# Visualising Risk for Hill Walkers

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**Abstract**
The map plays a critical role in the planning and execution of a hill walk. The walker takes into consideration many factor such as distance, steepness, amount of ascent, the logistics of getting to and from the mountain, identifies 'exit' points, and alternate low routes. On the day, such things as the weather, level of fitness and amount of daylight remaining are taken into account. During the walk, all kinds of factors are continually under review. Woven into these decision making processes is an assessment of hazards, risks, susceptibility and the significance or consequences of 'suffering' various hazards. This research examines ways in which we might model risk, and then visualise that risk. The idea being that a risk variable might be included in topographic maps. A map is already brimming with information, so careful consideration needs to be made as to how best to include this information without 'hiding' other information already present in the map. The results were evaluated from a cartographic and a decision making perspective. The idea of making risk more explicit raises ethical questions but the results indicate that when risk is visualised, it does indeed alter people's decisions when selecting walking routes.

## 1.0 Introduction

The notion of risk, of human susceptibility, and the consequences of taking risks are in themselves fascinating topics. In the context of outdoor pursuits we can readily identify risk associated with the environment, and the changing nature of that risk, either in response to decisions made, or to changes occurring in the environment (changing weather or daylight). There are complex dependencies between risk (both perception and evaluation of that risk), and the decision making process (Slovic et al., 2004; Parkin & Balbus, 2000; Husdal, 2001; Sjöberg, 2000). Ralston (2004) provides an amazing illustration of how people assess and choose to cope with risk. This research has as its 'case study' the rambler or hill walker. In essence it explores ways in which we might visualise risk in order to support a number of activities associated with hill walking (namely route planning and execution).

## 2.0 Modelling and Visualising Risk

What is intriguing about risks typically associated with rambling is that we can infer a great deal about risk by viewing maps – in the UK via Ordnance Survey's 1:25 000 scale OS Explorer™ product, or the 1:50 000 scale OS Landranger® product. The interpretive process very much depends on 1) the user's experiences, 2) their cartographic knowledge and ability to interpret the map (particularly slope and form), 3) their understanding of the 'interaction' between the morphology of the landscape and the climatic conditions (and forecast). There is a complex interplay between (spatial) decision making, remoteness, resources and equipment, and changing conditions that can alter the situation from one of being relatively risk free to one of great danger and exposure (Saku, 1992; Walker, 1988; Carter, 2005).

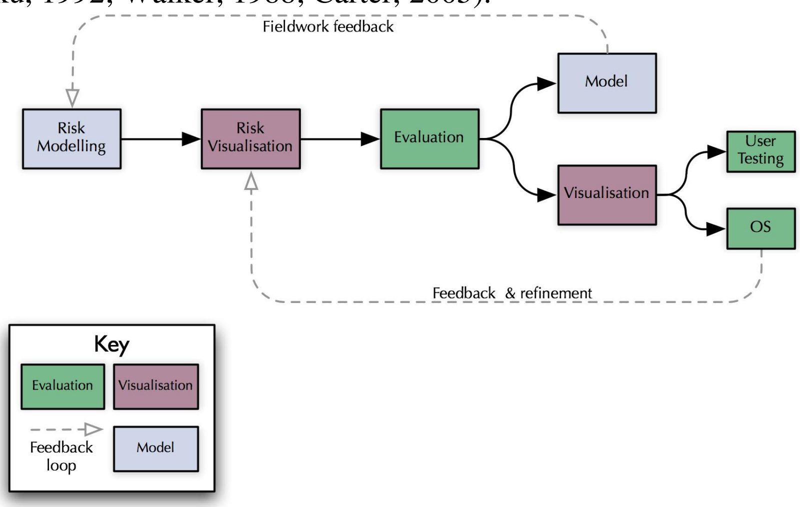


**Figure 1**: An overview of the methodology

Clearly then, there is a real dynamic to risk. But there are a set of variables related to risk that hold constant, and can be mapped – variables such as slope, aspect, and land cover type. The challenge of this research was to examine ways of making more explicit risk information, to model risk, and devise ways of including this information in 1:25 000 mapping. Such work is relevant in teaching, and in the context of changing access to land (Countryside Agency, 2004). Consequently, land that may not contain marked paths thus requires more careful assessment given the breadth of choice in where one can wander (for example over open moorland).

## 3.0 Methodology

There are two distinct components to this research. Devising and implementing a model of risk, and the visualisation of that risk (Figure 1). The model described below was built for a 12km² area in the Lake District National Park, in the UK. The results from the visualisation of risk were evaluated in a variety of contexts.

## 4.0 Modelling Risk

There are three aspects that need to be developed. How risk can be 1) defined, 2) 'experienced' by individuals in a walking context, 3) assessed by individuals in different ways. 'Hazard' can be defined as a situation or landform that may cause harm, or has the potential to do so. Risk is the likelihood of harm caused by the hazard. Risk assessment is the identification and quantification of the risks associated with those hazards (Barrow, 2004, p107). This research used a newly devised Subjective Risk Ranking (SRR) assessment to produce a quantitative model of walking risk, by first ranking hazards (Morgan et al., 2000) associated with walking risk, then applying a scale to the ranked values. Once the landcover types have been ranked, a numerical risk value was assigned to the landcover type. The scale used was initially devised by Malczewski (1999) and links a textual importance scale to a number (Table 1):

| |
|---|
| 1 - Equal importance |
| 2 - Equal to moderate importance |
| 3 - moderate importance |
| 4 - moderate to strong importance |
| 5 - strong importance |
| 6 - strong to very strong importance |
| 7 - very strong importance |
| 8 - very to extremely strong importance |
| 9 - extreme importance |

**Table 1:** Malczewski's classification of importance.

| | |
|---|---|
| Boulders* | Rock (Scattered)* |
| Boulders (Scattered)* | Rough Grassland* |
| Cliff* | Scree* |
| Coniferous Trees* | Scrub* |
| Coppice Or Osiers* | Slope* |
| Heath* | Coniferous Trees (Scattered)* |
| Marsh Reeds Or Saltmarsh* | General Surface |
| Multi Surface | Nonconiferous Trees (Scattered)* |
| Nonconiferous Trees* | Step |
| Rock* | Track* |

**Table 2**: Ordnance Survey's Landcover Types in OS MasterMap.

Ranking allows a hierarchy of risk to be assigned to the categories in relation to each other, which then facilitates a greater clarity when assigning numerical risk values to categories individually. Ranking the risks is not value free, and depends on the knowledge of an expert who might have previous biases or preconceptions. Establishing a list of variables that could affect the walker is essential, but should relate to the data available. In the case of this research, it was

OS MasterMap®, and the descriptiveTerm field. Initially it was assumed that the final output for the model would be the temporally-fixed paper map. Therefore temporal aspects were not considered, only those which can be defined in space (one could envisage much greater utility via delivery in real time over mobile devices – enabling incorporation of temporally variable information such as weather conditions).

OS MasterMap contains individual landcover types (Table 2), in the descriptiveTerm field. Only the non-generic landcover types were utilised (starred values) because no actual landcover can be inferred from 'Multi Surface' or 'General Surface' attributes. In accordance with the risk ranking methodology, these individual landcover (LC) types were ranked in risk order, then Malzewski's scale (MV) was applied to the ranked Landcover types (Table 3).

| Ranked Position | Landcover Type | Malzewski's value |
|---|---|---|
| 1 | Track | 1 |
| 2 | Scrub | 2 |
| 3 | Coniferous Trees | 3 |
| 4 | Coppice Or Osiers | 3 |
| 5 | Nonconiferous Trees | 3 |
| 6 | Coniferous Trees (Scattered) | 3 |
| 7 | Coppice Or Osiers | 3 |
| 8 | Nonconiferous Trees (Scattered) | 3 |
| 9 | Heath | 3 |
| 10 | Boulders (Scattered) | 4 |
| 11 | Rock (Scattered) | 4 |
| 12 | Boulders | 6 |
| 13 | Rock | 6 |
| 14 | Rough Grassland | 6 |
| 15 | Marsh Reeds Or Saltmarsh | 7 |
| 16 | Scree | 8 |
| 17 | Slope | 8 |
| 18 | Cliff | 9 |

**Table 3:**Linking Malzewski's scale to landcover type.

| Degrees of slope | % Weighting Increase |
|---|---|
| 0 | 100 |
| 5 | 111 |
| 10 | 122 |
| 15 | 133 |
| 20 | 144 |
| 25 | 155 |
| 30 | 166 |
| 35 | 177 |
| 40 | 188 |
| 45 | 199 |
| 50 | 210 |
| 55 | 221 |
| 60 | 232 |
| 65 | 243 |
| 70 | 250 |
| 75 | 250 |
| 80 | 250 |
| 85 | 250 |

**Table 4:** Modelling slope risk in the model.

The risk values in Table 3 assume there was flat ground, which is not realistic. The LC risk was multiplied by a slope risk increase percentage (S%), to produce a model with slope risk included. Slope information was derived from Ordnance Survey Land-Form PROFILE® data. The scale used is illustrated in Table 4. A linear percentage increase was used, anticipating that these values would be refined during the evaluation stage. This works in tandem with the established landcover risk. The risk value (RV) can be defined by the equation:

Risk value = (Landcover Malzewski Value) * (Slope Percentage Risk Increase) (1)

RV = (LCMV) * (S%) (2)

In practice, OS MasterMap contains concatenated categories, joining multiple single categories to accurately portray land, for example *Coniferous Trees; Nonconiferous Trees; Rock; Rough Grassland.* To cope with this equal weightings were applied for up to 3 categories, with the 4$^{th}$ ignored in all cases. Table 5 shows the weighting system applied:

| *Number of concatenated categories* | *Percentage weighting of individual categories* | | | |
|---|---|---|---|---|
| | *1* | *2* | *3* | *4* |
| *1* | *100%* | - | - | - |
| *2* | *50%* | *50%* | - | - |
| *3* | *33%* | *33%* | *33%* | - |
| *4* | *33%* | *33%* | *33%* | *[ignored]* |

The equation for a 3 category descriptiveTerm is:

Risk value (overall) = (33% * Risk Value 1) + (33% * Risk Value 2) + (33% * Risk Value 3) (3)

**$R_V$ Overall = (33% * $RV_1$) + (33% * $RV_2$) + (33% * $RV_3$)** (4)

In order to use the model with OS MasterMap data, slope was inserted into the attribute table, achieved by intersecting a TIN Feature class with OS MasterMap. This enabled the model to lookup the slope value along with the landcover type. The risk model was constructed in a spreadsheet, and the risk values are calculated by importing OS MasterMap's attribute table into the spreadsheet and performing a lookup routine on the data. The table is then imported back into ArcMap for visualisation. The model is flexible such that any future changes in OS MasterMap can be reflected in changes to the weightings in the model.

4.1 Risk Model Output

The risk model produced a range of output values from 0 (minimum risk) to 22.5 (maximum risk). Ground truthing indicated that modelled risk was accurately represented on the ground, where the landcover type was correctly attributed. Ground truthing was undertaken by walking some areas of the landscape, and re-adjusting the weightings where they were deemed out of place. Figure 2 shows the associated risk values for certain areas of land. There are a range of values for each polygon, representing the minimum and maximum risks for the associated polygonal areas. The polygons have been sketched on with reference to the original OS MasterMap data.

## 5.0 Visualising Risk

The key visualisation requirements were that it be readily interpretable (distinct from other map information), and visually ranked (from low to high risk). Three maps styles were created, and the process of iterative design was applied.

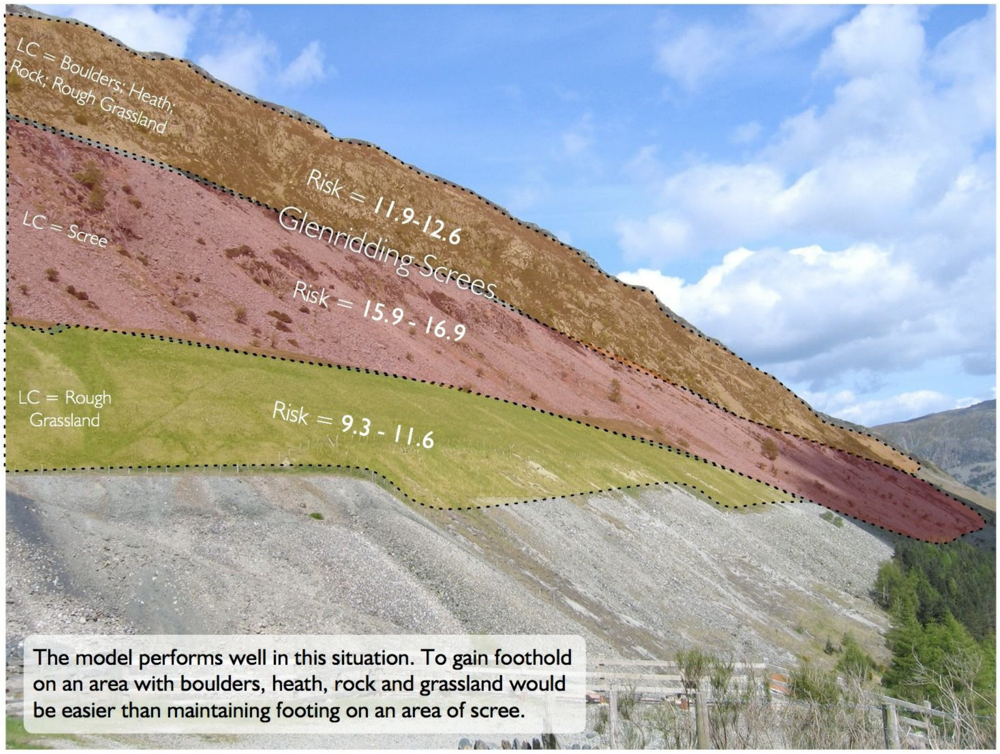


**Figure 2:** Ground truthing: Comparing output against visual imagery.

5.1 Map Style 1

There are specific benefits to using a spectral colour ramp to display all risk values (0-22), (*see* Brewer 1997 for detailed discussion). In response to comments from cartographers at the Ordnance Survey, a new style was designed (Figure 3). An interim design (formed from a critique of the first map style) was found to compete too much with the underlying information but again led to revisions which led to evaluation of a third style (Figure 4). Map style 3 embeds the risk information into the contour lines, which means there is no competition for space, only colour. Due to the production method of MS3, the contour values and spot heights are not present (not an ideal situation). The same spectral colour ramp was utilised from Map Style 1. Technically, this symbology is a separable bivariate symbol (Nelson, 2000), as it conveys risk and topography concurrently.

**6.0 Evaluation & Discussion**

Though cartographers expressed concern over the volume of information and the user's ability to interpret the information, the route testing conducted with novice users indicated that with some training, they could cope with this additional information and indeed that it influenced their choice of route. Map Style 3 comprehensively displays risk for an area, leveraging existing content whilst maintaining overall coherency of the OS Explorer map. The only competition is for colour, not space. OS Explorer is an already densely packed map, thus making the matching of styles very difficult.

Two maps were produced for route testing: plain OS Explorer, and OS Explorer with Risk Map Style 1. Subjects were asked initially to draw a route from A to B on plain OS Explorer. The task was repeated with the risk indicator map (RIM), and the results compared. To assess the difference in risk between the OS Explorer and the RIM, the routes were digitised and the average risk calculated for each. All routes are shown in Figure 5.

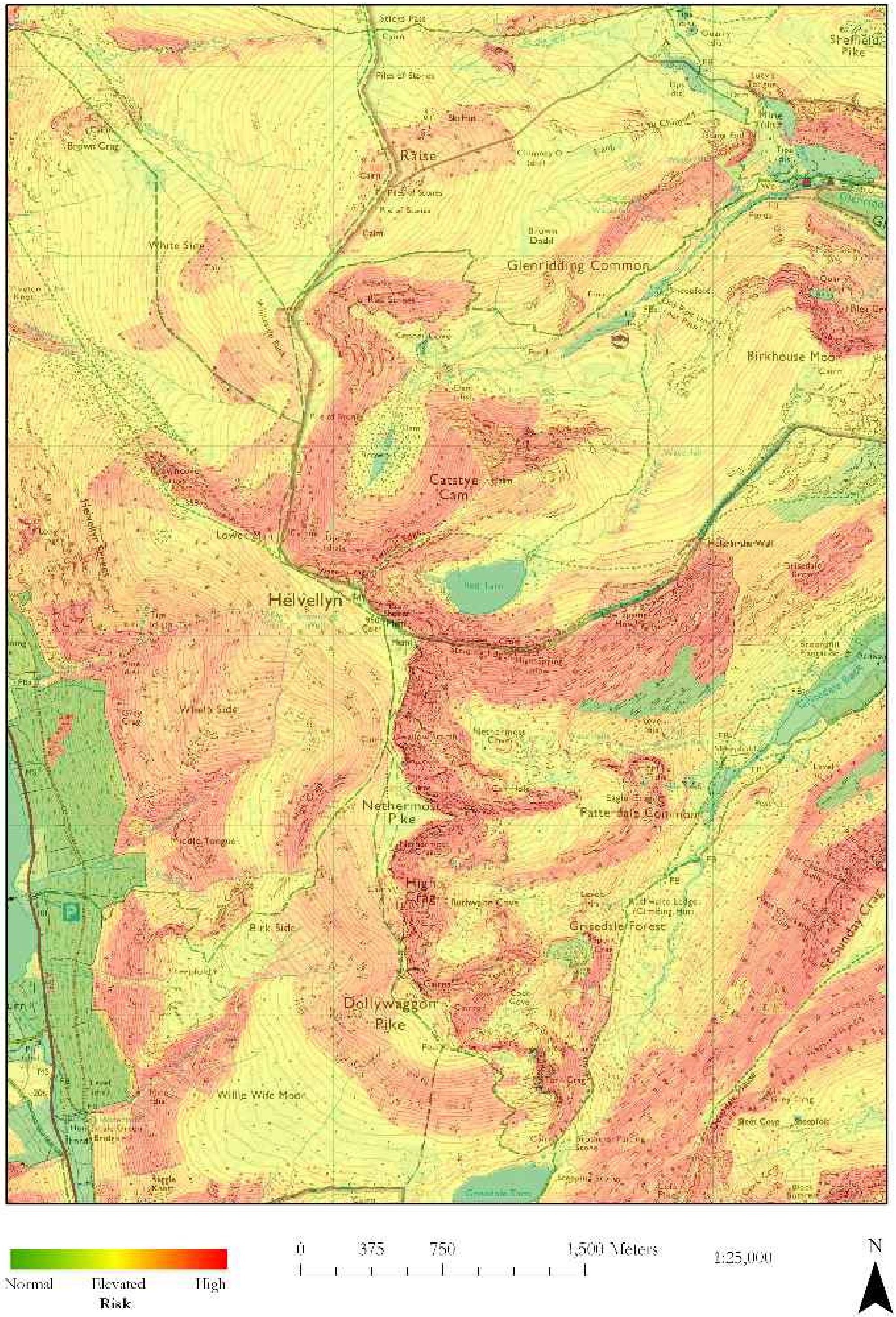


**Figure 3** Map Style 1

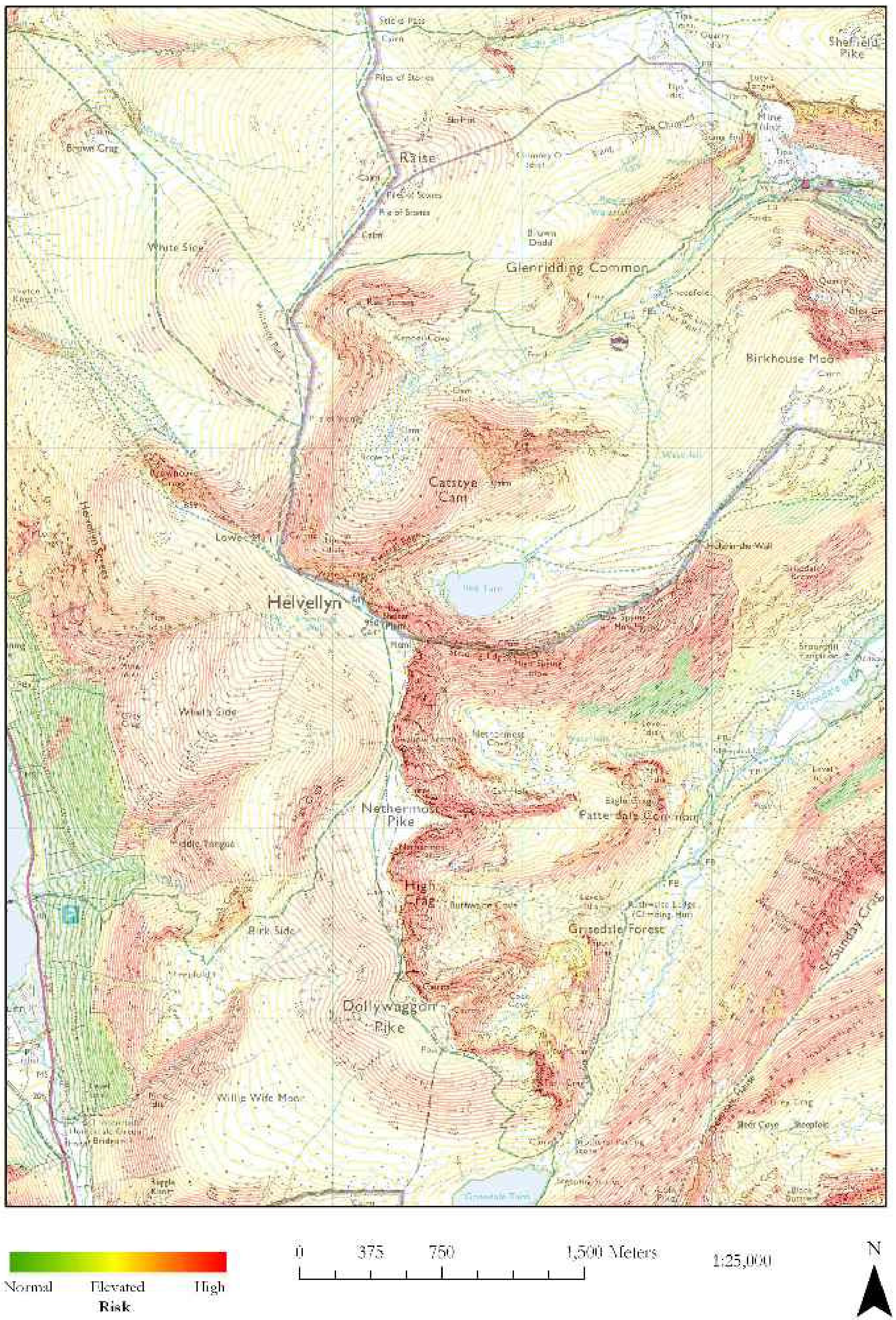


**Figure 4** Map Style 3

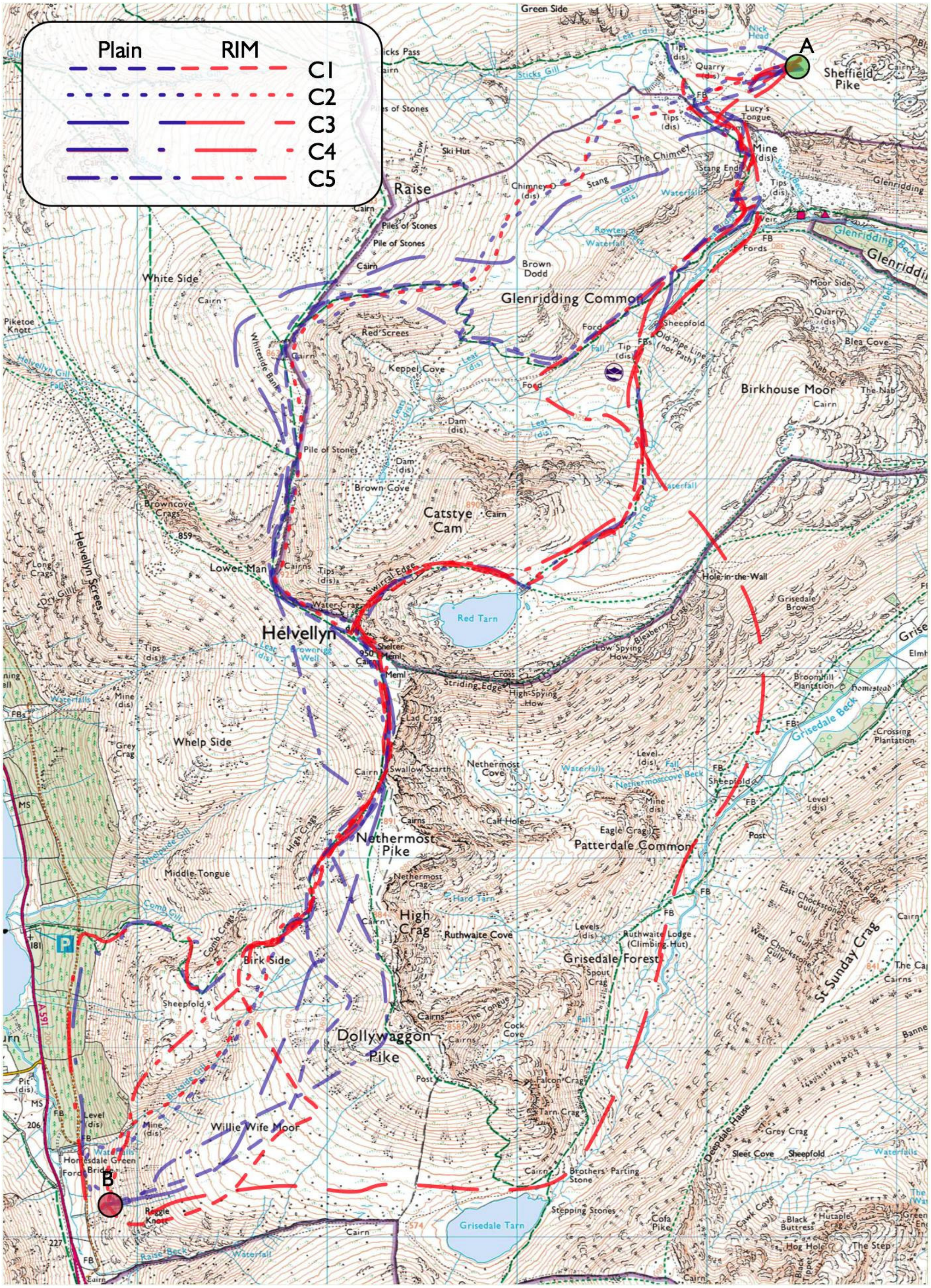


**Figure 5** Showing route choice for in user testing © Crown copyright/database right 2005. An Ordnance Survey/EDINA supplied service.

There were a number of interesting results. Two of the five candidates were inexperienced map users, two were experienced map users, and another who had some experience. The route choice for experienced users with the RIM was unaffected, but caused one to comment that it would be "useful for non-experienced users". Conversely, the way non-experienced users utilised the information was of more relevance. Using the plain OS Explorer map, a "beginner hiker" struggled to quickly interpret the information on the map. When presented with the RIM, the user immediately commented "it just makes sense", and said it allowed her to "take a more scenic route" whilst also allowing a "more accurate predecision [sic]". Another inexperienced candidate recognised that bunching contours would generally mean higher risk, and thus aimed to stay "on rivers and valley bottoms…it is flatter". The risk map allowed the user to "see right away what to avoid", speeding up the route selection when compared with OS Explorer. The user with moderate experience said the RIM was "much more easy to read by [just] looking at it, and that it was "easier for someone who isn't an expert user".

## 7.0 Conclusion

The quantification of risk is subject to a number of assumptions and simplifications that are open to challenge (e.g. the role of absolute height, soil moisture, or visibility). But the challenge was to model risk using only OS MasterMap and a DEM, and not to use external, temporally variable factors. If this type of risk mapping was available over mobile devices, then access to such dynamic information may well afford a more truthful and current representation of risk, and where ideas of augmented reality could be incorporated into the view.

The initial weightings were set by 'best guess' and adjusted slightly after fieldwork. The ordering of some categories were also adjusted. The sensitivity of the model was assessed by varying the weightings against each of the variables, but because of the spatial autocorrelation the changes in the map were slight.

The evaluation demonstrated that the more explicit presentation of risk information did indeed modify people's decision making. From a graphical point of view, it is clear that OS Explorer and OS Landranger products are already 'information full' – any design solution needs to avoid adding information to the point that the challenges of interpretation play against the benefits of this additional information. To that end there is a clear need for further investigation and evaluation of the risk model outputs.


## 8.0 Acknowledgements

Figure 3,4, 5 are © Crown copyright/database right 2005. An Ordnance Survey/EDINA supplied service. The authors are very grateful for the support of the Ordnance Survey and the invaluable advice of their cartographers.


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