View metadata, citation and similar papers at core.ac.uk
provided by NERC Open Research Archive

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Land Use Planning for High Pressure Pipelines – Ground Hazards from Landsliding

Urban Geosciences and Geological Hazards Programme

Research Report CR.03/218

BRITISH GEOLOGICAL SURVEY

RESEARCH REPORT CR.03/218

Land Use Planning for High Pressure Pipelines – Ground Hazards from Landsliding

A.Forster, A.D.Gibson and M.G.Culshaw.

The National Grid and other Ordnance Survey data are used with the permission of the Controller of Her Majesty's Stationery Office.
Ordnance Survey licence number GD 272191/1999

Key words

Report; key; words.

Front cover

Landslide reactivated due to exceptionally wet weather causing a road to be closed in North Yorkshire.

Bibliographical reference

FORSTER, A, GIBSON, A.D. AND CULSHAW, M.G. 2003 Land Use Planning for High Pressure Pipelines – Ground Hazards from Landsliding – *British Geological Survey Research Report*, CR.03/218. 18pp.

© *NERC 2003*

Keyworth, Nottingham British Geological Survey 2003

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham and Edinburgh; see contact details below or shop online at www.thebgs.co.uk

The London Information Office maintains a reference collection of BGS publications including maps for consultation.

The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.

The British Geological Survey is a component body of the Natural Environment Research Council.

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.thebgs.co.uk

Murchison House, West Mains Road, Edinburgh EH9 3LA

☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE

☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgslondon@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, 20 College Gardens, Belfast BT9 6BS

☎ 028-9066 6595 Fax 028-9066 2835

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

Landsliding is a significant geological hazard in the UK and can cause localised damage to built structures including buried pipelines. Detailed investigation is required to establish the true nature and risk of landsliding at a site but this is a costly and time-consuming process that is unnecessary in many instances. Although widespread in occurrence landslides tend to occur only in certain areas where geological, geomorphological and environmental conditions are conducive to failure. Thus it is possible, by assessing existing records and experience to gain some indication of the susceptibility to landsliding of any particular location.

In order to assess, on a national scale, the hazard to the high-pressure gas pipeline network from landsliding, Advantica Technologies commissioned the British Geological Survey (BGS) to collate available information regarding landslide hazards across the UK and present them in a way meaningful to the pipeline operators. The results of this research are presented in this report and accompanying data cd.

Acknowledgements

This study has made use of information gathered using the British Geological Survey Geoscience Spatial Model software running on ArcView. Keith Adlam is thanked for establishing and supporting that software interface. The work has also incorporated data gathered for the British Geological Survey GeoHazarD project managed by Jenny Walsby. Tony Myers in Cartographic Services is thanked for undertaking much of the GIS manipulation of the datasets.

Fiona Harding, Kamil Sahin (Advantica Technologies) and David McHugh and Neil Jackson (Transco) are thanked for their assistance in collating data and detailed advice on project specification and comments during report preparation.

Contents

Summary

This report is a product of a study by the British Geological Survey (BGS) for Advantica on behalf of Transco. It is written to accompany and explain the GIS layer provided as part of a research contract agreed as BGS Commissioned Research Project E1449R83.

Landsliding is a widespread hazard in the UK, occurring both as a natural phenomenon and in situations where anthropogenic disturbance has altered the stability of a slope. These situations can cause significant engineering and foundation problems that may affect pipelines and their infrastructure.

On instruction from Advantica, research was carried out to determine the landslide susceptibility of a 500 m wide buffer zone centred upon the 18 000 km long high-pressure gas transmission pipeline network. This involved the merging of existing datasets of landslide hazard in the UK with data of mapped landslide deposits and reported landslide events currently held by the BGS. The process was not entirely automated and was assessed by BGS staff experienced in the identification, classification and mitigation of landslide hazards.

All data were compiled and checked using ARCGIS Geographical Information System software. This report describes the manner in which the data have been manipulated and compared with linework provided by Advantica of the national gas pipeline network to identify areas that may be at risk from ground movements. Susceptibility to landslide activity within the buffered zone is indicated by the classification of the zone into one of five different classes of hazard, A-E. For each of the hazard susceptibilities, general management recommendations are given as to possible measures which may be undertaken to minimise landslide hazard. It is not the purpose of this report to detail actual management policies or make detailed recommendations for pipeline management.

Copyright of all materials is subject to conditions of the contract project.

1 Introduction

1.1 PROJECT BACKGROUND

The UK Health and Safety Executive (HSE) has introduced a risk-based approach for proposed development near gas transmission pipelines based on a simple decision matrix which considers individual risk and the nature of proposed developments.

Whilst Transco supports the use of hazard rather than consequence, as the basis for making decisions on land use near its transmission pipelines, the HSE's current risk methodology for ground movement failures may be considered to be conservative and may sterilise land near pipelines unnecessarily. The HSE is aware of the conservative nature of its methodology, and has participated in meetings between Transco, Advantica and the British Geological Survey (BGS) with the objective of developing a more refined approach. This project supports the development of a more refined approach to the assessment of ground movement risk for land use planning and also supports the safe operation of Transco's transmission system, for example by identifying pipeline locations which may have a higher susceptibility to ground movement than others.

To achieve the goal of developing a more refined approach to hazard assessment, the BGS, as the primary holder of national geological hazard data for the UK. was commissioned to produce datasets which would indicate to Transco, as the pipeline authority, those sections of pipeline which were susceptible to ground movement from natural causes.

Although there are many types of ground movement that can affect a pipeline route and infrastructure, it was felt that hazards posed by the dissolution of soluble rocks and by landslides were the most relevant. To this end the BGS was commissioned to produce a dataset of national coverage that indicated landslide hazards posed to the transmission pipeline network. These working datasets classify hazardous areas into five hazard zones, each of which has management recommendations to be incorporated into existing pipeline monitoring procedures. This report describes the procedure followed and results of the research that determines hazard resulting from landsliding.

2 Landslide Hazards in the UK

2.1 LANDSLIDE PROCESSES AND CONTROLS

Landsliding is a common but largely unrecognised occurrence in Britain (Department of the Environment 1996). Landslide is the internationally accepted term for down slope movements of material under the influence of gravity that falls somewhere within a spectrum of mass movements ranging from rock avalanche to soil creep. These mass movements are part of the denudation process of weathering and erosion by which the land's surface is worn down. Although landslides are very common in the United Kingdom (and elsewhere) they frequently remain unrecognised due to their characteristic features being removed by natural processes (weathering and erosion) or agricultural activity.

A landslide occurs when the shear strength of a slope is exceeded by stresses due to the force of gravity. It does not move if the shear strength of the material that forms the slope is greater than the stress due to gravity. If the balance is altered so that stress exceeds available strength, movement down slope will occur until a stable slope profile is formed (i.e. until the stress is reduced or material strength is increased.)

2.1.1 Factors which increase stress

2.1.1.1 Removal of support

The removal of support from the bottom of a slope may be by marine erosion, river erosion, seepage erosion, landsliding of the lower slope area, or by excavation during construction work. The result will be to concentrate the existing stress in the remaining part of the slope.

2.1.1.2 Loading the top of a slope

Loading at the top of a slope increases the potential total stress applied to the slope. It may be caused naturally by landslides, debris flows, rock or soil falls, depositing earth material onto the slope from an active area higher up the slope, or artificially by construction works or land fill operations. The growth of vegetation may give a net increase in mass and the saturation of the slope during seasonal rainfall or heavy rainfall events will also cause an increase in loading on the slope.

2.1.2 Factors which decrease strength

2.1.2.1 Pore water pressure

The strength of a soil material is dependent on the inter-particle friction of its component particles, which is proportional to the weight of the overlying mass, which forces the particles together. Where there is pore water in the inter-particle spaces the pressure of the pore water must be subtracted from the overburden stress to determine the effective stress acting between the particles. Thus the higher the water table the lower the effective stress and the lower the shear strength. Where a water-bearing soil is sealed by overlying impermeable strata a confined condition is produced which may result in pore water pressure of greater magnitude than for an unconfined condition with a water table at the ground surface.

2.1.2.2 Weathering

Fresh mudrocks will decrease in strength when weathered as stress relief causes their physical disintegration; swelling occurs as water is absorbed by their component clay minerals and the beneficial effects of soil suction are lost. In granular rocks and soils the strengthening effect of inter-particle cements may be lost as the cementing agents are dissolved.

2.1.3 Structural effects

Figure 1 Well-jointed and bedded rock masses at Gore Point, near Porlock Weir lead to structurally controlled block slides where the dip of the discontinuities coincides with a slope.

The geological structure of the slope and its surroundings may have a controlling effect on the incidence, nature and frequency of landslides. Discontinuities affect all geological materials at scales ranging from small to large and are found in the form of bedding planes, fissures in clay soils, jointing in rocks, faulting and unconformities. These disruptions in the continuity of the material provide paths for the flow of water into, and through, the ground and supply planes of weakness on which movement and detachment may take place.

Folds in strata may collect groundwater and concentrate its flow along the troughs formed by synclinal aquicludes. If such a pathway is inclined to a free face or slope it will concentrate water at a spring or seep, raise pore water pressures and supply a source of water to drive mass moments. Where planes are inclined towards a free face or slope block falls may occur or translational slides will be favoured. Where two such planes intersect wedge failures may take place.

2.1.4 Climatic effects

Rainfall is the most important aspect of climate. Its effect may be very rapid such as the role of heavy rain in generating hillwash and sand runs, which are apparent at the time of the rain or soon after. However, the more important effect is seen over a longer time scale which gives time for rain to infiltrate the ground to a greater depth, saturating materials and causing a build up of pore water pressures which reduce the available shear strength of the slope forming materials. The effectiveness of the infiltration will be affected by other factors such as vegetation cover and the time of year, both of which will influence the amount of water lost by evaporation. It is also possible that a period of very dry weather, which has caused ground shrinkage and cracking, will allow infiltration quickly and to a greater depth and reduce losses due to runoff.

2.2 LANDSLIDE TYPES

A landslide is defined by the outward and downward movement of rock or soil on a slope. This often takes place by falling, toppling, sliding, or flowing. Figures 1 to 6 illustrate a simple classification of landslide types found in the UK, from a subset of landslide types defined by McMillan & Powell (1999), (After Varnes, 1978, Varnes & Cruden 1996 and Department of the Environment 1994, 1996).

2.2.1 Rock Fall

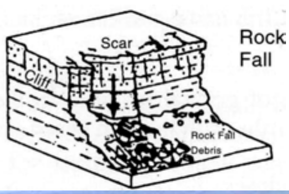


Figure 2 Where they form steep cliffs well jointed rock outcrops, such as Alport Castle in Derbyshire, may fail by rock blocks falling from the face as they are prized away by freezing water, roots or the erosion of weaker layers.

2.2.2 Rock Topple

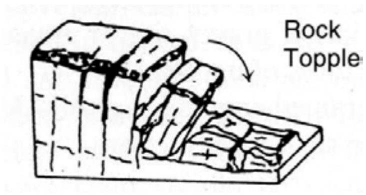


Figure 3 Vertical cliffs in well jointed rock with weaker strata below may fail by pivoting forward, or toppling, as the weaker base crushes. The failure at Garreg Lwyd in the Rhondda Fawr valley is a good example.

2.2.3 Rotational Slide

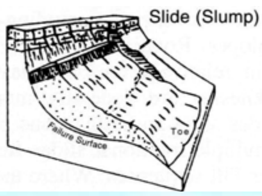
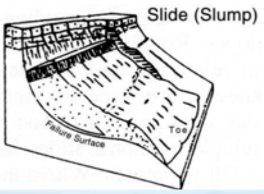


Figure 4 In relatively homogeneous material, failures may occur by sliding on curved or circular shear surfaces. This is the situation at Small Chine near Brook on the Isle of Wight. In material with strong structural discontinuities or comprising layers of material with contasting properties planar shear surfaces may control the failure (Figure 1).

2.2.4 Translational Slide



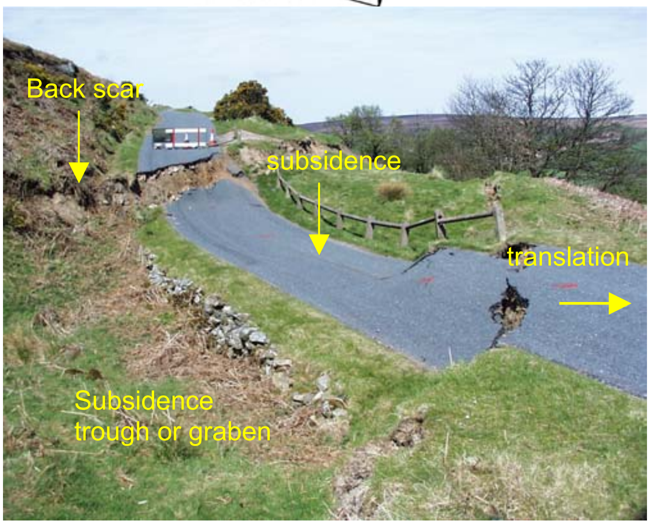


Figure 5 Where slides are non circular and have a translational element ground may subside into the void created between the backscar and the translated mass to create a subsidence trough or graben.

2.2.5 Flow

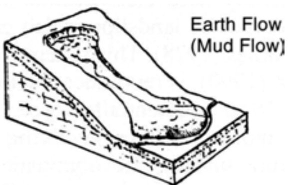


Figure 6 In relatively weak homogenous material a rotational failure may immediately transform into a flow as the movement destroys the integrity of the slumped mass.

2.3 DISTRIBUTION OF LANDSLIDE HAZARDS IN THE UK

The distribution of landslides in the UK is controlled by a number of factors including geology, slope gradient, hydrogeology and climate. This pattern is further complicated by the effects of past climates during which the prevailing weather in the UK was much colder and wetter, leading to intensive landslide activity. Such landslide activity has resulted in a legacy over much of the UK of 'relict' landslides which exist in a state of meta-stability, where only a small adjustment to the stress conditions in the landslide system can result in failure. An illustration of the broad distribution of landsides in the UK is provided in Figure 7 that shows the distribution of landslides recorded in the National Landslides Database, maintained by the BGS. It can be seen from Figure 2.6 that landslides are found throughout the UK but their distribution is not uniform. In part this is a reflection of the bias of the dataset towards large landslides and landslides in areas that have the greatest importance in terms of infrastructure or population. There are undoubtedly many landslides, as yet unrecorded, in the less populated rural areas of the UK. However, the distribution of landslides as a whole would not be expected to be uniform and if the occurrence of different types of landslide were considered the uneven distribution would be even more apparent.

In broad terms, it is to be expected that shallow flows and translational slides would be more common in the weaker rocks (clays and sands) of the south east than the harder rocks (limestones, sandstones and mudstones) of the north west and almost absent in the hard igneous and metamorphic rocks of the north of Scotland. Similarly rock falls and topples are only likely to occur where hard rocks that are capable of forming steep cliffs and crags are present, largely in the north and west of the UK. Large rotational, translational and composite landslides are found mainly in areas where there are extreme contrasts of topography typically in glaciated upland valleys, in areas such as the Pennines and South Wales, where river erosion has created steep-sided valleys such as the Avon Valley at Bath, Ironbridge in Shropshire or on the coast in areas of harder rocks or soft rocks where marine erosion is rapid. The upland hard rock areas of northwest Scotland are also noted for large-scale landslides.

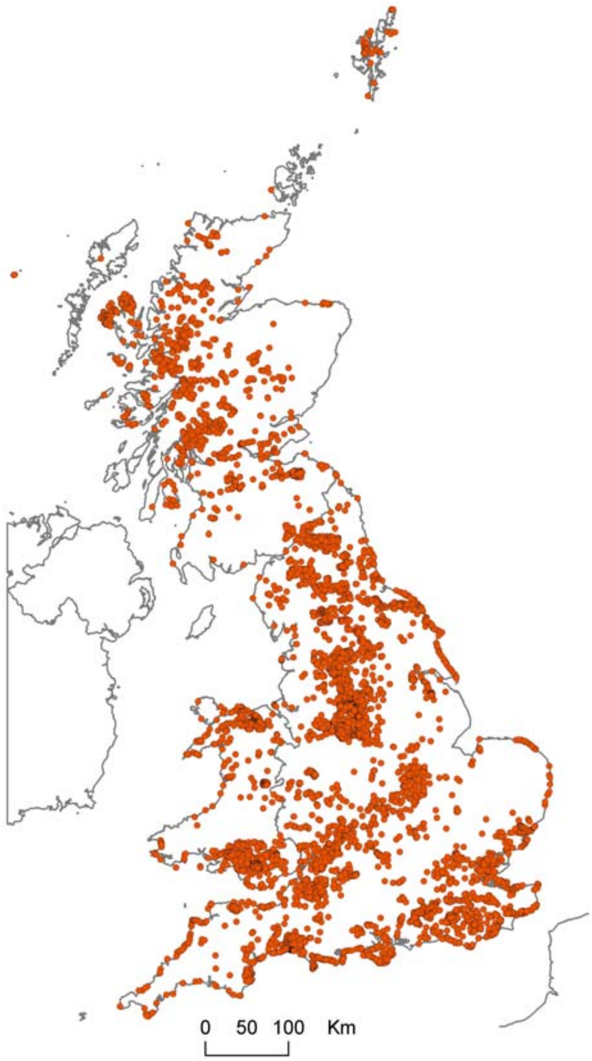


Figure 7 Distribution of landslides recorded in the BGS National Landslide Database.

.

It is important to recognise that the distribution of landslides that are present in the national landslide database are the result of landsliding under a wide variety of climatic and anthropomorphic conditions that have occurred over more than 10 000 years. These include glaciation, periglaciation, major episodes of deforestation at various times since the Iron Age and, more recently, the construction of canals, roads and railways. Thus the distribution will not reflect entirely accurately where or when future landsliding will take place. The prediction of areas prone to landslides in the future, landslide potential assessment, has been addressed in the short to medium term by the present assessment. However, the approach required to make a more rigorous assessment of landslide potential in the long term is a deterministic one based on the presence of causal factors. This is currently under development.

3 Landslide Hazards to Buried Pipelines in the UK

3.1 LANDSLIDE HAZARD

The process of landsliding includes the movement of material by the act of falling, toppling, sliding and flowing (see above) depending on the topography of the ground surface and the nature of the material of which it is composed. The effect of such movements on rigid linear infrastructure such as a gas pipeline includes sudden impact, loading, longitudinal compression or tension and lateral deflection or shearing.

Property and infrastructure are damaged if landslides remove ground that is supporting them and may be damaged by stretching or compression as the ground moves. Damage can also result if the installation is below a landslide, and material falls onto it from above or slides or flows into it from the side

3.2 IMPACT

Rock fall or rock topple from a steep rock face are rapid movements that may cause significant damage to structures at the bottom of the face but the initial impact point from a fall or topple will not be far from the bottom of the face unless the face is high. Further impacts or rolling out from the rock face will depend on local slope morphology. Likely impact points, loads and run outs can be modelled on a site specific basis.

3.3 LOADING

Where successive falls accumulate or slides or flows overrun the ground surface down slope of the origin of the landslide the underlying ground will become subject to increased normal load. This can cause damage to underlying structures or can start additional landsliding as a result of undrained loading.

3.4 TENSION AND COMPRESSION.

Where landslides move downslope in the same direction as a linear rigid structure those parts in the upper portion of the landslide (zone of depletion) will experience tension as the landslide drags it down hill but in the lower parts (zone of accumulation) may suffer compression.

3.5 SHEARING

Where a rigid linear structure traverses a landslide normal to its direction of movement the structure will experience lateral deflection. This may be concentrated at the margins of the landslide as zones of lateral shearing. The structure may also experience uplift if it traverses the toe region of a rotational slide.

4 Derivation of landslide hazard ratings: BGS Methodology

4.1 LINEAR ROUTE HAZARD ASSESSMENT

To assess the hazards to the gas pipeline network, the digitised lines supplied to BGS were buffered at 250m (500m corridor) and cut against the enhanced BGS GHASP (formerly **G**eo-**HA**zard **S**usceptibility **P**ackage) dataset to produce a GIS layer indicating the areas where there may be high hazard ratings for the pipeline.

4.1.1 The GHASP dataset

The GHASP dataset was initially designed for assessment of geological hazards causing building damage. Some geological hazard areas included in it are not hazardous to pipelines, but are very hazardous to shallow foundations of buildings.

GHASP was originally constructed using a code system in which district geologists (experts in the geology of a particular UK region), supported by engineering geologists, identified geological hazards within their district. By this method, the susceptibility to landslide, dissolution of soluble rocks, running sand, shrink-swell, compressible soils and mining induced subsidence was determined for each postcode sector.

Landslide hazard was determined by the professional judgement of each district geologist. Assessments of hazards in each district were based upon known incidents of landsliding, the broad geotechnical character of each postcode sector, typical gradients and observations of geomorphology made by the geologist an his/her mapping team. Where required, engineering geologists who alongside their own professional knowledge and expertise had access to a considerable library of geotechnical data across the UK advised district geologists on geotechnical and geomorphological parameters.

Although the system is essentially based upon empirical data and judgement; it is a practical method of collating and interpreting a great deal of complex and experiential information that would otherwise have been very difficult to use. It has proven to be an effective tool for assessing hazards at a national and regional (1:50 000) scale and is still widely used by many BGS clients including engineering companies and members of the insurance industry.

4.1.2 The modified GHASP dataset

The GHASP dataset has been modified to create more detailed geohazard polygons, in particular, areas deemed to be at greatest risk from landslide hazard. Each GHASP rating has been modified by comparison with the data in the BGS National landslide database and GIS system and the mass movement (landslide) layer in BGS DiGmap50. This comparison showed areas where additional data regarding landslide occurrence have been collected or become available since the GHASP rating system was devised. The delineated areas have been incorporated into the GIS and each given a hazard rating on a scale of one to five. Areas of known landslide deposits are given a hazard rating of five.

The landslide hazard assessment has been made using information at a scale of 1:50k and will not identify areas subject to small-scale landslide due to local geological conditions that are below the resolution of the data set. The detailed BGS datasets are still being populated and it is possible that in the future more information will come to light that will require some of the areas in this report to be reassessed.

4.2 EXPLANATION OF HAZARD RATINGS

The operational dataset for use by pipeline managers contains 6 hazard zones:

0. Slope instability problems are not likely under current conditions.
1. Slope instability problems are not likely to occur under current conditions but consideration of potential problems in adjacent areas impacting on the site should always be considered.
2. Slope instability problems may have occurred in the past or may occur in the future. Site inspections should consider specifically early signs of slope movement in the area.
3. Slope instability problems are probably present or may occur in the future. Site specific assessment of risk may be advisable. Site inspections should consider specifically early signs of slope movement in the area.
4. Slope instability problems almost certainly present and may be active. Site specific assessment may be required to assess risk. Periodic or continuous monitoring may be necessary. Possibility that remedial work will be required.
5. Landslide deposits present, slope instability problems almost certainly present and may be active. Site specific assessment required to assess risk. Periodic or continuous monitoring may be necessary. Possibility that remedial work will be required within the zone and possibly in adjacent areas.

Hazard ratings provided in this research relate to landslide susceptibility as a whole rather than to the specific different types of landslide as described in Sections 2.2.1-2.2.5 but described the susceptibility of an area to some form of landslide activity. They should be regarded as a guide with which further investigations at specific locations can be made.

5 Areas of Landslide Hazard Zone

The information held by the British Geological Survey in its GIS databases has allowed the UK gas pipeline network to be assessed for the potential ground instability caused by landslides.

For the majority of the network there is little cause for concern. However, a significant proportion of the buffered zone defined in this research has been identified as being at some risk to landslide activity. This is partly due to the nature of the GHASP dataset that considers landslide hazard averaged over postcode sectors but is also a reflection of the widespread distribution of landslide hazard in the UK

The 250 m buffered zone used in this research has a total area of 8403 km^2 (8 402 903 402 m^2). Just under half of the total buffer area (49.1%) is affected by one of the landslide hazard classes. The great majority of this (48.2% of the total buffer area) falls within zones 1, 2 and 3. The remaining 0.9%, a total area of 71 km^2 lies within zones of hazard ratings 4 and 5 (Figure 8 and Table 1).

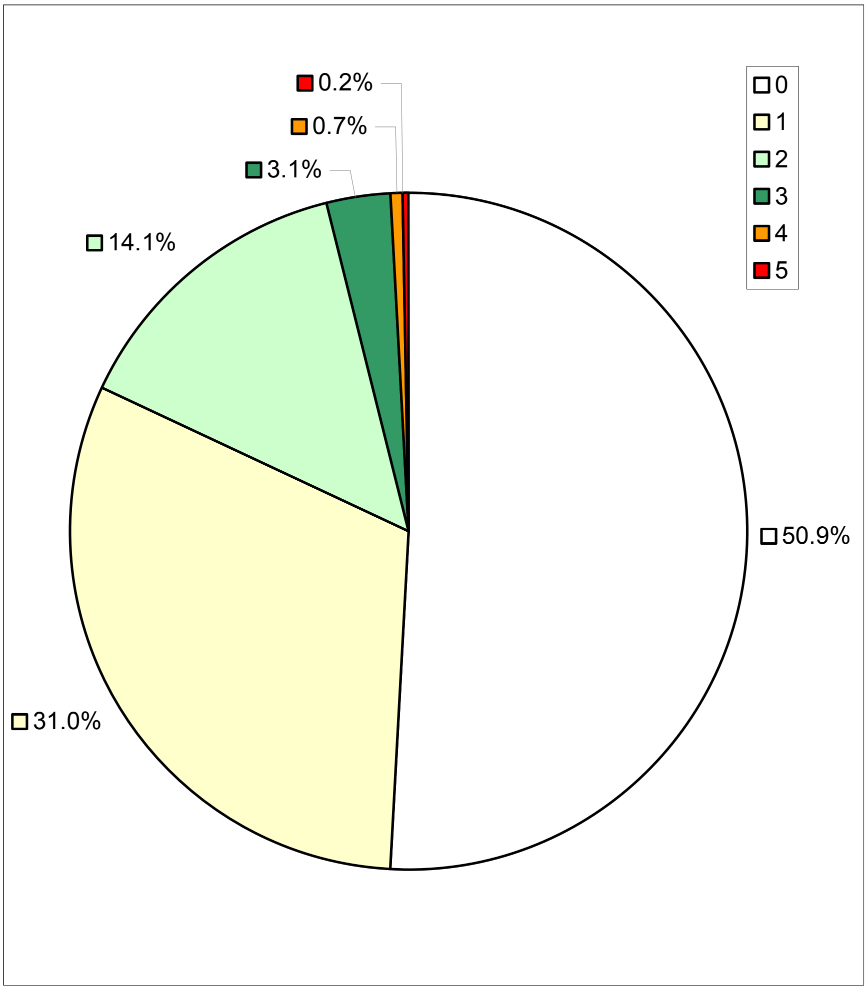


Figure 8. Percentage of Total Buffer Zone affected by Landslide Hazard Ratings

Table 1. Area of Total Buffer Zone affected by Landslide Hazard Ratings

		Area in sq m	Area in sq km	Percentage Area of Buffer
Landslip CLASS	1	2 603 571 145	2604	31.0
	2	1 184 230 517	1184	14.1
	3	263 298 184	263	3.1
	4	56 378 052	56	0.7
	5	14 649 407	15	0.2
	All	4122127305	4122	49.1
Area Unaffected	0	4 280 776 097	4281	50.1

6 Management Recommendations

6.1 MANAGING SLOPE INSTABILITY

Although it is outside the scope of this report to make detailed recommendations on the management of pipeline hazard susceptibility, there are a number of general recommendations that can be applied to the management of areas susceptible to instability. These relate to the general consequences of failure in the close proximity of buildings or fixed installations and how best they can be mitigated.

In the case of slope instability, procedures should consider the inclusion of detailed hazard assessments, monitoring schemes and possible engineering works, each commensurate with the hazard rating given here.

The evolutionary nature of hazards resulting from the landslides mean that it is important that, where deemed necessary, a reporting procedure is used and, for areas of specific concern, reference is made to a baseline dataset (interpreted photograph/ geomorphological survey). It is also important that periodic revisions of these hazard zonations are made to ensure that such hazard classes are based upon the most up to date information available. It should be emphasised that these hazard zonations are not site-specific (except for some parts of Zone 5 which include areas of known landslide deposits) and this assessment should be regarded as a first level assessment pass of the UK network to identify areas for further investigation. Any detailed assessment should be carried out by appropriately trained and instructed staff.

Using the terminology of this report, only areas within zones 5 and 4 are deemed to possess a significant susceptibility to landsliding. It is these areas that are most likely to require further landslide assessment for the purposes of detailed recommendations and for the purposes of verifying and if necessary amending the hazard zonation given here. The susceptibility to landsliding in Zones 1,2 and 3 is thought unlikely to warrant such attention, but the risk of landsliding in these areas should always be considered.

Areas with lower hazard ratings are unlikely to require such detailed monitoring. An example of general good practice in the management of unstable slopes, provided to landowners and managers is provided in Table 2.

6.1.1 Areas within Zones of High Hazard (Zone 5)

Management policies should, in addition to the general recommendations, consider the presence of ground features such as:

- Piles of debris and fallen material below steep slopes and cliffs.
- Hollows in slopes with lobes of material below them.
- Bulges in the ground especially at the foot of slopes.
- Ridges in the ground usually along the slope but sometimes down the slope
- Open cracks in the ground.
- Scarps or steps in the ground surface
- Patches of very wet soft ground on slopes.
- Cracks in walls, paths and roadways.
- Tilting of trees, walls or buildings.

6.1.2 Areas within Zones of Moderate to High Hazard (Zone 4)

Management policies should consider verification and where necessary, amendment of Zone 4 status and subsequently to consider assessment of any landslide features.

6.1.3 Areas within Zones of Moderate Hazard (Zone 3)

Management policies should consider verification of Zone 3 status by examination of field and/or remote data and where necessary, amendment of Zone 3 status and subsequently to consider assessment of any landslide features.

6.1.4 Areas within Zones of Low to Moderate Hazard (Zone 2)

Management policies should consider verification of Zone 2 status by examination of field and/or remote data and where necessary, amendment of Zone 2 status and subsequently to consider assessment of any landslide features.

6.1.5 Areas within Zones of Low Hazard (Zone 1)

Management policies should consider verification of Zone 1 status by examination of field and/or remote data and where necessary, amendment of Zone 1 status and subsequently to consider assessment of any landslide features.

Table 2. Summary of good practice measures for managing unstable slopes

Do	• Ensure water supply pipes are in good repair and are not leaking • Ensure ditches and drains are directed away from potentially unstable ground and are maintained. • Maintain gutters and down pipes and direct them to piped drainage systems. • Manage wooded slope to enhance stability.
Do not	• Remove material from the bottom of slopes. • Place material on, or at the top of, slopes. • Dispose of rainwater or surface water to soakaways. • Allow surface drainage to discharge water on to slopes or the ground behind slopes. • Remove vegetation whose roots may be strengthening loose or weak material or which may strengthen the slope by removing soil moisture.

7 References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

Varnes, J. & Cruden, D.M. (1996). Landslide type and process. I*n Special Report 247: Landslides – Investigation and Mitigation*. Transport Research Board, Washington DC.

DEPARTMENT OF THE ENVIRONMENT (1996). Planning Policy Guidance: 14 (Annex 1)– Development on Unstable land: Landslides and Planning. HMSO

DEPARTMENT OF THE ENVIRONMENT (1994). Landsliding in Great Britain: HMSO

MCMILLAN, A.A. & POWELL, J.H. (1999). *BGS Rock Classification Scheme, Volume 4.*

VARNES, J. (1978) Slope movements types and processes. In Landslide analysis and control. In: R.L. Schuster & R.J. Krizek (eds.) Special Report 176 Transportation Research Board, National Academy of Science, Washington, USA. 11-33.