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Explanatory notes to accompany the Aquifer Vulnerability GIS for Aberdeenshire Council

Groundwater Systems and Water Quality Programme
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BRITISH GEOLOGICAL SURVEY

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Contents

LIST OF FIGURES

1 Introduction

These notes are designed to accompany the ArcView geographical information system (GIS) format aquifer vulnerability maps produced by the British Geological Survey (BGS) for Aberdeenshire Council. The GIS is based on digital geological information for both bedrock and superficial deposits. It covers the whole of the Aberdeenshire county area plus a 3 km ‘buffer zone’ around the county area to account for any differences in boundary area data and to allow for more meaningful interpretation at county boundaries.

The purpose of the GIS is to show, in broad terms, the vulnerability of groundwater to contamination. Groundwater is contained within aquifers of various types. Abstractions from these aquifers provide water for potable supplies and various domestic, industrial and agricultural uses. Some highly permeable aquifers are very productive and of regional importance as sources for public water supply while less permeable formations are important locally. Groundwater also provides the baseflow to surface watercourses. Groundwater is typically of high quality and often requires little treatment before use. However, it is vulnerable to contamination from both diffuse and point source pollutants, from direct discharges into groundwater and indirect discharges into and onto land. Aquifer remediation is difficult, prolonged and expensive, and therefore, the prevention of pollution is important.

The approach and classifications used in the production of this vulnerability GIS can also be used in the assessment of specific land use practices, proposed developments and land use changes over aquifers where these could have an impact on groundwater quality. More detailed site specific assessment of vulnerability will be required where it is considered that development may have an impact on groundwater quality.

This GIS is a compromise between the representation of natural complexity and simplicity of interpretation at a scale of 1:50,000. This places limitations on the resolution and precision of map information. In this case, the variety of geological strata and potential pollutants that have to be covered is wide, and the classification used is, of necessity, generalised. Individual sites and circumstances will always require further and more detailed assessment to determine the specific impact on groundwater resources. The GIS only represents conditions at the surface of the solid and/or drift geology and, therefore, where these formations have been disturbed or removed, for example, during mineral extraction, the vulnerability class may have been changed. Hence, where there is evidence of disturbance, site specific data need to be used to determine the vulnerability of the groundwater.

The methodology used for this GIS map has not included consideration of the soils. The overall permeability of each geological unit has been interpreted, enabling an estimation of the vulnerability of groundwater occurring under the Aberdeenshire area. The vulnerability classification does not follow the methodology devised for published groundwater vulnerability maps used by the Scottish Environment Protection Agency (SEPA). The latter methodology includes a system in which superficial geology and soil data are used to produce a series of detailed vulnerability classifications. The accompanying GIS system used in the current methodology, however, provides a broad-based view of both the vulnerability of groundwater and the location of the more permeable aquifers under the Aberdeenshire area.

The data used for the compilation of the vulnerability GIS use part of the 1:50,000 DigMap solid and drift geology coverage. The ‘thick drift’ polygons found in the GIS were interpreted and drawn based on BGS borehole records. The GIS should not be used at scales larger than 1:50,000.

There are three themes within the GIS: Solid Geology Permeability, Drift Geology Permeability and Aquifer Vulnerability, formed by combining solid and drift geology permeability.

2 Overview of solid and drift geology

The oldest and most widespread rocks in the district are metamorphic rocks, which are often well exposed along coasts and run inland in belts with a general south-south-westerly trend. Originally deposited as sedimentary sands, clays and limestones, they have been subject to metamorphic processes, and now appear as schists, gneisses, quartzites and other metamorphic rock types. There are two main divisions of metamorphic rocks in the district: one comprising highly metamorphosed rocks such as schists, and the other largely low-grade metamorphic rock, such as meta-greywackes.

Two distinct groups of igneous rocks have been identified in the district: an older series, formed before the original sedimentary rocks were metamorphosed, and a younger series, formed after metamorphism. The igneous rocks include ultra basic, basic and acid rocks, and the rocks of the older series often form elongated sill-like masses.

After the intrusion of the younger igneous rocks there was a long period of erosion which left an uneven land surface, on which sandstones, siltstones and conglomerates were deposited in Silurian and Devonian times. From the late Devonian to early Quaternary times, rock formation has been confined to small patches of well-sorted gravel deposits laid down in Tertiary times.

The effects of glaciation dominate the Quaternary. The movement of large ice sheets, largely from the west and north, deposited till (boulder clay), which covers much of the district to depths of between 1 and 5 metres. In some areas pockets of deeper till, up to 20 metres, can be found. As the ice retreated, sands and gravels were deposited in channels by glacial meltwater. In coastal regions, clays and poorly sorted sands and gravels were deposited in lakes that may have been formed by ice or till dams as the ice sheets retreated. More recently, heterogeneous alluvial deposits comprising poorly sorted sands, gravels, silts and clays have been laid down in valleys by rivers.

3 Aquifer permeability and vulnerability

The permeability of a geological unit determines the ease with which groundwater can flow through it. In sedimentary rocks such as sandstone, groundwater normally flows between individual sand grains (intergranular) and through fractures and other voids. Sandstones can vary greatly in permeability but are often among the most highly permeable and porous (able to store groundwater) rocks. In limestones and metamorphosed limestones, groundwater flow and storage is almost entirely within fractures, which in certain places can be so extensively developed they form karst (caves, pipes, conduits), allowing rapid groundwater flow. In most other metamorphic and all igneous rocks there is little or no primary (intergranular) permeability and groundwater storage and flow is confined to weathered zones and/or fractures, which are generally thin and/or limited in extent, making these rocks poor aquifers.

Superficial deposits vary in permeability from coarse gravels and blown sand, which are highly permeable, to sandy silts or clays (which may have low to moderate permeability), to virtually impermeable lake clays.

The vulnerability map is based on the general assumption that where more highly permeable formations outcrop at the ground surface, water can infiltrate at a faster rate to the water table compared to less permeable formations. Where less permeable formations outcrop at the surface, such as clayey drift deposits or crystalline igneous or metamorphic bedrock, a larger proportion of the rainfall falling on the ground will flow directly to surface watercourses instead of infiltrating below the soil. More permeable formations are, therefore, more vulnerable to contamination. Permeable drift formations can act both as aquifers in their own right, and as pathways for groundwater to reach underlying bedrock (solid) aquifers. Areas where high permeability drift overlies low or moderate permeability bedrock; where high permeability drift overlies high permeability bedrock, and where high permeability bedrock outcrops at the surface, are therefore treated as equally vulnerable on the vulnerability map.

Where a thick clayey drift deposit overlies a permeable aquifer, the clay can act as a barrier to the downward movement of pollutants, and thus as a protective barrier. However, where there are relatively thin sandy clay layers (generally less than 5 metres), a certain amount of recharge to deeper aquifers will occur. The GIS distinguishes where low permeability drift (generally till but also peat and lacustrine clays) overlies bedrock aquifers, shown in pink, but it should not be assumed that this low permeability drift layer always acts as an effective barrier, as there may be significant variations in the thickness and lithology of the drift.

The detailed identification, location, thickness and extent of any clayey deposits can be difficult due to a lack of data. However, an interrogation of BGS borehole records has been made and these records interpreted to show where there is a strong probability that there is greater than 5 metres thickness of clay in the drift sequence. This is shown on the maps as a transparent hatched overlay. This information is limited to where borehole geological data is present, and therefore represents the likely minimum extent of thick clayey drift, and not the complete picture.

3.1 SOLID GEOLOGY PERMEABILITY

The solid bedrock has been divided into three main groups based on permeability (High, Moderate and Low), shown on the map in Figure 1. There is a fourth category to cover a number of very small areas totalling approximately 0.04 square kilometres on the north coast where the solid geology has been classed as ‘unknown’. These areas are small enough to be effectively discounted. The groups include the following rock units:

High Permeability:
(Red on GIS)

Upper Devonian sandstones (Kinnesswood and Glenvale Sandstone Formations)
Tertiary gravels (Buchan and Windy Hills Gravels Members)

Moderate Permeability:
(Yellow on GIS)

Precambrian and Palaeozoic metamorphosed limestone, dolomites and calcareous schists
Lower Devonian conglomerates and sandstones
Middle Devonian conglomerates

Low Permeability:
(Green on GIS)

All other metamorphic rocks (e.g. schists and quartzites)
All igneous rocks (e.g. granites, pegmatites and gabbros)
Lower Devonian mudstones and siltstones
Silurian sandstones, siltstones and conglomerates

3.2 DRIFT GEOLOGY PERMEABILITY

Drift deposits are also divided into three main groups according to permeability (High, Moderate and Low), shown on the map in Figure 2. There is also a category to cover areas of no drift cover. The final category covers areas where the drift geology is classed as 'unknown': i.e. drift cover is present but it has not been classified. This covers a number of small areas each an average of approximately 1 square kilometre.

The drift coverage in the Aberdeenshire district is highly varied, and some of the drift mapping is relatively old and does not account for recent advances in drift typology. Many of the drift units mapped are internally heterogeneous, often composed of sands, gravels, silts and clays in varying amounts at different locations, but mapped as a single unit. Parts of such a unit may therefore be relatively permeable, while other parts are largely impermeable. The classifications used in the aquifer vulnerability GIS and map and described below represent the best attempt at interpreting such drift units in terms of their overall permeability. In most cases this has been done using a precautionary principle, so that for example alluvial clays, sands and gravels, which are thought to have largely low permeability but which may contain significant sand and gravel at certain locations, have been classified as having moderate permeability. Another example is alluvial sands or gravels with silts and clays, thought to be largely moderately permeable but with pockets of highly permeable sands or gravels, have been classified as having overall high permeability.

The groups include the following units:

High permeability:
(Red on GIS)

Alluvial, alluvial fan, glaciofluvial, river terrace, and hummocky glacial sand and gravel
Blown sand
Alluvial and alluvial fan sand and gravel with silt and clay

Moderate permeability:
(Yellow on GIS)

Alluvial clays with sand and gravel
Hummocky glacial deposits with diamicton[1], sand and gravel
River terrace deposits with sand, silt and clay
Head deposits

[1] A general term for any unsorted, unstratified sediment regardless of its genesis. Diamicts may be formed in various situations: glaciation, mudflow, landslide, avalanche, and turbidity current. Till is a special kind of diamicton that was formed directly from glacier ice. The terms diamictite and tillite are used for the ancient, consolidated equivalents of diamicton and till sediments.

Low permeability:
(Green on GIS)

Till (boulder clay)
Lacustrine, saltmarsh, beach deposits and tidal flat clay, silt and sand
Peat
Logie Buchan Drift Group and East Grampian Drift Group clay with sand, gravel and silt
Glen Dye Silts Formation and Kirk Burn Silt Formation clay, silt and sand

4 The map of aquifer vulnerability

The basic assumption made in defining the three vulnerability categories shown on the accompanying map (shown in Figure 3) and GIS is that that high aquifer permeability equates with high groundwater vulnerability: i.e., pollutants at ground level are able to migrate downwards more easily and in greater volume where permeable material such as gravel or sandstone is present. Formations of this type are therefore more vulnerable.

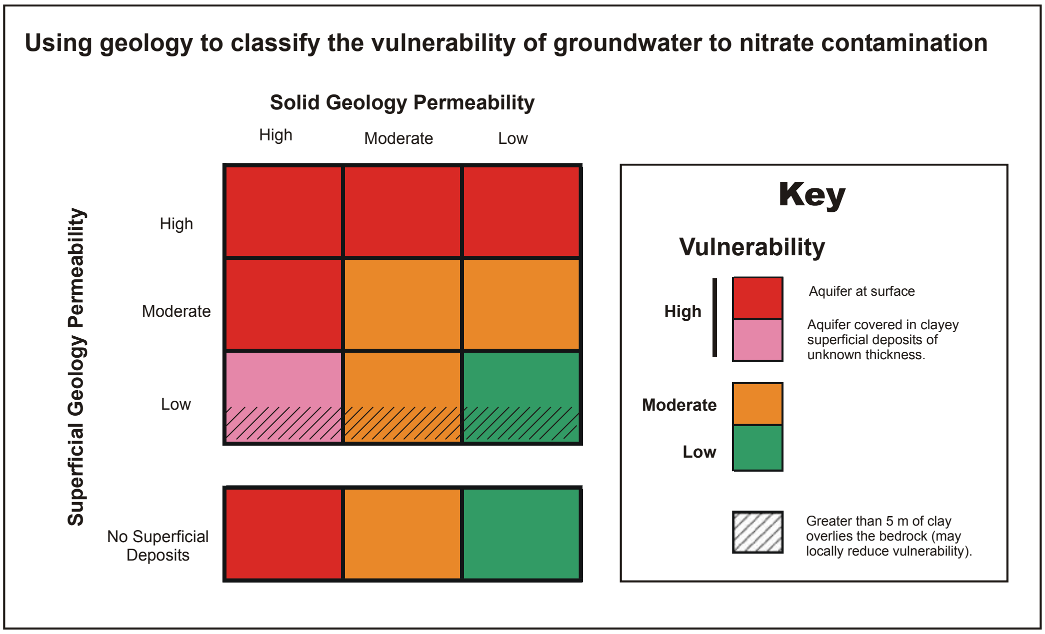
The vulnerability map incorporates both the solid and drift permeability classifications previously described to produce twelve combinations of solid and drift permeability. These combinations are referred to by two-letter codes: ‘HH’, ‘HM’, etc. The letters are as follows:

H High permeability
M Moderate permeability
L Low permeability
N No drift cover present over the bedrock formation
U where solid or drift geology is unknown.

The first letter in the code refers to the solid (bedrock) permeability and the second letter to the drift permeability. For example, ‘HM’ refers to High Permeability Solid Geology overlain by Moderate Permeability Drift Geology.

These twelve combinations have then been grouped into three main categories of aquifer vulnerability labelled ‘High’ (red on map), ‘Moderate’ (yellow) and ‘Low’ (green). A sub-category, (pink on map), shows areas where a highly permeable bedrock aquifer is covered by low permeability drift (till/boulder clay or other clayey drift). It should be noted that the thickness, and therefore the effectiveness, of this clay as a barrier to pollution is uncertain. The vulnerability categories are summarised in the matrix overleaf.

A summary of the vulnerability categories is as follows: anywhere in the Aberdeenshire area where there is a highly permeable aquifer present beneath the ground surface, either bedrock or drift, the map is coloured red or pink to denote high vulnerability. Aquifers (bedrock or drift) of moderate permeability are coloured yellow to indicate an overall moderate vulnerability (except where a moderate aquifer is combined with a highly permeable aquifer). Areas where low permeability formations (bedrock or drift) occur, where groundwater is least vulnerable, are coloured green. There still remains a risk of groundwater pollution within areas classified as moderate or low vulnerability, but owing to reduced permeability, the risk, and therefore vulnerability of groundwater, is considered to be lower.



There are a number of small areas where drift geology is unknown (see section 3.2). These areas are distinguished on the aquifer vulnerability map because it is impossible to determine aquifer vulnerability (of either solid or drift aquifers) without taking drift permeability into account. There are also a few very small areas where solid geology is unknown (see section 3.1).

5 Drift Thickness

The final overlay shows where there is a strong probability that greater than 5 metres thickness of clay is present in the drift sequence, shown as a transparent hatching. Because the drift sequence can be highly heterogenous, high permeability sands and gravels may outcrop at the surface while at depth there is a thick sequence of till or lacustrine clays. Any bedrock aquifers beneath these areas will receive a certain amount of protection from the clay layer in the drift, which will inhibit recharge to the bedrock aquifer. The information to create this overlay is derived from BGS borehole archives. It should be noted that where no hatching is present it does not necessarily mean that there is less than 5 metres thickness of clayey drift. In many areas a lack of borehole records may make it impossible at present to identify the presence of clays. If more permeable drift deposits (e.g. sands and gravels) overlie the thick clay layer, they will not be protected.

6 Copyright

The digital line work and vulnerability classifications on the GIS are the intellectual property of the British Geological Survey and the use of the GIS is subject to a licence agreement between the Council and BGS (Licence No. 2002/61). It follows that the GIS should only be used by Aberdeenshire Council for internal purposes and therefore should not be given or lent to a third party.

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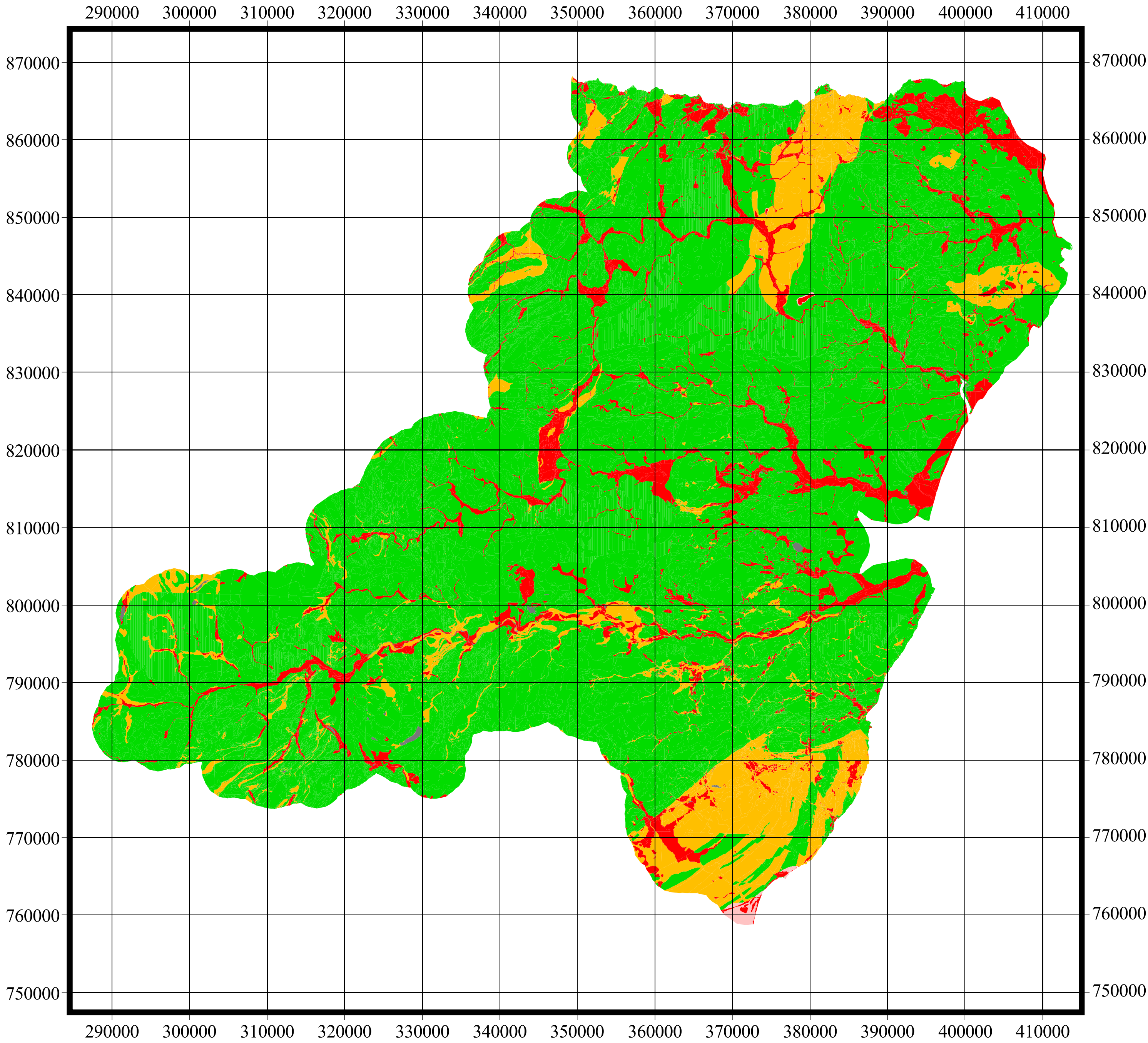


Coastline

County boundary

Greater than 5 m clay in drift

Aquifer Vulnerability

HH HN HM MH LH

HL

MM MN ML LM

LL LN

MU LU

UN

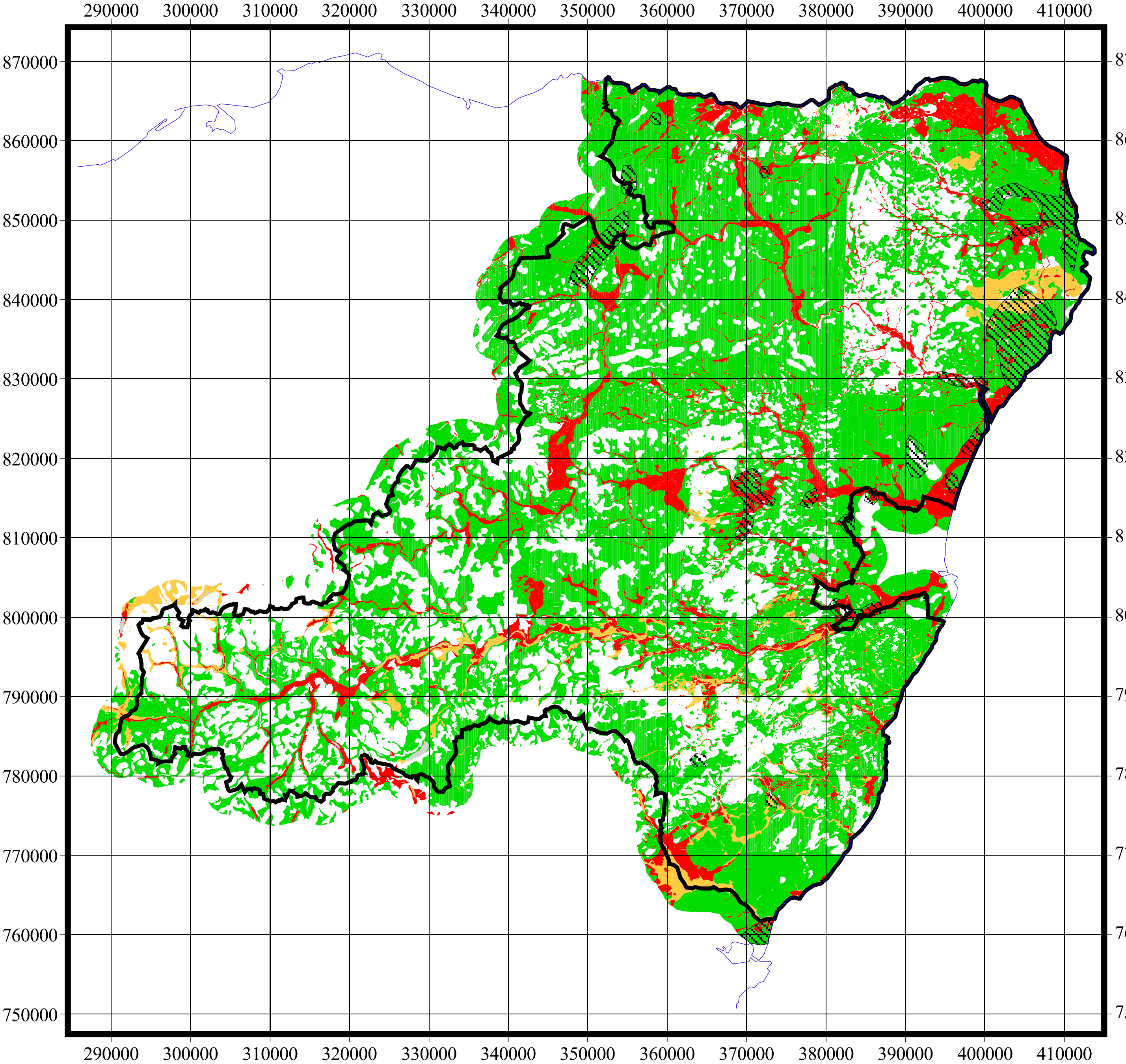
The first letter in the permeability combination corresponds with Solid Geology permeability. The second letter corresponds with Drift Geology permeability.

H = High
M = Moderate
L = Low
N = No Drift
U = Unknown Geology

Map prepared by the British Geological Survey 2002.

This map is intended for general use only and should not be used for detailed site investigations. Contact the British Geological Survey for further guidance.

Figure 3 Aberdeenshire Aquifer Vulnerability



Coastline
Greater than 5 m clay in drift
County boundary
Drift Permeability
High
Moderate
Low
Unknown Geology

Map prepared by the
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Figure 2 Aberdeenshire Drift Geology Permeability

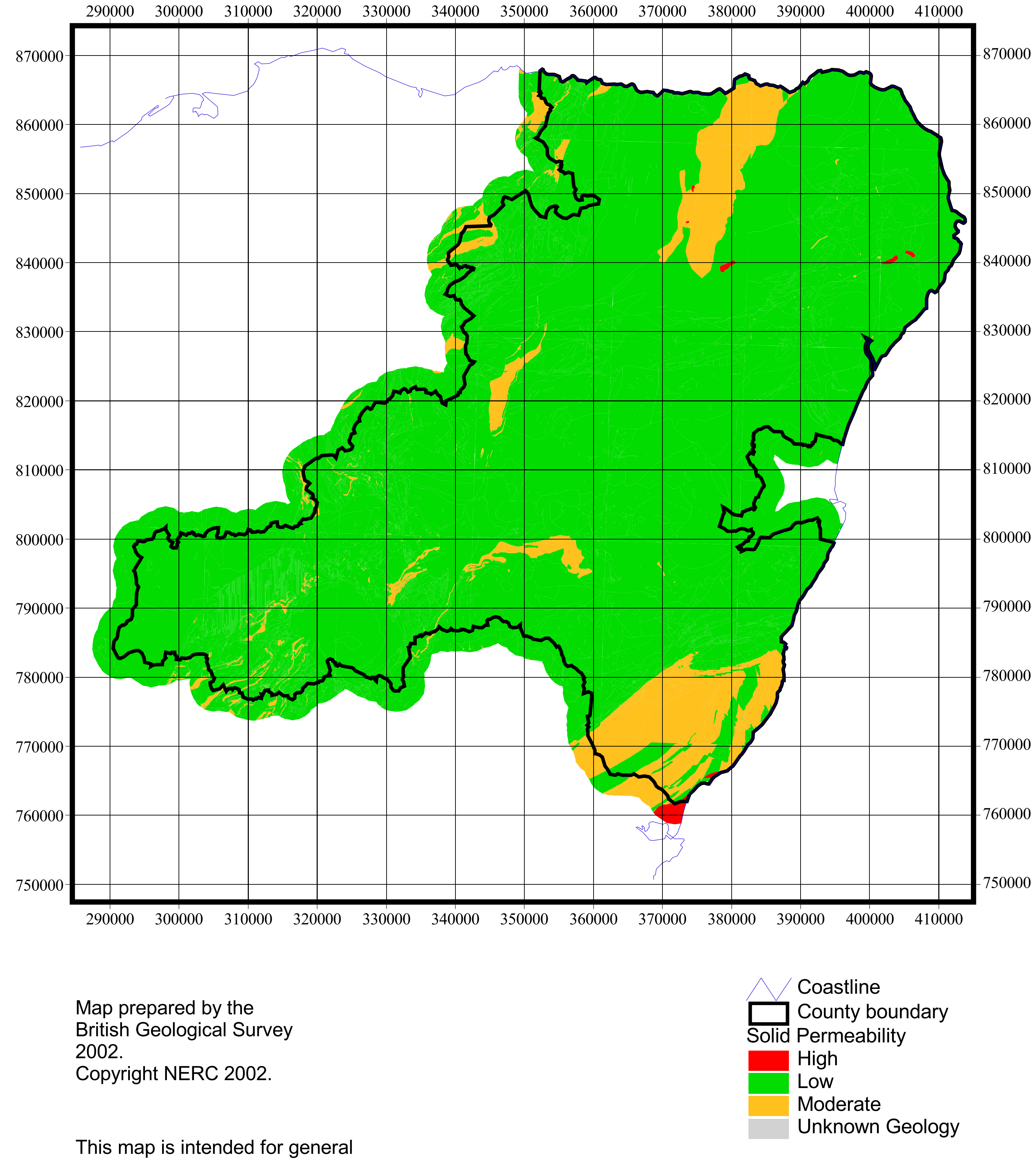

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Figure 1 Aberdeenshire Solid Geology Permeability