LANDSLIDE MANAGEMENT IN THE UK, – THE PROBLEM OF MANAGING HAZARDS IN A 'LOW RISK' ENVIRONMENT

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ABSTRACT

As a country with limited direct experience of natural disasters, the UK has not developed a sophisticated legal and regulatory framework for the mitigation for many of the geological hazards, including landslides, which affect the population. Although the 1966 Aberfan disaster led to a limited amount of research into landslide distribution and mechanisms, it left no long-term legacy of managing landslide risks. A number of high-profile events in the late 20th Century, and a series of 'near-misses' since then have failed to stimulate a significant social or economic awareness. Perhaps understandably, this has limited political motivation to develop landslide management policies. This paper examines this situation and discusses some implications of how landslides are dealt with by the UK government and devolved governments in Scotland, Wales and Northern Ireland.

Policy is based mainly upon national assessments of geohazards (including landslides) carried out in the 1980s and 1990s. These assessments provided the basis for planning policies and guidance that to some degree control development on or around unstable ground. Although this was an encouraging start, limited resources and political support over the longer term ultimately meant these initiatives failed to develop into an effective, integrated, national response to landslide hazards. Policies and regulations are open to interpretations which vary between devolved governments, building regulations and local planning offices.

Crucially, the resulting system offers no framework for the legal or financial responsibilities for hazard management. As a result, landslide management in the UK has been influenced more by planning and political structure than actual risks to the population. This situation partially arises from the limited data available on the overall cost of landslides on a national basis. Until this situation is rectified it will be difficult to establish a mitigation strategy based on risk.

This paper discusses how landslides are managed in the UK and provides examples from around the country of how the system responded to some serious landslides occurring over the last twenty years. Examples are presented that show how this framework has affected the investigation and mitigation of different types of landslides. The paper also briefly discusses the role of insurance in landslide hazard management and highlights the effective response of Transport Scotland in the aftermath of the debris flows in 2004.

Keywords: Landslides, management, land-use planning, responsive planning

GEOHAZARDS AND LANDSLIDE HAZARDS IN THE UK

In an international context, the UK is relatively unaffected by major disasters. The country is seismically stable, contains no active volcanoes, has few active large-scale inland landslides (though there are a number of active coastal ones where marine erosion contributes to instability, for example, at Black Ven in Dorset and Sidestrand in Norfolk) or karst failures and, due to its temperate climate, has few problems with droughts or wildfires. Swelling, and particularly shrinkage, of clay soils cause the largest ongoing financial losses of any ground condition (Culshaw & Harrison 2010) but do not cause injury or loss of life. Economically, storms and flooding are the most significant hydro-meteorological hazards, which for the June-July 2007 floods, caused around £4bn of damage - £3bn in insurance claims (Pitt 2008) and about £1bn in further costs (Chatterton *et al*. 2010). However, flood events are not regular and only affect limited parts of the UK landmass, along the lengths of certain vulnerable floodplains and coastal areas. This relative safety has had a pervasive effect upon the attitudes of the general public, planners, politicians and even some geoscience professionals towards geohazards, when compared with other countries in geologically less stable areas.

The largest loss of life caused by a single landslide in the UK occurred on 21st October 1966 when a waste tip formed by coal spoil failed and destroyed a school in the South Wales town of Aberfan, killing 144 people, most of whom were children (Anon. 1967). In recent years, the only other landslide incidents to result in multiple fatalities involved a school party at Lulworth Cove, 21st February 1977, and an incidence at Boscombe, Wiltshire, which killed 3 workmen in 1925.

All recorded deaths due to landsliding in the UK have resulted from rock falls or debris flows (Table 1). Despite the small dataset, the nature of fatal landslides shown provides a number of important points relevant to the basis of land-use planning in relation to landslides in the UK. First, there are very few fatal landslides in the UK. Second, fatal landslides are very isolated and tend to involve only single individuals. Third, there is no consistent pattern from year to year.

Table 1. Recorded fatal landslides in the UK categorised by type and by the activity of the casualties at the time of the incident. Indirect fatalities such as vehicle collisions or dam bursts are not included, nor are those fatalities occurring in quarries.

Landslide Event	Year	Killed	Type (after Varnes 1978)	Geographical setting
Newbiggin, Northumberland	2010	1	Rock fall	Coast
Whitehaven, Cumbria	2007	1	Debris fall	Coast
Ben Nevis, Lochaber	2006	1	Rock fall	Mountain
Nefyn, Gwynedd	2001	1	Debris flow	Coast
Newquay, Cornwall	1986	1	Rock fall	Coast
Durdle Door, Dorset	1979	1	Rock fall	Coast
Lulworth Cove, Dorset	1977	3	Rock fall	Coast
Swanage Bay, Dorset	1976	1	Rock fall	Coast
Kimmeridge Bay, Dorset	1971	1	Rock fall	Coast
Aberfan, S Wales	1966	144	Debris flow	Hillside/spoil tip
Alum Bay, Isle of Wight	1959	1	Rock fall	Coast
Boscombe, Wiltshire	1925	3	Rock fall	Coast
Loch Ness, Scotland	1877	1	Rock fall	Mountain

Bearing in mind the limitations of the dataset, there also appears, once the Aberfan disaster is removed, to be a trend of increased *reported* fatal landsliding in the UK during and since the 1970s. Further research is underway to investigate this pattern, but it is possibly a result of increasing utilisation of coastal sections for leisure activities (French 1997). The trend may also reflect a general increase in UK society's sensitivity to the impacts of natural disasters.

Regardless of the statistical significance, it is difficult to underestimate the wider impact of the

Aberfan disaster upon British society. Prior to this event, there was little government interest in mitigating any dangerous ground – rebuilding the economy and national infrastructure following World War II was the priority, with resources prioritised towards developing the manufacturing sector, and supporting exploitation of energy and mineral resources. The disaster prompted a government-appointed Tribunal of Inquiry into the landslide (Anon. 1967). Research into mapping landslides was stimulated in the 1960/70s after unexpected problems during construction projects highlighted ground movement as a potentially significant problem in other parts of the country (Early and Skempton 1972; Skempton and Weeks 1976; Chandler 1970).

In the mid-1980s, the UK Government's Department of the Environment (DOE) commissioned a study to build a national register (database) of landslides in Great Britain (not the UK, therefore omitting Northern Ireland, the Channel Islands and the Isle of Man). This was completed in 1994 by Geomorphological Services Limited (GSL) in collaboration with Rendel, Palmer and Tritton. The work was effectively a desk study of readily available information sources (including British Geological Survey [henceforth referred to as BGS] maps, which provided over 35% of the recorded landslides) and built a picture of 8835 landslides (Jones & Lee 1994).

However, as discussed by those authors and elsewhere (Foster *et al*. 2008), the study was limited and underestimated the landsliding problem in Britain (because it was based on information in the public domain [Jones & Lee 1994]). Anticipated long-term funding (from sales of information or research grants) to develop the database was not forthcoming and further formal studies ceased.

However, this study did produce the first overview of the pattern of landslides and landslide hazards across the country. Though limited in detail, it provided sufficient information to inform government on the development of planning policy for landslide mitigation. Further papers describe the new BGS National Landslide Database that has been developed since 2000 (Foster *et al.* 2008; Pennington *et al*. 2009; Foster *et al.* in press). By the end of 2010, the BGS National Landslide Database contained information on over 15 000 landslides in Great Britain.

Since 2006, the BGS has also collated information on landslides reported in the media that have affected the UK (Table 2). This shows that there are an average of about 28 reported landslides in the UK every year. However, not all these landslides will be added into the BGS National Landslide Database, as some information reported lacks detail and cannot be verified without field evidence; there are between 10-15 new landslides entered into the BGS National Landslide Database each year.

Table 2. Landslides reported in the media in the UK, April 2005-December 2010.

Year	Number of landslides
2010	38
2009	38
2008	10
2007	38
2006	32
2005 (from April)	11

The BGS has also developed a Geographical Information System (GIS)-based system, GeoSure, to assess the principal geological hazards across the country (Foster *et al*. 2008; Walsby 2007, 2008). The output from this is a series of GIS layers that provide ratings of the susceptibility of the country to landsliding on an A-E scale, where A is very low susceptibility and E is very high susceptibility (a simplified small-scale version of the map is shown in Fig. 1). The model has been produced at 1:50 000 scale and can be usefully output as a map to show the spatial distribution of landslide susceptibility. By comparing this with the known locations of population centres and properties the model can be used to provide a useful estimate of the significance of landsliding nationally. According to the dataset, 350 000 households in the UK, representing 1% of all housing stock, are in areas considered to have a 'significant' (susceptibility zones D and E) landslide susceptibility.

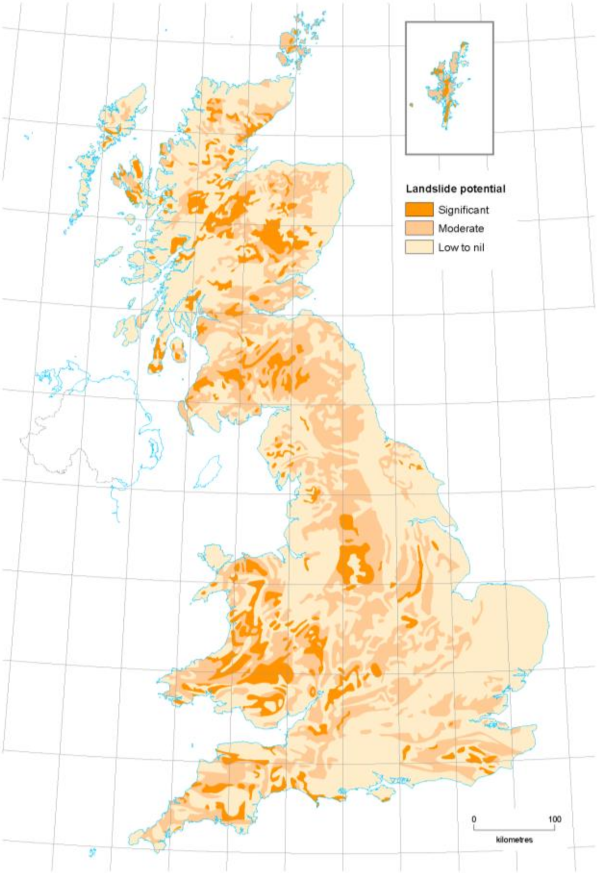

Fig. 1 Landslide susceptibility map of Great Britain derived from the BGS GeoSure model. This version of the dataset has been produced for the general public, with susceptibility zones used to depict areas of low to nil, moderate or significant landslide potential. The map is based on data at an original scale of 1:50 000

In the authors' experience of working with geologists, civil engineers, planners, politicians and the general public, landslides are recognised as a problem but the threat that they pose to life, property and infrastructure is not always well understood. Many scientists and engineers seem to regard them as a localised problem, occurring only at a limited number of sites, or under extreme weather conditions. In the light of this perception, this paper uses the increased amounts of recently available information on landslide susceptibility and from case studies, to discuss how landslides are managed in the UK.

LAND-USE PLANNING FOR LANDSLIDES IN THE UK

There is no centralised, legally binding mechanism for the management or mitigation of landslides in the UK. Issues relating to landslide problems are dealt with under common law and the primary responsibility is with the landowner (Department of the Environment 1996). The planning system, through the Town and Country Planning Act (1990), regulates the development of land and its powers are exercised through Local Authorities. The Housing Acts (various) and Building Regulations Act also allow the Local Authorities to exercise control over certain aspects of development. Similarly, the Construction (Design and Management) (CDM) Regulations (Anon. 2007) also are relevant to safe construction. Further considerations of public safety are made in the Coal Mining (Subsidence) Act

(1991), Coal Industry Act (1994) and Occupiers Liability Acts (1957, 1984). The elements of these regulations and acts relevant to Local Authorities regarding landslide management are:

1. Strategic planning: production of a development plan, which, once approved by central government, is a blueprint for development of the whole area for at least the next 10 years (Alker *et al*. 2002).
2. Development control: provide planning permissions for (re)development that accord with the development plan ensuring that these meet all statutory and regulatory requirements (Alker *et al*. 2002).
3. Building control: ensure that buildings are designed, constructed or altered so as to be structurally safe and robust (Anon. 2004).
4. Emergency planning: plans prepared for, and enacted in the event of, crises and disasters (Alexander 2002).

The Government has advised planning authorities, through Planning Policy Statements (PPS) 1 and 12, that the planning system must regulate the development of land in the public interest and take into account whether proposals would affect amenities, building and land which should be protected in the public interest (Office of the Deputy Prime Minister 2005; Communities and Local Government 2007, 2008). Further guidance covering unstable land (including landslides) is given in Planning Policy Guidance Notes, PPG14 and Annexes (Department of the Environment 1990, 1996; Department for Transport, Local Government and the Regions 2002) which set out the responsibility of the developer to determine whether the land is suitable for the proposed purpose. PPG14 and its annexes provide guidance on how slope instability should be considered in any planning decision and that, if landsliding is a known issue, 'a developer' must provide evidence that any development activity will not exacerbate landslide activity and that any building will be safe. The guidance note related to slope instability is not legally binding. It does state that *"The stability of the ground in so far as it affects land use is a material consideration which should be taken into account when deciding a planning application."* However, it goes on to state that: "*Many local planning authorities may not, in any event, have the required expertise available to them. Where relevant expertise is available on issues such as mineral planning, waste disposal, land reclamation, building control, surveying or engineering, the local authority should endeavour to make use of it."* The list does not include geological or geotechnical expertise but details of some sources of information are provided, including the BGS. There is no legal compulsion for a planning authority to understand the extent or nature of landslide hazards within their area of concern and, thus, include them in planning decisions.

Building regulations provide a further control on the impact of slope instability requiring that *"The building shall be constructed so that ground movement caused by (a) swelling, shrinkage or freezing of the subsoil; or (b) land-slip or subsidence (other than subsidence arising from shrinkage), in so far as the risk can be reasonably foreseen, will not impair the stability of any part of the building"* (Anon. 2004). Again, the liability is placed upon the developer, but there is no compulsion to seek out or use information that might indicate landslide hazard in, or around the development site. Building regulations and planning policy guidance were reviewed by Brook (1991, 2007). Brook & Marker (2008) warned about the threat to the perceived status of PPG/PPSs, particularly PPG14, which covers many geohazards, as the current planning system is 'reformed.' These reforms may further diminish the degree to which planning controls can be used as a mechanism to control landslide hazards.

The delivery mechanism for Health and Safety legislation is a complex series of regulations that oblige operators of utilities such as roads, pipelines and railways to protect citizens from any potential harm caused by their operations. These mechanisms place responsibility on the operators requiring them to prove to the government Health and Safety Executive that their activities do not compromise the safety of others. For instance, industry specific regulations require that quarry, pipeline and chemical warehouse operators and other such organisations must consider the potential impact of landslides upon their operations and any potential impact upon third parties. Although a complex system, it addresses concerns for specific industries. For instance, operators of chemical warehouses must submit a report which should demonstrate that the probability of a major fire is around 0.01/year. As part of this report, the possibility of a landslide initiating a fire must be considered, and if it is a problem, it must be shown that the risk is acceptable.

Citizens are also responsible for not causing damage to their property or that of others by exacerbating landslide hazards. For the most part, this will be managed by the application of planning or building code regulation, enforced by local governments. Citizens, landowners, operators and others will all come under the umbrella protection offered by the insurance and re-insurance industries. Most insurers provide some sort of geohazard cover as part of buildings/construction insurance policies. Insurers will, of course, assess risk according to their own policies and procedures but it is useful to consider that not all companies utilise geological data in their appraisals.

None of these mechanisms or supporting documentation provide comprehensive, up-to-date guidance on:

- the information that should be sought to assess landslide hazard;
- sources of appropriate information;
- how landslide information should be used and interpreted;
- how landslide information should be presented;
- what measures are appropriate in terms of public safety; nor
- what measures are appropriate for long term remediation.

The responsibility for accessing and using appropriate information always lies with the operator or their technical advisor. Recently, the international scientific community has produced a series of guidelines for local and national government officials, land-use planners, geo-professionals and project managers on landslide susceptibility, hazard and risk zoning (Fell *et al.* 2008a, b). These guidelines are similar to those produced in Australia (Australian Geomechanics Society 2007a, b). The guidelines are highly technical and no attempt is made to relate them to specific planning regulations in individual countries.

In the UK, current planning policy guidance, published in 1990, predates the era of GIS and advises that citizens consult geological maps and the Department of the Environment Landslide Database (now superseded by the BGS National Landslide Database [Foster *et al.* 2008]). Both datasets were difficult to access and virtually unintelligible to anyone without a geoscience background.

Such information has been made more accessible to the non-specialist by new geoinformation systems, for example, the BGS's 'GeoSure', described above and by making selected information from the BGS National Landslide Database freely available on the Internet. This and other data sources are easily accessible from a range of suppliers across the internet, yet guidance has never been updated to take this into account. So, even though there have been significant improvements in geohazard mapping and the generation of hazard data, much at public expense, there is still no requirement to use or even consider it within a landslide hazard assessment.

THE INSURANCE OF LANDSLIDE LOSSES IN THE UK

Losses caused by landslides were incorporated into domestic property insurance policies in the early 1970s (Doornkamp 1995a, b; Wyles 1983). The umbrella term 'subsidence' came to be used for natural ground movements whether caused by landsliding, dissolution, swelling and shrinkage of clays or some other geohazard process. Indeed, the vast majority of losses incurred by the UK insurance industry have been caused by shrinkage of clay soils during extended periods of low rainfall. These losses have occurred mainly in the south east of England.

However, claims against 'subsidence' losses, including those caused by landslides remained very low throughout the 1970s and 80s. Then, following a particularly dry period between 1989 and 1991, the UK insurance industry lost £1-2 bn. Since then, losses have averaged between £3-400m per year (Culshaw & Harrison 2010). Less than 5% of these losses are thought to relate to landsliding. The industry realised that it needed to understand better the risks to which it was exposed from geological hazards. As a result, a digital geohazard information system (GHASP – GeoHAzard Susceptibility Package) was developed by the BGS, which came to be used by around 35% of the Industry (Culshaw & Kelk 1994). This system was developed at a time when digital geological information was only just becoming available. Following the digitisation of most of the BGS spatial data in the early 2000s, a much improved geohazard information system (GeoSure) was developed (Walsby 2007; Foster *et al*. 2008). However, such information systems do not appear to be widespread, even in the more developed world.

Whilst buildings insurance is not compulsory, when obtained it does provide the property owner with a good measure of financial cover in the event of landslide damage occurring despite policy holders having to pay part of the cost of any claim. The existence of such cover is of particular value to owners of some older properties built in landslide susceptible areas before the planning guidance and building control standards, described above, were developed.

LANDSLIDE RISK TO INFRASTRUCTURE

It is the responsibility of infrastructure owners to assess the risks to their utility (pipeline, power line, road, railway, canal etc.) However, the owners are regulated by Health and Safety legislation and the level of acceptable risk is set by the UK Health and Safety Executive. As a result, infrastructure owners must assess the risk of damage, injury and death resulting from failure of their utility and take steps to reduce it to the acceptable level if the risk is too high.

Gibson *et al*. (2005) described research for the major national distributor of natural gas to determine the distribution and potential severity of geohazards across the UK. Of the many geohazards that affect the UK, landsliding and the dissolution of soluble rocks were considered to pose the greatest threat to the transmission network. BGS national hazard datasets for landslide and dissolution hazard were truncated to buffer zones centred upon the pipeline. These data were enhanced by detailed information from the BGS National Landslide Database and Karst Database (Foster *et al.* 2008; Foster *et al.* in prep.; Cooper *et al.* 2001; Cooper 2008).

The result of this research was a set of continuous GIS layers that showed the level of susceptibility to landsliding or dissolution of soluble rocks at any location on the pipeline network in the UK. The operator will use these data to: improve their risk assessment methodology, inform discussions on pipeline safety with their safety regulator and improve their surveillance strategies where it is considered that geohazards represent a potential threat to the integrity of the pipeline.

RESPONSE TO MAJOR LANDSLIDES IN THE UK

As with the planning system, response to landslide events in the UK is essentially a local matter, with little guidance available on the responsibilities to be taken or procedures to be followed. In the event of a major landslide, initial response is controlled by the civilian emergency services, police, fire service and medical personnel, working with the local authority and others within the framework of the local authority emergency plan (Siddle 1999). A multi-agency control centre may be formed to deal with initial rescue and security efforts. For example, following the Holbeck Hall landslide (see below), police and the coastguard provided security for the first 72 hours to prevent access to the slipped area (Clements 1994). Once this has been completed, responsibility for the site will pass to the landowner of the property affected or from where the landslide was sourced. Often it is the local government body or operator of a road or pipeline that will be responsible for repairing or stabilising the site to the extent that it will no longer pose a threat.

Less significant events, where a landslide may not cause immediate threat to life or property but may cause disruption to roads or railways, such as an embankment collapse, also tend to be dealt with locally. Typically, the landslide will be cleared within a few hours, with no record kept of the nature of disruption or repair. The Highways Agency, for instance, which is responsible for the maintenance of motorways and major roads in the UK, does not routinely record landslide events that affect its network; rather, it records that a repair action has occurred at a certain chainage, with little supporting information on the nature, cause or impact of the failure.

Some aspects of how this system operates in reality for both major and less significant landslides are illustrated by four case studies:

Holbeck Hall Hotel Landslide, Yorkshire, England, 1993

The Holbeck Hall Hotel in Scarborough, North Yorkshire, England (Fig. 2), was destroyed as a result of a landslide that took place over a period between the night of the 3rd and 5th of June 1993 (West 1994; Lee *et al*. 1998; Lee 1999; BGS 2008a). The hotel had been built in 1880 close to the coastal cliff top; the coast was known to have been susceptible to movement and slipping (though not recognised as landsliding at that time). Following an unusually wet period in May (West 1994), a pre-existing relict landslide reactivated and began to move downslope, the bulk of the movement taking place overnight. The foundation of the hotel was partially undermined and most of the structure of the hotel subsequently collapsed (Fig. 3). The remains of the hotel were demolished. The subsequent movement of the slide and collapse of the hotel was sufficiently slow to allow repeat visits to the site to monitor progress. The slow movement of the hotel also meant that all residents could be evacuated and that electricity and gas supplies could be switched off before they caused fire.

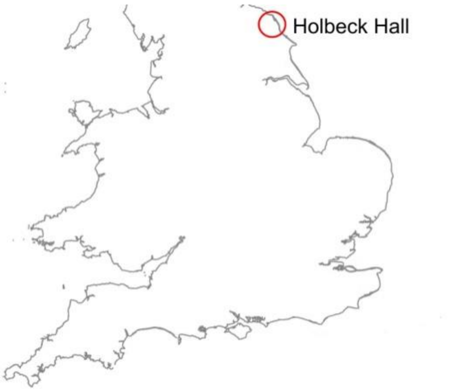

Fig. 2 Location map for the Holbeck Hall landslide

Fig. 3 The Holbeck Hall Hotel landslide, Scarborough, North Yorkshire

The landslide occurrence led to an extensive series of legal arguments due to a dispute over who was ultimately responsible for the landslide – whether it was the servant landowner (the owner of the hotel), or the local authority upon whose land the actual slide took place, or the organisation that had, some years before been commissioned to investigate the potential for slope instability in the area. The nature of legislation, where a duty of care is owed by the landowner (but only if they know the extent of the problem, and where there is no compulsion for them to fully investigate the problem), led to a situation where there was no clear responsibility for the event (Holbeck Hall Hotel Ltd v. Scarborough Borough Council, English High Court, London, 2000).

St Dogmaels Landslide, Pembrokeshire, South Wales, 1994

On 14th February 1994, landsliding was reported on slopes above the village of St Dogmaels (also known as Llandudoch), Pembrokeshire, Wales, which lies on the left bank of the Afon (River) Teifi (Fig. 4). This landslide (Fig. 5) occurred following a period of heavy rainfall. Though the landslide appeared to be slow-moving and did not immediately threaten the village, provisions were made to implement the local emergency plan, which involved evacuating the village. This preparation was led by the police with the support of the fire brigade, ambulance service and the military. On advice from engineering geologists, it was decided not to implement the emergency plan, though people from houses located on the landslide were evacuated. Several houses were severely affected and damage was caused to an 11 kV power line and to water mains supplies. In the event, the landslide did not impact on the main village.

Fig. 4 Location map for the St Dogmaels landslide

Subsequent investigations showed that the landslide was a reactivation of part of an ancient (12 000 years ago), complex, multiple retrogressive failure. The landslide was a moderately deep-seated non-circular failure and took place in glacio-lacustrine deposits which were up to 60m thick infilling a deeply-incised valley (Fletcher & Siddle 1998). Ground movements of up to 1m began at the head of the landslide and gradually progressed downhill. Movements continued for almost eight months. The ground movement affected the upper part of the ancient landslide, which, itself, extended down to the edge of the main part of the village of St Dogmaels.

The landslide appeared to be caused by the presence of artesian and sub-artesian groundwater levels in the glacio-lacustrine deposits and periods of higher-than-average rainfall in the months and weeks leading up to the failure (Maddison 2000). Other factors, such as the presence of a waste tip at the head of the landslide, poorly-maintained land-drains on the landslide and poorly-controlled drainage of water from springs upslope from the landslide, may have contributed to the failure.

Planners in the local authority had no previous knowledge of the landslide. This is not surprising as it was also unknown to the BGS, not being shown on the then current geological map which dated from the 19th century. Also, the landslide had not been described in any of the scientific literature.

Fig. 5 Landsliding at St Dogmaels. Image courtesy of Dyfed Police

One outcome of the landslide occurrence was the commissioning of a geological mapping and research project to identify geological factors relevant to planning and development in the catchment of the Afon Teifi (Walters *et al*. 1997). The study included a detailed landslide survey which identified 385 landslides; almost none were known previously. The results of the study have enabled the local authority to provide information, to developers and others seeking planning permission for building and construction, on the potential for landsliding. This must be taken into account in the submitted planning application.

Glen Ogle Landslide, Stirlingshire, Scotland, 2004

The Glen Ogle debris flow (Fig. 6) was one of several that took place in the summer and autumn of 2004 in the Highlands of Scotland for example, on the A83 trunk road between Glen Kinglas and to the north of Cairndow and on the A9 to the north of Dunkeld (Winter *et al*. 2006; BGS 2008b). This particular event involved two flows that crossed the A85 highway, north of Lochearnhead. The slopes in this area, formed within the Dalradian (Late Pre-Cambrian/Cambrian) Ben Lui Schist Formation, are characteristic of a glaciated terrain, with flat-topped hills (usually blanketed in peat), above steep (15-45°) slopes that lead down into flat-bottomed valleys. At this location, the A85 road traverses the side of one of these valleys, as a narrow two lane, single carriageway highway. Existing streams and channels in the schist are culverted underneath the road.

Fig. 6 Location map for the Glen Ogle landslide

On 18th August, a debris flow was triggered by an intense rainfall event that displaced a small peat slide into one of the streams that would normally drain through one of the road culverts (Fig. 7). This peat slide set off a cascade within the stream channel, first ripping up weathered bedrock, then mobilising a relict deposit of granular head/landslide material. This dense flow moved rapidly down slope, scouring superficial materials on the way and eventually overwhelming the drainage culvert designed to protect the road. The flows entirely blocked the highway, trapping 57 people in 20 vehicles, with potential for further failures. All 57 people were airlifted to safety by military helicopters. Vehicles were retrieved over the next 48 hours, after the debris flow had been cleared. The emergency evacuation was a complete success. However, disruption to the road was significant and lasted for weeks after the flow. A key outcome from this event was the realisation by Transport Scotland, that there was little strategic information on the debris flow problems that affected upland Scotland. As a direct result, a study was commissioned, which developed a model of the distribution of potential debris flows in Scotland, and the risks to the road network associated with them (Winter *et al*. 2005). The final results of this study were published by Winter *et al*. (2008) and will probably form the basis of a programme of remediation and further investigation of the problem.

Fig. 7 Debris flow deposit at Glen Ogle.

Nefyn Landslide, Gwynedd, North Wales, 2001

Fig. 8 Location map for the Nefyn landslide

The fourth example presented did involve a fatality and further illustrates the danger in the UK posed by debris on steep slopes. The slide involved a mass of only 100m^3 of material, moving just 12m down slope. The landslide occurred at Nefyn, Gwynedd, on the north coast of Wales (Fig. 8). The coastal slopes in this area comprise a complex sequence of Glacial Till and Pro-glacial outwash deposits. Over the past 16 000 years, these deposits have been affected by deep-seated rotational landslides, coastal erosion, periglaciation and weathering, resulting in a coastal cliff, 60m in height, with a distinctive stepped profile and a series of sub-horizontal benches separated by low cliffs. The horizontal benches have provided flat ground where debris, comprising weathered soil from the cliff and rotten vegetation, had accumulated in thicknesses of up to 8m. The days preceding the landslide had been characterised by very high rainfall, which had left the debris accumulation saturated. On 2nd January 2001, a small landslide in the upper cliff moved down slope onto the debris accumulation, causing this to fail by undrained loading (Fig. 9). Two separate debris lobes moved down slope, engulfing a number of parked vehicles, pushing two of them over a low sea cliff, resulting in a fatality to an occupant of one of the cars and serious injury to another.

The emergency response to the landslide was controlled by local police and fire officers who made the area safe and allowed access to investigation crews and specialist personnel (Fig. 10). Following the event, the BGS was commissioned to carry out an investigation into the cause of the landslide and the surrounding area. The result was a hazard map that provided guidance on future development in the vicinity (Gibson & Humpage 2002; Gibson *et al*. 2002; Jenkins *et al*. 2007). The report recommended that no development be allowed on, or below, the debris covered slopes; this recommendation has been followed and no new development has been allowed. However, there is no mechanism to prevent alterations, improvements or repair to existing property in the area. Since the 2001 landslide, a number of nearby properties have been damaged by small landslides and have been rebuilt. There is no legal mechanism to prevent this so long as there is no risk posed to third parties by the actions of the property owners.

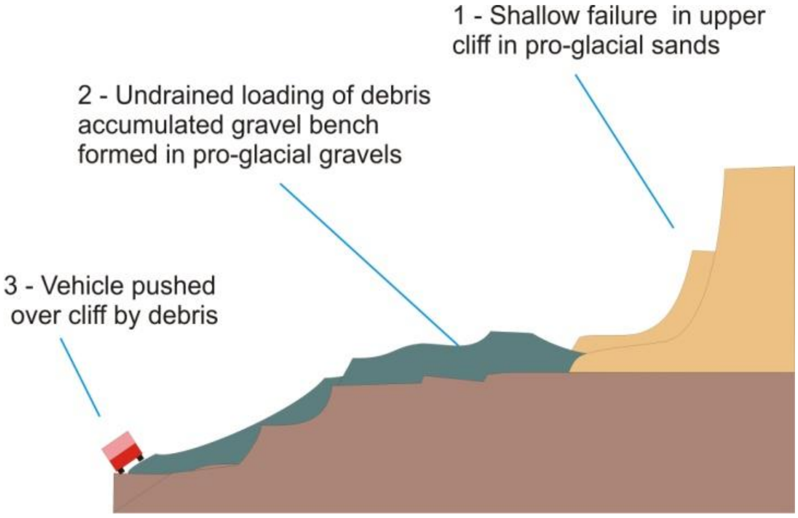

Fig. 9 Sequence of landslide events at Nefyn, 2 January 2001

Fig. 10 Landslide at Nefyn. Note the dark mudslide at the top of the slope (right hand side of the image) that could have triggered a similar debris flow above a residential property. Image courtesy of North Wales Police

RESPONSIVE MANAGEMENT OF LANDSLIDES IN THE UK

Although there are only a few examples presented here, they have been selected to illustrate the response to landslides that had a direct impact on people. When a landslide event occurs in the UK that requires emergency action, the response, by the emergency services, military, local government officials and general public is exemplary. It appears, from the case studies, that incidents are dealt with promptly in a well-structured and well-considered manner to ensure that public safety is maintained. In the case of the Nefyn landslide, this was confirmed by the Coroner's Court set up to inquire into the death that occurred. Each of the events presented here was followed by some form of investigation or review of the cause and impact of the landslide and led to follow-on actions, usually in the form of a public inquiry followed by a change in local planning policy or, in the case of the Glen Ogle debris flow, a national-scale study to fully investigate and assess the problem.

FINANCIAL LOSSES DUE TO LANDSLIDES IN THE UK

A brief examination of recent events presented by this paper shows that there have been, on average, around 28 landslide events in Britain each year reported by the media since 2005 (Table 2). As recording of new events and further research into past events continues, this picture may become clearer. Several of these events caused significant disruption to important transport links and had financial impacts of several million pounds.

Little information has been found about the total economic costs of landslides in the UK. For the Holbeck Hall landslide, economic costs, including emergency response, engineering works and insurance claims have been estimated as being in excess of £3.5m (£2m insurance claim and £1.5m for the emergency protection scheme needed to protect the slope from further landslides [Byles 1994; Clements 1994, Isle of Wight Centre for the Coastal Environment 2006, Forster *et al*. 2006]). For the St Dogmaels landslide costs were around £2.5m (£1.9m for the remediation scheme [Anon. 1999] and at least £0.5m for the demolished or damaged houses). However, costs are not available for the 2004 Scottish debris flows (including the Glen Ogle debris flows) and the Nefyn landslide of 2001. Costs for smaller landslides are very variable according to the assets they affect. For example, the Pennan landslide in Aberdeenshire in 2007 cost around £600 000 for stabilisation alone (BBC, 2009); the Cooper’s Hill landslide in Gloucestershire cost £1.24m for stabilisation (BBC, 2011).

These estimates of cost relate mostly to the direct cost of remediation. Little information is available on the indirect costs such as the cost of disruption to traffic and to the local economy. These figures do not take into account a further category of landslides: those well known complexes that have a continuing impact upon specific locations. These include the large areas of landsliding that affect the coastal towns of Ventnor, Isle of Wight (for example, Hutchinson & Bromhead 2002; Lee & Moore 2007; McInnes 2007), Lyme Regis, West Dorset (for example, Clark *et al*. 2000; Sellwood *et al*. 2000), Scarborough, North Yorkshire (for example, Lee & Clark 2000) and the World Heritage Site of Ironbridge, Shropshire, (for example, Culshaw 1973a, b; Carson & Fisher 1991). The continuing costs of some these major UK landslide complexes are available. For example, the total cost of the Ventnor Undercliff landslide on the Isle of Wight has averaged £1.4m per year over the last twenty years in terms of structural damage, insurance costs, engineering measures and monitoring (McInnes *et al.* 2000). Since 1990, investigation and engineering works at Lyme Regis have cost over £30m (including works not directly involved with slope stabilisation or coast protection), with a further £23m requested for future developments (Lyme Regis Environment Improvements Team *pers. comm.*, 2011; Anon. 2010). Landslide research, investigation, mitigation and remediation have been going on at some of these locations for more than 50 years. For example, in the Ironbridge Gorge, Henkel & Skempton (1954) discussed the causes of the Jackfield landslide that ultimately contributed to the closure of a railway line and the placing of previously buried services on the ground surface where they need regular maintenance. Carson & Fisher (1991) suggested that the landslide may have been active for over 200 years. In addition, a government review of the cost of coastal erosion in the UK found that the average cost was £126m per year, a significant part of which (not identified by the study) actually resulted from landsliding (Office of Science and Technology, 2003). However, such schemes are usually integrated with environmental improvement schemes that have design briefs far outside that of simple landslide remediation.

The figures above cover major landslides, long-term landslide complexes and small disruptive events. Further small losses are experienced in relation to houses. The BGS estimates that 350 000 houses in the UK are in areas where there is a significant landslide susceptibility. In December 2010, the average purchase price of a house in the UK was approximately £162 435 (Source: Halifax House Price Index:http://www.lloydsbankinggroup.com/media/pdfs/halifax/2011/HousePriceIndexDecember2010FINAL2.doc). This means that, in the worst case, there is, potentially, about £57bn worth of housing stock at significant risk of landslide damage in the UK. Hypothetically, if 1% of those properties received 1% damage in any given year, the total losses would be in the region of £5.7m per year. The figure seems to be in broad agreement with anecdotal evidence from the UK insurance industry on their losses from landsliding. However, specific data on insured losses to housing is not easily available. This is partly because losses caused by a range of geohazards (for example, swell-shrink, dissolution, compressible soils and others, as well as landslides) are grouped together under the misleading category 'subsidence' (Culshaw & Harrison 2010).

Taking all the costs above together, these losses might be considered to be large enough to warrant greater concern, even though injury and loss of life from landslides is very low. This is particularly the case if the climate becomes wetter as a result of climate change and the number of landslides increases. However, no systematic assessment of annual losses (including death and injury) resulting from landsliding in the UK has been made. This deficiency needs to be rectified before an appropriate response (if any) can be determined. This is a similar situation to much of Europe though landslide cost data are available for some countries such as Spain, Sweden, Norway and Italy (European Environment Agency 2010).

It is difficult to compare the losses from landslides with those resulting from other natural hazards such as flooding. The Association of British Insurers has indicated that losses from flooding are around £500m per year (Dailey *et al*. 2009), while losses from geological hazards ('subsidence') are of a similar magnitude (around £350m per year [Culshaw & Harrison 2010]). However, this figure does not separate out the contribution from landsliding alone. Further research is needed to more accurately determine the true cost of landsliding in the UK. Until this is done, it is difficult to determine if the current expenditure by government on landslide mitigation is appropriate.

THE IMPORTANCE OF 'NEAR-MISSES'

The case studies presented here were chosen also to illustrate a further point. Although each of these events was damaging, and one fatal, they could be considered to be 'near-misses' - the consequences of all of these events could have been much more significant.

The Holbeck Hall landslide could have occurred more rapidly, limiting the possibility of escape for the hotel residents. Equally, the landslide could have led to fire, or could have resulted in collapse of the building on residents as they tried to escape. Had the landslide occurred during the day, more people may have been on the beach in front of the hotel. The St Dogmaels landslide could have continued downhill to engulf more densely populated parts of the village. The Glen Ogle debris flow could have resulted in the deaths of some of the persons rescued. The timing of the events, where one flow blocked the road, and a second trapped the parked vehicles was unusual. The fact that no-one was actually struck by either flow and that neither flow travelled any distance down the roadway, into the vehicles was fortunate.

Nefyn, led to the death of a resident of a nearby village and serious injury to her partner. However, the occupants of other vehicles were able to escape injury. It was also fortunate that a separate mudslide (right hand side of Figure 10), stopped part way up the cliff. If it had travelled further down slope, it could have triggered more movement within the perched debris accumulation. This could have triggered a similar debris flow to the fatal slide. In this instance, the flow would have impacted on a part-wooden building used as a restaurant and could have injured or trapped the customers that were inside at the time.

Between them, the authors of this paper have investigated or reported on many landslides which could be considered to be 'near-misses,' and a great many more case studies could have been presented in this paper. However, at some point in the near-future (years or decades), there will be a more tragic event that involves multiple fatalities. As is the experience of many involved in this around the world, the potential for successful rescue from a landslide depends very much upon the nature of the failure as much as human factors such as the speed of response and medical facilities. Although the emergency response to each of the events described here was excellent – timely, structured, and well executed, there has been an amount of good fortune that the slides were of such a nature that rescue was possible and human losses low.

DISCUSSION AND CONCLUSIONS

Whilst any analyses of landslide hazard must try to indicate the real level of the problem, it is difficult to escape the fact that, in the UK, in a ‘normal’ year, an average landslide will cause little long-lasting damage and will be adequately managed by local action. Evidence from the case histories given here indicates that the emergency services react promptly and effectively. Similarly, for small landslides that obstruct communication links or impact on a few properties, local authorities and utility operators respond efficiently. In other words, landslide management in the UK is working well at a responsive level.

While emergency teams, utility operators and local authorities might be helped if they knew more about landslides in their area (in particular) and the risks they pose, the benefit is likely to be relatively small. Knowing the type of landslide likely to occur in an area, its magnitude and the rate at which it might move will help preparedness and awareness but, ultimately, the response teams have to deal with circumstances as they find them. Only where multiple landslides might occur (as at Nefyn), is prior knowledge and information likely to reduce risk to life.

Land-use planning systems in the UK are well intentioned for new development and should, on the whole, reduce the potential for damage. Planning guidance for landslides (and other geohazards) exists (though it is somewhat inconsistent between the devolved countries that make up the UK), as do appropriate building codes. However, many local authorities lack expertise in geohazards (Brook & Marker 2008) and have insufficient appropriate information with which to make informed decisions. Geohazard databases developed in the late 1990s to support the planning guidance were flawed and not kept up-to-date. Newly created geohazard databases (Foster *et al*. 2008; Foster *et al.* in prep.) will rectify the flaws in the original ones (for example, Jones 1999) but will take quite some time to be fully populated at current rates of investment. Once fully developed they can then be used in conjunction with national geohazard information systems such as GeoSure.

Buildings insurance provides a financial safety net for existing properties. There are flaws in the system in that insurance is not compulsory but at least landslides (and other geohazards) are included in all policies for household property insurance. However, many insurance companies do not fully understand the risks and so premiums may not be set at an appropriate level.

Health and Safety legislation drives geohazard and risk assessment for infrastructure. Utility and transport network owners are required to assess the level of risk from geohazards and, if necessary, reduce it to the acceptable level. This process of risk assessment generally works well when applied.

Overall, therefore, whilst a number of mechanisms are in place to mitigate and remediate the effects of landslides in the UK, a strategic approach is not taken at national, regional or local level. Rather, prevention is focussed at the level of an individual property or structure while everything else is responsive and, usually, short term. The principle exceptions have been the development of planning policy guidance/statements and the response of Transport Scotland to the Glen Ogle landslide and others in Scotland (Winter *et al.* 2008).

There is still much to be done in making a full assessment of the true landslide hazards in the UK and assessing the spatial, temporal, financial and human risks involved. This research will need to highlight those areas most at risk from new and reactivated landslides, ensure that that risk 'hot-spots' could be mitigated, and ensure that best practice is disseminated to reduce overall risks and, hopefully, prevent or mitigate future disasters. However, it seems unlikely, at the present time, that a strategic approach to landslide management, and indeed of other geohazards, will be developed in the UK. This may be regarded as a cost-effective response to the level of risk that exists.

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REFERENCES

Alexander, DE (2002). Principles of emergency planning and management. Terra Publishing, Harpenden, Hertfordshire, UK.

Alker, SC, Duffy, TR, Swetnam, RD, Bealey, W, Bell, P, Careless, J, Culshaw, MG, Davies, H, Fowler, D, Gibson, A, Leeks, GJL, Lelliott, M, Lowndes, J, Bridge, DMc, Nathanail, CP, Packman, JC, Wadsworth, R & Wyatt, B (2002). Integrating environmental information into a decision support tool for urban planning – an environmental information system for planners (EISP). In: Fendle, EM, Jones, K, Laurini, R & Rumor, M (eds), "30 years of UDMS – Looking Back, Looking Forward." Proceedings of the 23rd Urban Data Management Society Symposium, Prague. Urban Data Management Society, Delft, VI29-VI40.

Anon. (1967). Report of the Tribunal appointed to inquire into the disaster at Aberfan on October 21st 1966. Her Majesty's Stationery Office, London.

Anon. (1999). St Dogmaels Landslide Remediation Scheme, New Civil Engineer, 21 Oct 1999.

Anon. (2004). The Building Regulations 2000 (Structure), Approved Document A, 2004 Edition. Office of the Deputy Prime Minister. Her Majesty's Stationery Office, London.

Anon. (2007). The Construction (Design and Management) Regulations. 2007.

Anon. (2010). Lyme Regis environmental improvements, Phase IV (East Cliff). Approvals and funding. Report of the Technical Services Manager, Planning and Environment, to West Dorset District Council Executive Committee, 18 May 2010.

Australian Geomechanics Society (2007a). Guideline for landslide susceptibility, hazard and risk zoning for land use management. Australian Geomechanics Society Landslide Taskforce Landslide Zoning Group. Australian Geomechanics, 42(1): 13-36.

Australian Geomechanics Society (2007b). Commentary on guideline for landslide susceptibility, hazard and risk zoning for land use management. Australian Geomechanics Society Landslide Taskforce Landslide Zoning Group. Australian Geomechanics, 42(1): 37-62.

BBC (2009). Pennan landslide funds deferred, http://news.bbc.co.uk/1/hi/scotland/north_east/7851836.stm, accessed January 2010, last updated 27th January 2009.

BBC (2011). A46 landslip damage work in Gloucestershire continues. http://www.bbc.co.uk/news/uk-england-gloucestershire-12181389, accessed January 2011, last updated, 13th January 2011.

BGS (2008a), The Holbeck Hall landslide, Scarborough, British Geological Survey website: www.bgs.ac.uk/landslides/HolbeckHall.html, accessed January 2011, last updated December 2010.

BGS (2008b). Landslides on the A85 road, Glen Ogle, Lochearnhead, Stirlingshire, British Geological

Survey website: www.bgs.ac.uk/landslides/GlenOgle.html, accessed January 2011, last updated 2010.

Brook, D (1991). Planning aspects of slopes in Britain. In: Chandler RJ (ed.), “Slope stability engineering – developments and applications.” Thomas Telford, London, 85-93.

Brook, D (2007). The planning response to climate change. In: McInnes, RG, Jakeways, J, Fairbank, H & Mathie, E (eds). “Landslides and climate change.” Taylor & Francis, London, 497-504.

Brook, D & Marker, B (2008). Planning for development on land that is potentially prone to subsidence in England. Quarterly Journal of Engineering Geology and Hydrogeology, 41: 403-408.

Byles, R (1994). Scarborough Rock. New Civil Engineer, 3 February. 18-20.

Carson, AM & Fisher, J (1991). Management of landslides within Shropshire. In: Chandler, RJ (ed.), “Slope stability engineering.” Thomas Telford, London. 95-99.

Chandler, RJ (1970). The degradation of Lias Clay Slopes in an area of the East Midlands: Quarterly Journal of Engineering Geology, 2, 161 - 181.

Chatterton, J, Viavattene, C, Morris, J, Penning-Rowsell, E & Tapsell, S (2010). The cost of the summer 2007 floods in England. Environment Agency, Bristol.

Clark, AR, Fort, DS & Davis, GM (2000). The strategy, management and investigation of coastal landslides at Lyme Regis, Dorset, UK. In: Bromhead, EN, Dixon, N & Ibsen, M-L (eds), Proceedings of the 8th International Symposium on Landslides, “Landslide research, theory and practice.” Thomas Telford, London. 1: 278-286.

Clements, M (1994). The Scarborough experience – Holbeck landslide, 3/4 June 1993. Proceedings of the Institution of Civil Engineers, Municipal Engineer, 103, June, 63-70.

Communities and Local Government (2007). Planning Policy Statement and climate change. Supplement to Planning Policy Statement 1. London: The Stationery office.

Communities and Local Government (2008). Planning Policy Statement 12: creating strong safe and prosperous communities through Local Spatial Planning. London: The Stationery Office.

Cooper, AH (2008). The GIS approach to evaporite-karst geohazards in Great Britain. Environmental Geology, 53(5): 981-992.

Cooper, AH, Farrant, AR, Adlam, KAM & Walsby, JC (2001). The development of a national Geographic Information System (GIS) for British karst geohazards and risk assessment. In: Beck, BF & Herring, JG (eds.), *Geotechnical and Environmental Applications of Karst Geology and Hydrology,* 125-130. AA Balkema, Lisse.

Culshaw, MG (1973a). A stability assessment of the north slope of the Ironbridge Gorge, Telford, Shropshire. Institute of Geological Sciences Report No. EG/73/1.

Culshaw, MG (1973b). A stability assessment of the slope around Lee Dingle, Telford, Shropshire. Institute of Geological Sciences Report No. EG/73/5.

Culshaw, MG & Kelk, B (1994). A national geo-hazard information system for the UK insurance industry - the development of a commercial product in a geological survey environment. In: Proceedings of the 1st European Congress on Regional Geological Cartography and Information Systems, Bologna, Italy. 4, Paper 111, 3p.

Culshaw, MG & Harrison, M (2010). Geo-information systems for use by the UK insurance industry for 'subsidence' risk. In: Williams, AL, Pinches, GM, Chin, CY, McMorran, TJ & Massey, CI (eds), 'Geologically active.' Proceedings of the 11th Congress of the International Association for Engineering Geology and the Environment, Auckland, New Zealand, September 2010 (on CD-ROM, 1043-1051). Leiden, The Netherlands: CRC Press/Balkema.

Dailey, P, Huddleston, M, Brown, S & Fasking, D (2009). The financial risks of climate change:

examining the financial implications of climate change using climate models and insurance catastrophe risk models. Association of British Insurers Research Paper No 19.

Department for Transport, Local Government and the Regions (2002). Planning Policy Guidance 14 (Annex 2): Development on Unstable Land: Subsidence and Planning. The Stationery Office, London.

Department of the Environment (1990). Planning Policy Guidance 14: Development on Unstable Land. Department of the Environment, Welsh Office. Her Majesty's Stationery Office, London.

Department of the Environment (1996). Planning Policy Guidance 14 (Annex 1): Development on Unstable Land: Landslides and Planning. Department of the Environment, Welsh Office. Her Majesty's Stationery Office, London.

Doornkamp, JC (1995a). Legislation, policy and insurance aspects of landslips and 'subsidence' in Great Britain. In: McGregor, DFM & Thompson, DA (eds), “Geomorphology and land management in a changing environment.” John Wiley and Sons, Chichester, 37-50.

Doornkamp, JC (1995b). Perception and reality in the provision of insurance against natural perils in the UK. Transactions of the Institute of British Geographers, 20(1): 68-80.

Early, KR & Skempton, A (1972). Investigation of the landslide at Walton's Wood, Staffordshire. Quarterly Journal of Engineering Geology, 5, 19-41.

European Environment Agency (2010). Mapping the impacts of natural hazards and technological accidents in Europe: an overview of the last decade, European Environment Agency Technical Report No 13/2010, Luxembourg: Publications Office of the European Union.

Fell, R, Corominas, J, Bonnard, C, Cascini, L, Leroi, E & Savage, WZ (2008a). Guidelines for landslide susceptibility, hazard and risk zoning for land use planning. Engineering Geology, 102: 85-98.

Fell, R, Corominas, J, Bonnard, C, Cascini, L, Leroi, E & Savage, WZ (2008b). Commentary - Guidelines for landslide susceptibility, hazard and risk zoning for land use planning. Engineering Geology, 102: 99-111.

Fletcher, CN & Siddle, HJ (1998). Development of glacial Lake Teifi, west Wales: evidence for lake-level fluctuations at the margins of the Irish Sea ice sheet. Journal of the Geological Society, 155: 389-399.

Foster, C, Gibson, AD & Wildman, G (2008). The new national landslide database and landslide hazards assessment of Great Britain. In: Sassa, K, Fukuoka, H & Nagai, H + 35 others (eds), Proceedings of the First World Landslide Forum, United Nations University, Tokyo. The International Promotion Committee of the International Programme on Landslides (IPL), Tokyo, Parallel Session Volume, 203-206.

Foster, C, Pennington, CVL, Culshaw, MG & Lawrie, K (In preparation). The National Landslide Database of Great Britain: development, evolution and applications.

Forster, A, Culshaw, M, Wildman, G & Harrison, M (2006). Implications of climate change for urban areas in the UK from an engineering geological perspective. In: Proceedings of the 10th International Association for Engineering Geology International Congress, Engingeering geology for tomorrow’s cities, Nottingham, UK. 6-10 September 2006.

French, PW (1997). Coastal and estuarine management. London: Routledge.

Gibson, AD & Humpage, AJ (2002). The geology and cliff stability at Nefyn, North Wales – final report. British Geological Survey Report CR/01/267.

Gibson, AD, Humpage, AJ, Culshaw, MG, Forster, A & Waters, RA (2002). The Geology and Landslides of Nefyn Bay, Gwynedd. In: Nichol, D, Bassett, MG & Deisler VK (eds), *Landslides and Landslide Management in North Wales*. Geological Series No. 22, National Museum of Wales, Cardiff. 14-17.

Gibson, AD, Forster, A, Culshaw, MG, Cooper, AH, Farrant, A, Jackson, N & Willet, D (2005). Rapid geohazard assessment system for the UK natural gas pipeline network. In: Arnould, M & Ledru, P (eds), “Geology and Linear Infrastructures.” Proceedings of an International Symposium (GEOLINE), Lyon, France. Orléans: BRGM Éditions. ISBN 2-7159-2982-X. (On CD-ROM only).

Holbeck Hall Hotel Limited v Scarborough Borough Council (2000). QBENF 98/0902/A2 Court of Appeal (Civil Division) 22nd February 2000, http://www.coastlaw.uct.ac.za/iczm/cases/holbeck3.htm.

Henkel, DJ & Skempton, AW (1954). A landslide at Jackfield, Shropshire, in a heavily over-consolidated clay. Geotechnique, 5(2): 131-137.

Hutchinson, JN & Bromhead, EN (2002). Keynote paper: Isle of Wight landslides. In: McInnes, RG & Jakeways, J (eds), “Instability planning and management: seeking sustainable solutions to ground movement problems.” Proceedings of the International Conference organised by the Centre for the Coastal Environment, Isle of Wight Council. Ventnor, Isle of Wight. London: Thomas Telford. 3-70.

Isle of Wight Centre for the Coastal Environment (2006). The economic impacts of natural hazards in coastal zones, taking account of the consequences of climate change: LIFE Environment Project 2003-2007 ‘RESPONSE’: Life 03 ENV/UK/000611, Isle of Wight Council, UK.

Jenkins, GO, Gibson, AD & Humpage, AJ (2007). Climate change and evolution of landslide hazard at Nefyn Bay, North Wales. In: McInnes, R (ed.) Landslides and climate change: challenges and solutions. Proceedings of the International Conference on Landslides and Climate Change. London: Taylor and Francis, 113-119.

Jones DKC (1999). Landsliding in the Midlands: a critical evaluation of the contribution of the National Landslide Survey. East Midlands Geographer, 21(2) & 22(1), 106-125.

Jones, DKC & Lee, EM (1994). Landsliding in Great Britain. Her Majesty's Stationery Office, London. 360p.

Lee, EM (1999). Coastal planning and management; the impact of the 1993 Holbeck Hall landslide, Scarborough. East Midlands Geographer, 21: 78-91.

Lee EM & Clark AR (2000). The use of archive records in landslide risk assessment: historical landslide events on the Scarborough coast, UK. In: Bromhead, EN, Dixon, N & Ibsen, M-L (eds). Proceedings of the 8th International Symposium on Landslides, “Landslides in research, theory and practice.” Thomas Telford, London. 904-910.

Lee, EM & Moore, R (2007). Ventnor Undercliff: development of landslide scenarios and quantitative risk assessment. In: McInnes, RG, Jakeways, J, Fairbank, H & Mathie, E (eds), “Landslides and climate change – challenges and solutions.” Proceedings of the International Conference, Ventnor, Isle of Wight. Taylor & Francis, London. 323-333.

Lee, EM, Clark, AR & Guest, S (1998). An assessment of coastal landslide risk, Scarborough, UK. In: Moore, D. & Hungr, O. (eds), 'Engineering geology: a global view from the Pacific rim.' Proceedings of the 8th Congress of the International Association of Engineering Geology and the Environment. Rotterdam: A. A. Balkema, 3, 1787-1794.

Maddison, JD (2000). St Dogmaels landslide: deep drainage by wells. In: Siddle, HJ, Bromhead, EN & Bassett, MG (eds), Landslide and landslide management in South Wales. 106-108. National Museum of Wales, Geological Series No. 18, Cardiff.

McInnes, R (2007). The Undercliff of the Isle of Wight – a guide to managing ground stability. Isle of Wight Centre for the Coastal Environment, Ventnor. 69p.

McInnes, R, Tomalin, D & Jakeways, J (2000). LIFE-Environment Project: LIFE – 97 ENV/UK/000510 1997-2000 Coastal change, climate and instability: Final Technical Report. Isle of Wight Council, Isle of Wight, UK.

Office of the Deputy Prime Minister (2005). Planning Policy Statement 1: delivering sustainable development. London: Her Majesty's Stationery Office.

Office of Science and Technology (2003). Foresight Flood and Coastal Defence Project, Main Report, Phase 1 – Drivers, scenarios and work plan. Her Majesty's Stationery Office, London. 46p.

Pennington, CVL, Foster, C, Chambers, J & Jenkins, GO (2009). Landslide research at the British Geological Survey: capture, storage and interpretation on a national and site-specific scale. Acta Geologica Sinica (English edition), 83, 801-840.

Pitt, M (2008). The Pitt Review: learning lessons from the 2007 floods, June 2008. Cabinet Office. http://webarchive.nationalarchives.gov.uk/20100807034701/http://archive.cabinetoffice.gov.uk/pittreview/thepittreview/final_report.html

Sellwood, M, Davis, G, Brunsden, D & Moore, R (2000). Ground models for the coastal landslides at Lyme Regis, Dorset, UK. In: Bromhead, EN, Dixon, N & Ibsen, M-L (eds), Proceedings of the 8th International Symposium on Landslides, “Landslide research, theory and practice.” Thomas Telford, London. 3: 1361-1366.

Siddle, HJ (1999). Technical response to emergency planning following a landslide. Proceedings of the Institution of Civil Engineers, Municipal Engineer, 133, June, 65-69.

Skempton, A & Weeks, A (1976). The Quaternary history of the Lower Greensand escarpment and Weald Clay vale near Sevenoaks, Kent. Philosophical Transactions of the Royal Society, A, 283, 493-526.Varnes, DJ (1978). Slope movements, types and processes. In: Landslides: analysis and control (Eds Schuster, RL & Krizek, RJ). Special Report 176, Transportation Research Board, National Academy of Sciences, Washington DC, 11-33.

Walsby, JC (2007). Geohazard information to meet the needs of the British public and government policy. Quaternary International, 171/172: 179-185.

Walsby, JC (2008). GeoSure; a bridge between geology and decision-makers. In: Liverman, D.G.E., Pereira, CPG & Marker, B (eds.) Communicating environmental geoscience. Geological Society, London, Special Publications, 305: 81-87.

Walters, RA, Davies, JR, Wilson, D & Prigmore, JK (1997). A geological background for planning and development in the Afon Teifi catchment. British Geological Survey Technical Report, WA/97/35. 102p.

West, LJ (1994). The Scarborough landslide. Quarterly Journal of Engineering Geology, 27: 3-6.

Winter, MG, Macgregor, F & Shackman, L (eds) (2005). Scottish road network landslides study. Scottish Executive, Edinburgh. 119p.

Winter, MG, Heald, AP, Parsons, JA, Shackman, L & Macgregor, F (2006). Scottish debris flow events of August 2004. Quarterly Journal of Engineering Geology and Hydrogeology, 39: 73-78.

Winter, MG, Macgregor, F & Shackman, L (2008). Scottish road network landslides study: implementation. Transport Scotland, Edinburgh. 270p.

Wyles, R (1983). The legal aspects of the influence of vegetation on the swelling and shrinking of clays. Géotechnque, 33, 89-91.