physical cover, as seen from the ground or through remote sensing, including natural or planted vegetation and human constructions (e.g. roads, buildings) which cover the land surface. Therefore water, rock and ice are also included as land cover. Land cover is therefore distinct from land use which is based upon function: the purpose for which the land is being used. CORINE land cover does not include an assessment of land use.

There is one land cover classification within the Killeen GWS catchment (Figure 8): Peat bogs.

The management of the risks associated with this land cover classification will form the basis of this source protection report.

5.2 Forestry

Forestry plantations present threats to the quality of water bodies during the planting and early growing phase of a forestry as well as 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 phosphorus availability with the potential to increase phosphorus (P) volumes in the run off from planted land. During felling, sediment loss, siltation and nutrient release can also occur. In addition, the exposure of unvegetated soil can lead to the run off of P in soil suspension. The construction of forestry roads causes disturbance, erosion and compaction of the soil surface resulting in sedimentation and nutrient run-off.

There are no forested areas within the Killeen GWS catchment.

5.3 EPA licensed facilities – Integrated Pollution Prevention Control (IPPC)

There are no IPPC licensed facilities within the Killeen GWS catchment.

Figure 8: CORINE Land Cover classification within the Killeen GWS catchment.

5.4 Rural housing and on-site waste water treatment plants

On-site waste water treatment systems, including septic tanks, can add nutrients, chemicals and pathogenic organisms to water bodies. These risks are particularly elevated when systems are installed in areas of high groundwater vulnerability (i.e. where there is good hydrological linkage between surface water and groundwater) and where soil drainage is poor.

There are no dwellings located within the Killeen GWS catchment area.

5.5 Overall interpretation of catchment land use

The abstraction point for Killeen GWS is located in Mweelrea/Sheefry/Erriff Complex Special Area of Conservation and has a catchment has a small catchment area of approximately 1.37 km^2. Water is abstracted from the north-western region of the lake. The poorly productive aquifer may deliver groundwater to both Lough Cunnel and the surface water streams within the catchment area through small shallow cracks and fissures in the bedrock, facilitating the potential delivery of contaminants into the surface water. However given the small area of the catchment and the predominance of bedrock at the surface, there are unlikely to be significant groundwater-surface water interactions, and limited contaminants present within either water source. Groundwater vulnerability is at the highest classification throughout the catchment as a result of bedrock being typically at the surface, and the presence of peaty soils and subsoils.

Sheep farming occurs within blanket bog areas in the vicinity of the catchment area and access to water bodies is typically unrestricted. However stocking densities are relatively low and therefore risks of peat erosion through overgrazing; and faecal contamination of the GWS raw water supply is likely to be low. Killeen GWS has not undertaken a *Cryptosporidium* Risk Assessment report but given the small catchment area, the low stocking rates and lack of other agricultural pressures within the catchment; it is unlikely that risk of *Cryptosporidium* contamination will be high.

There are no dwellings within the catchment area and therefore risks of contamination from on-site waste water treatment systems are not applicable in this situation.

Given the peaty soils present throughout much of the catchment, there is risk of pH and colour issues within the raw water. Further details with regards to recommendations made on the basis of catchment land use in combination with assessments of water quality data (Section 6.0) are given in Section 7.0.

6.0 Raw Water Quality

Data was recorded by AECOM on behalf of Killeen GWS in two ways: Daily measurements that were averaged over the period of each month (here termed 'Monthly Average'); and once monthly spot samples (here termed 'Monthly Spot Samples'). As outlined in section 6.1.1, the monthly spot samples only give an indication of the water quality on that particular sampling occurrence whereas the monthly average data takes into account the variation in water quality observed over the course of a calendar month. Therefore it is the monthly average data that is typically presented below.

Included below are details of important parameters that have not been monitored to date. These parameters have been described and it is noted when such parameters have not been monitored for the Killeen GWS catchment.

6.1 Raw Water Quality

6.1.1 pH

The pH value of water is generally only of concern if it is extremely low or extremely high indicating acid or alkaline waters respectively. High or low pH values may have consequences for odour or taste, lead to corrosion in distribution systems and affect fish survival. The pH of water generally ranges from 6.5-8.0 and the Surface Water Regulations (1989) recommend a pH range of 5.5-8.5 for Class A1 waters. The Drinking Water Regulations (2007 and 2014) recommend a pH range of 6.5-9.5 for treated water.

pH was monitored in the raw water from March 2009 through to December 2013 (Figure 9). As discussed above in Section 6.0, disparities can be observed between the two different sampling frequencies, with monthly spot sampling values being typically greater that the monthly average values (Figure 9). Values ranged from a minimum monthly average of pH 5.22 in December 2011 to a maximum monthly average of 6.31 in November 2012, with an overall average of pH 5.80 observed over the sampling period. Monthly average pH values were below the recommended limit for Class A1 waters of pH 5.5 as stated in the Surface Water Regulations (1989) on six occasions throughout the sampling period. pH values were also reported in AECOM's Monthly Status Reports as being frequently below the parametric values stated in the Drinking Water Regulations (2007 and 2014).

There is limited association between rainfall and pH levels. Given the acidic nature of the peaty soils within catchment, low pH values and subsequent caustic dosing in the treatment process are likely to be a continuing issue for Killeen GWS.

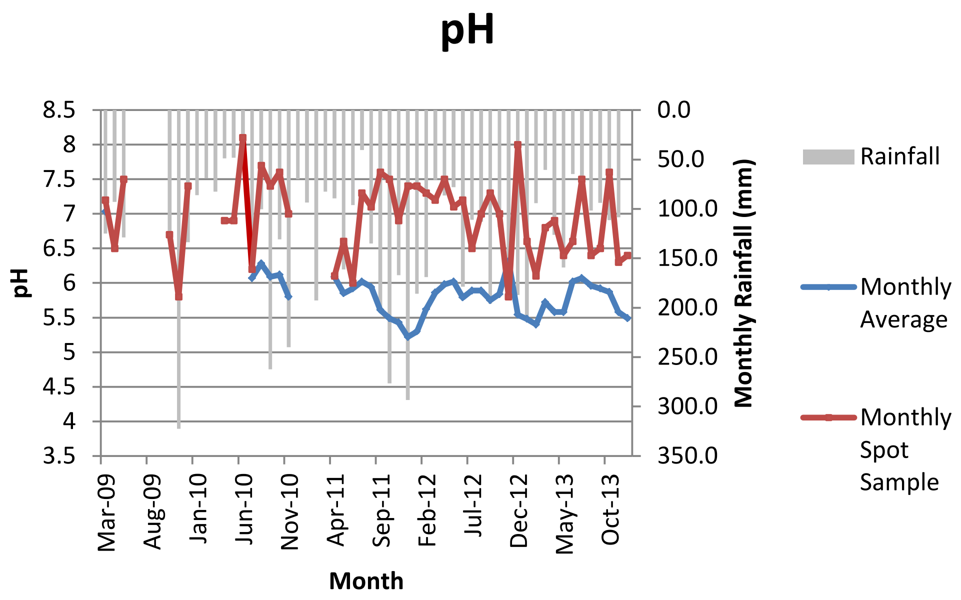

Figure 9: Raw water pH (primary axis) from April 2008 to December 2013. Monthly rainfall data (from Newport (Furnace) Met Eireann weather station) is presented on the secondary axis.

6.1.2 Colour and Trihalomethanes

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 produce trihalomethanes (THMs) which can be carcinogenic and their removal from drinking water can add significantly to the cost of treatment. The formation potential of THMs can also be correlated with the amount of Total Organic Carbon (TOC) in the raw water supply. For these reasons, high levels of colour should be avoided where possible; however colour can vary greatly as a parameter, depending on quantities of precipitation and run off, leading to spikes in results. Results of colour analyses can be presented as apparent colour (from an unfiltered sample) or true colour (from a filtered sample). Irvine *et al*. (2001) reported that colour in Irish lakes ranged between 5 mg/L PtCo to 134 mg/L PtCo. The Surface Water Regulations (1989) recommend a value of 20 mg/L PtCo (or Hazen equivalent units) (True Colour) for A1 waters. The Drinking Water Regulations (2007 and 2014) recommend a parametric value of 100 µg/L for total Trihalomethanes.

Colour was monitored in the raw water from March 2009 until December 2013 (Figure 10). From March 2009 until December, colour values are recorded as Apparent Colour (Hazen). After December 2009, there is no clarification as to whether it is Apparent Colour or True Colour that is recorded. Therefore it is presumed that it is Apparent Colour that continued to be measured and as such, no comparisons can be made with the Surface Water Regulations (1989) parametric value.

Monthly average colour values have been steadily increasing since early 2010 (Figure 10). Monthly average values ranged from a minimum of 32 Hazen recorded in May 2010 to a maximum of 191

Hazen recorded in April 2013, with an average value of 89 Hazen for the sampling period. Highest colour values were typically observed during the late summer to early winter period.

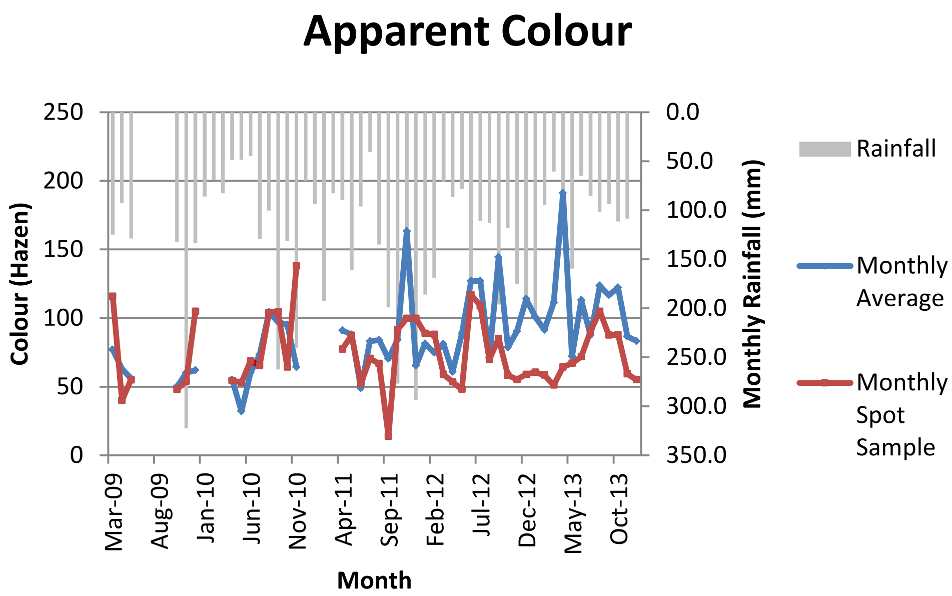

Figure 10: Raw water Apparent Colour (primary axis) from March 2009 until December 2013. Monthly rainfall data (from Newport (Furnace) Met Eireann weather station) is presented on the secondary axis.

Trihalomethanes (THMs) were monitored in the treated water on two occasions between March 2009 and December 2013. THM values of 20.3 µg/L and 12.31 µg/L were recorded in April 2011 and April 2012 respectively. The Drinking Water Regulations (2007 and 2014) parametric value of 100 µg/L was not exceeded on any occasion. Total Organic Carbon has not been monitored within the Killeen GWS raw water and therefore no potential associations with THM values can be determined.

6.1.3 Turbidity

Turbidity in water consists of very finely divided particles that are too small to be removed through 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. Turbidity can be represented using the following units: Jackson Turbidity Units (JTU); Formazin Turbidity Units (FTU); and Nephalometric Turbidity Units (NTU). Each of these units can be interpreted to mean the same thing.

Turbidity was monitored in the raw water from March 2009 until December 2013 (Figure 11). Values ranged from a minimum monthly average of 0.59 NTU in August 2011, to a maximum monthly average of 4.43 NTU recorded in April 2013, with an average of 1.94 NTU for the sampling period. A large turbidity value of 25.5 NTU was observed in the monthly spot sample for October 2011. There appears to be little obvious relationship between turbidity values and monthly rainfall (Figure 11).

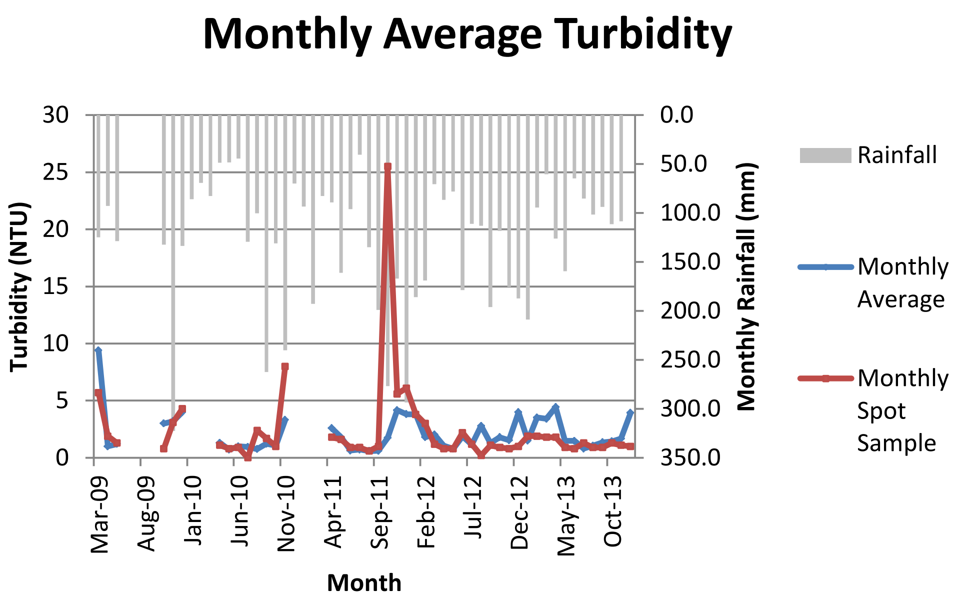

Figure 11: Raw water turbidity (primary axis) from April 2008 until December 2013. Monthly rainfall data (from Newport (Furnace) Met Eireann weather station) is presented on the secondary axis.

6.1.4 Sulphates and Chlorides

Drinking water that contains high levels of sulphates has been reported to have the potential to cause diarrhoea. Issues with taste and odour may occur where sulphate levels exceed 250 mg/L. The Drinking Water Regulations (2007 and 2014) state a parametric value of 250 mg/L sulphate whilst the Surface Water Regulations (1989) (the quality of surface waters intended for the abstraction of drinking water) recommend a parametric value of 200 mg/L sulphate for all water categories (Class A1, A2 and A3 waters). Group Water Schemes should aim to achieve the parametric values identified for Class A1 Waters (surface waters that only require simple physical treatment and disinfection to become drinking water).

High concentrations of chlorides in freshwater systems can be indicative of pollution by sewage and industrial wastes or the intrusion of saline water. High chloride content can also have a deleterious effect on metallic pipes and structures. The Surface Water Regulations (1989) recommend a parametric value of 250 mg/L chloride for all water categories (Class A1, A2 and A3 waters). The same parametric value is stated in the Drinking Water Regulations (2014).

Sulphates and chlorides have not been monitored within the Killeen GWS catchment.

6.1.5 Iron

Iron (Fe) is present in rocks and soil in an insoluble form but can become soluble when water passes through ground formations containing iron. Large amounts of iron in water are not usually harmful to consumers, but can be aesthetically unpleasing as a result of causing changes in colour or turbidity. This can lead to staining of laundry, discoloration of vegetables following cooking and taste problems. The Surface Water Regulations (1989) parametric value for iron in Class A1 waters is 0.2 mg/L.

Iron has not been monitored within the Killeen GWS catchment.

6.1.6 Manganese

Manganese is found in soils and groundwaters and is generally not considered harmful to humans. However it can cause more severe staining problems than iron and can adversely affect taste and potentially block pipes in large volumes. The Surface Water Regulations (1989) parametric value for concentrations of manganese in Class A1 waters is 0.05 mg/L

Manganese has not been monitored within the Killeen GWS catchment.

6.1.7 Alkalinity

Alkalinity is a measure of a water's capacity to neutralise acids, with high alkalinity providing a buffering capacity against pH change. The alkalinity of water is typically associated with bicarbonates in catchment soils. There is little known sanitary significance to alkalinity; however increased levels can be indicative of eutrophication and photosynthesis.

Alkalinity has not been monitored within the Killeen GWS catchment.

Eutrophication and Trophic Status (Note)

Eutrophic means well-nourished and eutrophication is the process where water bodies become more eutrophic through the addition of nutrients, primarily nitrogen and phosphorus (N and P). These additional nutrients, often in combination with low flow or still conditions and increased water temperatures, 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. Water bodies suffer different degrees of eutrophication, termed trophic status. Lakes are often characterised by their trophic status using the following scale: Oligotrophic (low in nutrients and algal growth); Mesotrophic (moderately productive, less clean than oligotrophic bodies); and Eutrophic (high levels of nutrients and algal growth combined with poor water quality). Lakes suffering from excessive eutrophication can be classed as hypertrophic. Trophic status is typically determined by algal abundance (using Chlorophyll *a* assessments as an indicator of abundance) or total phosphorus concentration (the most important nutrient in the eutrophication process).

6.1.8 Total Phosphorus

Phosphorus occurs widely in nature but much of the phosphorus found in surface waters occurs as a result of anthropogenic activities. Human and animal wastes contain large amounts of phosphorus and therefore agriculture and waste water treatment plants are large sources of phosphorus and often provide pathways for phosphorus to enter the aquatic environment. Artificial fertilisers used in agriculture and forestry are also primary sources of phosphorus. Phosphorus and, to a lesser extent, nitrogen are the two key drivers of eutrophication events in the aquatic environment (see Eutrophication and Trophic Status Note, above, for details on eutrophication) as they are the primary nutrients required by the algae and plants that can flourish during eutrophication events. Eutrophication can lead to a loss of biological diversity (particularly of sensitive and/or desirable species), increased plant growth, the development of algal scums and a general deterioration in water quality. Eutrophication is the largest threat to Irish water quality and is of great importance to drinking water sources. Increased algal abundance can create problems in treatment plants and decomposing algae can release toxins into the water and cause taste and odour problems. The management of phosphorus levels entering the aquatic environment is central to the long-term viability of many drinking water sources.

Total Phosphorus has not been monitored within the Killeen GWS catchment.

6.1.9 Chlorophyll

Chlorophyll is used as an indicator of overall algal abundance within a water source. High levels of chlorophyll can indicate high algal abundance which can have negative implications for the treatment process and lead to taste and odour problems in treated water. Chlorophyll values are typically greatest in the summer when the water temperatures are warmer, and light availability is high. It is monitored as chlorophyll *a*, the most abundant form of chlorophyll in lake algae.

Chlorophyll has not been monitored within the Killeen GWS catchment.

6.1.10 Transparency

Transparency can give an indication of the presence of suspended matter within a water body and is measured using a Secchi disk (a coloured disk). The disk is lowered through the water until it can no longer be seen by the naked eye and the distance lowered recorded: the greater the distance, the greater the transparency. The transparency of the water can be used as an overall indicator of quality as algae and/or sediment can reduce transparency. Low transparency levels can effect light penetration and also potentially affect the ability of fish to find prey.

Transparency has not been monitored within the Killeen GWS catchment.

6.1.11 Nitrogen

Nitrogen, together with phosphorus, is central to the development of eutrophication as nitrogen is a key nutrient for plant and algal growth. Although approximately 78% of the earth's atmosphere is made up of nitrogen gas, this form of nitrogen is not available as a nutrient to plants. Instead it is converted to different forms such as ammonium, nitrite and nitrate through the nitrogen cycle. Nitrate is the most common form of nitrogen that exists in aquatic environments and typically originates from human and animal wastes as well as from the application of artificial fertilisers to agricultural lands. The Surface Water Regulations (1989) recommend a parametric value of 50 mg/L NO_3 for Class A1 waters. Nitrite is an intermediate form between ammonium and nitrate and typically only represents a small proportion of nitrogen in water. Nitrite and nitrate are often presented together as Total Oxidised Nitrogen (TON). As well as having environmental implications with regards to nutrient enrichment, high levels of nitrate in drinking water can have important health implications. Large amounts of nitrate in drinking water can cause methemoglobinemia in pregnant women and infant children, with those under 6 months particularly vulnerable. Methemoglobinemia, also known as 'blue baby syndrome' reduces the ability of the red blood cells to carry oxygen as a result of nitrate in the drinking water being converted into nitrite by stomach bacteria. This nitrite is absorbed into the blood and results in the conversion of haemoglobin to methemoglobin which does not efficiently carry oxygen. Severe cases can lead to brain damage and death. Importantly, *nitrates and nitrites cannot be removed from raw water during the standard treatment process*. The Drinking Water Regulations (2014) stipulate maximum acceptable values of 50 mg/L for nitrate and 0.5 mg/L for nitrite.

The source of ammonia in the aquatic environment is most likely from human and animal waste and high concentrations of ammonia can indicate pollution from these sources. Ammonia also arises from peat drainage. In aquatic environments, ammonia (NH_3) is frequently ionised to ammonium (NH_4^+) and equally ammonium can be converted back into ammonia. The pH of the water is the major factor than influences the ionisation of ammonia to ammonium and at the typical pH of most Irish freshwaters; it is ammonium that is the most common form. Although naturally present in small amounts in aquatic environments, values of over 0.1 mg/L N is interpreted as an indication of human waste pollution or industrial contamination. With regards to lake quality classes based on total ammonia levels (NH_4^+ plus NH_3), the Surface Water Regulations (2009) state that bodies must have ≤0.040 mg N/L as a mean for high status (or ≤0.090 95%ile) and ≤0.065 mg N/L as a mean for good status (≤0.140 95%ile). Following treatment, the Drinking Water Regulations (2014) parametric value for ammonium is 0.3 mg/L.

Total Oxidised Nitrogen (TON)

Total Oxidised has not been monitored within the Killeen GWS catchment. However, nitrate has been monitored in the drinking water on an approximately quarterly basis from March 2009 until December 2013, with additional nitrate monitoring undertaken annually through audit monitoring. As nitrates cannot be removed from the standard treatment process and raw water values are not typically affected during the treatment process, it is valid to use the nitrate concentrations monitored in the drinking water as a proxy for raw water nitrate content.

Of the 16 sampling events, nitrate concentrations were below limits of detection on 14 occasions (88% of occasions). Values of 0.06 mg/L NO_3 and 0.55 mg/L NO_3 were recorded in December 2011, April 2012 respectively. On no occasions was the Drinking Water Regulations (2007 and 2014) parametric value for nitrate exceeded.

Ammonium

Ammonium has not been monitored within the raw water of the Killeen GWS catchment.

6.1.12 Conductivity

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

Conductivity has not been monitored within the raw water of the Killeen GWS catchment.

6.1.13 Dissolved Oxygen (DO)

The amount of oxygen dissolved within a water body is important for fish survival. If a water body is suitable for fish survival then it generally meets the quality requirements for most other forms of water consumption.

Dissolved oxygen saturation is dependent on water temperature: warmer waters typically contain less dissolved oxygen then colder waters. Summer temperatures resulting in lower DO levels, in combination with low water levels can leave aquatic environments particularly vulnerable to organic pollution. DO saturation and concentration can also be affected by photosynthesis, with increased eutrophication and photosynthesis leading to high oxygen concentrations during daylight hours, and these high oxygen concentrations can be depleted at night when respiration takes over from photosynthesis.

Dissolved oxygen has not been monitored within the raw water of the Killeen GWS catchment.

6.1.14 Biological Oxygen Demand (BOD)

Unpolluted water is typically saturated with dissolved oxygen, but when organic pollution enters a water body, bacteria break it down through a process that uses available oxygen, thus reducing DO levels. The Biological Oxygen Demand (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. The Surface Water Regulations (1989) recommend the value for BOD in Class A1 Waters to be 5 mg/L O_2.

BOD has not been monitored within the raw water of the Killeen GWS catchment.

6.1.15 Coliforms

Faecal coliforms such as *Escherichia coli* (*E. coli*) originate in animal or human wastes. A typical measurement of coliforms is Total Coliforms which include faecal and soil-born coliforms. Total coliforms is used as an indicator or pathogenic organisms within a water body and the Surface Water Regulations (1989) recommend that Class A1 waters should not exceed 5,000 total coliforms per 100ml, or 1,000 faecal coliforms per 100ml. Following treatment, the Drinking Water Regulations (2007 and 2014) state that Total coliform values above 0 numbers per 100ml are unacceptable.

E. coli

Escherichia coli bacteria are present in high numbers in human and animal faeces and are rarely found in waters in the absence of faecal pollution.

E. coli have not been monitored within the raw water of the Killeen GWS catchment. On no occasion were the Drinking Water Regulations (2007 and 2014) parametric values exceeded for treated water.

Clostridium perfringens

Clostridium perfringens exists as part of the natural bacterial intestinal flora of humans and therefore serves as an indicator of faecal pollution.

Clostridium perfringens has not been monitored within the raw water of the Killeen GWS catchment. On no occasion were the Drinking Water Regulations (2007 and 2014) parametric values exceeded for treated water.

Total Coliforms
Total coliforms have not been monitored within the raw water of the Killeen GWS catchment. On no occasion were the Drinking Water Regulations (2007 and 2014) parametric values exceeded for treated water.

6.1.16 Biological data

Q values
Clabby *et al.* (2006) state that in the presence of pollution, characteristic and well documented changes are induced in the flora and fauna of rivers and streams. Organic pollution that impacts the aquatic macroinvertebrate communities are particularly well documented, with changes occurring due to varying sensitivities of different species to the stresses caused by pollution.

Macroinvertebrate diversity declines in the presence of pollution and sensitive species are progressively replaced by more tolerant species as pollution increases. The EPA classify benthic aquatic macroinvertebrates into five arbitrary 'indicator groups' based on sensitivity to pollution, with Group A being the most sensitive and Group E being the most tolerant. These groups, in combination with physico-chemical assessment of water quality, are used to produce Quality (Q) Values. The values range from Q1 to Q5, with Q5 waters having the greatest macroinvertebrate diversity (with sensitive species present) and good water quality; and Q1 waters having the little macroinvertebrate diversity (with communities dominated by tolerant species) and poor water quality.

Macroinvertebrates have not been monitored within the Killeen GWS catchment.

6.4 Overall Interpretation of Water Quality

A limited number of raw water quality parameters have been monitored within the Killeen GWS catchment, however given the location of Lough Cunnel and the limited pressures acting on the small catchment, the likelihood of poor water quality is low.

Colour values have been monitored consistently in the raw water by AECOM and reported in the Monthly Status Reports. From March 2009 until December 2009, colour values are recorded as Apparent Colour (Hazen). After December 2009, there is no clarification as to whether it is Apparent Colour or True Colour that is recorded. Therefore it has been presumed that it is Apparent Colour that continued to be measured and as such, no comparisons can be made with the Surface Water Regulations (1989) parametric value. Apparent Colour is a measure of both dissolved and suspended components whilst the later are removed by filtration for the measurement of True Colour which is therefore an assessment of dissolved components. Clarification should be made with AECOM as to whether the values reported from December 2009 onwards are Apparent or True Colour values. True colour should be added to the suite of monitoring parameters in order to allow comparisons with the Surface Water Regulations (1989) parametric value for True Colour for Class A1 waters.

Given the peaty soils present throughout the Killeen catchment and the humic compounds likely leached into surface waters, it is not surprising that colour values of the raw water are consistently high and have the potential to exceed the Surface Water Regulations (1989) parametric value for Class A1 waters (although as True Colour has presumably not been monitored, no direct comparisons can be made). As discussed in this report, high levels of colour do not represent health risks. However, upon treatment with chlorine, THMs can be produced when the chlorine reacts with naturally occurring organic matter in the raw water (high colour values can be an indication of high organic matter). These THMs have potentially significant health implications, but THM values in the Killeen GWS treated water are well below levels of concern. However THMs have only been monitored on two occasions, with samples taken in April 2011 and April 2012. High THM concentrations can be associated with high raw water True Colour and high raw water Total Organic Carbon (TOC) values. TOC has not been monitored within the Killeen GWS raw water, and THM monitoring has not been aligned with periods when colour values are typically highest (late summer, early autumn). Recommendations regarding improved THM and colour monitoring are given in Section 7.0.

The peaty soils of the catchment also influence the pH of the raw water supply which has frequently been below of the Surface Water Regulations (1989) recommended range resulting in pH being below the Drinking Water Regulations (2007 and 2014) recommended range on a number of occasions. This has resulted in the caustic dosing of the raw water supply to bring pH into the accepted range for drinking water. Given the naturally low pH of the peaty soils through which the surface waters of the catchment flow, there are limited catchment-level source protection management actions available to improve raw water pH.

The upland location of the Killeen GWS catchment area results in reduced point source pressures (from, for example, waste water treatment systems) and diffuse pressures (from, for example, agriculture) acting on the surface waters. Nutrient levels within the catchment surface waters would be expected to be relatively low, particularly with the source of the raw water being an oligotrophic (low in nutrients) upland lake. Nitrate concentrations measured in the treated water, and used as an indicator of raw water nitrate levels, are low as expected. Total Phosphorus has not been monitored within Lough Cunnel, but given the lake's location and the lack of likely nutrient sources within the catchment area, monitoring of Total Phosphorus is not essential.

Turbidity within the raw water supply is relatively high and has the potential to be significantly elevated. Although turbidity is not a direct indicator of health risk, microbial pathogen levels can be elevated in raw waters of high turbidity. Despite the potential free access of livestock to Lough Cunnel and the lack of a *Cryptosporidium* Risk Assessment report, given the likely low stocking densities, and the lack of pressures acting on the lake and catchment area, it is unlikely that microbial contamination of the raw water supply is of high risk to the consumers. Indeed, on no occasion has the treated water breached the Drinking Water Regulations (2007 and 2014) for microbial pathogens. However, if stocking rates within the catchment are expected to increase, and subsequently microbial pathogens are found to be present in the drinking water, then it would be important to consider the fencing of all surface water bodies within the catchment where feasible.

7.0 Recommendations

The assessment of geology, soils, land cover and available water quality data has identified that the Killeen raw water supply is of good quality with limited pressures acting on the catchment that are likely to cause a deterioration in that water quality in the short to medium term. A few issues have been identified and these are outlined below with recommendations made as to how to maintain good water quality within the catchment.

Put source protection on the agenda

Within many group water schemes 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 Killeen 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 source protection measures and potential pollution within the catchment should also be discussed.

Engage with local farmers

Although the livestock densities present within the Killeen GWS catchment are low, it will be important to engage with local farmers to discuss source protection and ensure that such densities are kept low to reduce the potential of overgrazing (which can lead to soil erosion and subsequent sediment and turbidity issues in the raw water supply) and faecal contamination of Lough Cunnel. If livestock densities are likely to increase dramatically in the catchment, then consideration should be given to the fencing of all surface water bodies within the catchment where feasible.

Engage AECOM regarding raw water colour and Trihalomethane monitoring

Clarification should be made with AECOM regarding whether it is Apparent Colour or True Colour that has been monitored since January 2010. True colour should be included in the raw water monitoring programme in order to ensure that the Surface Water Regulations (1989) parametric value for True Colour is being achieved.

As discussed in this report, relatively high levels of raw water colour that are present in the Killeen GWS raw water supply do not represent health risks. However, upon treatment with chlorine, THMs can be produced when the chlorine reacts with naturally occurring organic matter in the raw water (high true colour values can be an indication of high organic matter). These THMs have potentially significant health implications and further information on THMs and their monitoring within Ireland is provided by the Environmental Protection Agency:
http://www.epa.ie/pubs/advice/drinkingwater/DrinkingWaterGuide4_v8.pdf. Although THM values recorded in the Killeen treated water have not been at levels of concern, the timing of the monitoring has not been aligned with the period when raw water colour values are typically highest: late summer through to early winter. It is therefore recommended that a once-off short-term THM monitoring programme (aligned with True Colour monitoring) should be initiated over the period from late summer through to early winter as this is when true colour values are typically highest. Following this initial short term monitoring programme, subsequent monitoring should be undertaken on an annual basis when True Colour values are found to be highest.

The following mitigation methods for raw water are advised by the EPA if THM levels are found to be high in the treated water:

- Improve raw water management ; including storage, intake management and monitoring and control (e.g. raw water turbidity monitors or automation of coagulant dosing based on raw water conditions);
- Install automatic shut off when water quality is poor;
- Examine the option for using an alternative raw water source.

8.0 References

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