Discussion Session 5

W. R. DEARMAN (University of Newcastle) from the Chair commented on the paper by Mr Roche. New editions of Ordnance Survey Maps, most regrettably, do not always show old mine shafts. Therefore it is most necessary to go back to old editions. This is true of areas like south-west England and also, of course, coal mining areas generally.

Written contribution

J. C. CRIPPS (University of Sheffield) writes: In Fig. 1 of his paper Mr Roche identifies areas of low, medium and high risk of shallow workings. Given that the mineral veins vary in dip and direction and there is a possibility of other veins between known ones, how is the width of these zones determined? Besides the character of the veins themselves, it must also depend on several factors, including the mining methods, type of bedrock and superficial deposits, the thickness of the superficial deposits and the water conditions.

D. P. ROCHE (Frank Graham Geotechnical) replies: The figures presented in the paper represent an illustrative model example. Dr Cripps is correct that real cases are sometimes more complex and there is always a need to give full consideration to the various geological and mining factors. In arriving at a site assessment it is necessary to make the best interpretation based on the available factual data. The prime objective in defining hazard and risk zones is to identify the better land from the worst, in order to 'steer' development away from the worst land. As described in the paper, the high risk zone contains all recorded shafts and adits and the outcrop zones of lodes with recorded workings. The width of the envelope drawn around the features depends upon the degree of certainty with which they have been plotted, and also on the need to allow for an angle of draw around any subsurface void over which subsidence might occur. A typical envelope width is 10 m but this might be varied depending upon the level of confidence. In circumstances similar to the model example illustrated in the paper, the high risk zone might initially be drawn some 40 m or so in breadth. This might be reduced following ground investigation and taking account of the nature, locations and geometry of any subsurface voids or loosely backfilled workings that are detected.

D. N. HOLT (Freeman Fox & Partners) observed that one of the themes running through the conference was that hazard and risk assessment maps generally have to be drawn up with the constraint of avoiding implications of planning blight constantly in mind. This is because there is always a risk that someone may argue that the maps have, unnecessarily, degraded the price of some of the property involved and this creates the possibility of legal acton being taken against those responsible for the maps. Therefore, in drafting such maps one has to be very careful in how far it is possible to be specific without becoming the subject of legal action. The problem is much greater with large scale and site specific maps compared with regional maps. With this in mind would Mr O'Hara indicate whether the Jamaican maps he describes were published and, if so, whether the possible consequences of legal action by property owners was considered and allowed for.

M. O'HARA (Plymouth Polytechnic) replied that the maps were not published or sold to the public but copies were available to interested parties and the Geological Survey still receives regular requests for copies. The small scale (1:250 000) undoubtedly helped to minimize the risk of legal action as it would be very difficult to identify a particular plot of land and therefore the risk of serious litigation was minimised. However, the Survey was aware of the implications of doing this work and potential problems were discussed at great length before the decision was taken that the need for the service far outweighed the risk. Fortunately Jamaica is not a particularly litigatious society and it is interesting to note that similar maps have been published in what is perhaps the most litigatious country of all, the United States.

P. G. FOOKES (Consultant) commented that he had attempted to apply the methods of subsidence hazard prediction recommended in the paper by Edmonds *et al.*, to limestones in Borneo and to limestones in Devon, and found that the method was not transferable to either formation. This concerned him because, whilst the system appeared to be based almost entirely on the Chalk in the London Basin, it was proposed as being generally applicable. He wondered whether any sensitivity checks on limestones and terrains other than south-west England had been carried out and expressed concern that the system might be applied in the future in regions where it has no validity.

C. EDMONDS (Applied Geology) replied that he did not intend to imply that the model in its present form could be used for any limestone formation. However, the data were based on areas of southern England other than the Thames Basin and the model worked on the Chalk generally and not just in the Thames Basin area. The concept should be applicable elsewhere to other limestones and some of the factors used could also be used on other limestones, particularly if factors such as glacial history, previous drainage and particularly the interaction between solution feature development and infill deposits could be established. The model in its current form has not been applied to other limestones. However, field work has suggested that it would be applicable to, for example, the crystalline limestones of South Wales.

From CULSHAW, M. G., BELL, F. G., CRIPPS, J. C. & O'HARA, M. (eds) 1987. *Planning and Engineering Geology*, Geological Society Engineering Geology Special Publication No. 4, pp. 335–37.

J. Cook (Wimpey Laboratories Ltd) queried whether there might be a danger of foundation designers equating particular designs to numbers of numerical hazard analysis in the system.

C. Edmonds replied that the model was developed at 1:25 000 scale and had been applied down to 1:5000 scale. He thought that the model could be used to draw attention to hazardous zones on site, at which point it should be possible to propose simple site investigation procedures to define the hazard more precisely.

I. Statham (Ove Arrup & Partners) commenting on Mr Edmonds's paper made the point that sophisticated techniques for hazard mapping now exist but, for them to give clear and helpful advice to planners, they should realistically represent the risk. What do terms such as 'high', 'medium' and 'low' really mean? He suspected they meant 'low', 'very low' and 'negligible' for most environmental hazards encountered in the UK. There is a danger of overstating the level of the hazard (knowingly or not) in the terms we use. The next step should be to assign numerical values to the risk, that is the probability of an event occurring and its scale. Planners would then be better equipped to make sensible financial decisions on the risks and the consequential solutions for remedial measures. Such numerical values would have to be deduced from databanks of recorded events which should be continuously updated and the values revised as necessary.

Written contribution

J. C. Cripps (University of Sheffield) writes: In his paper Mr Fulton referred to the difference between planning and geological timescales with respect to the evolution of unstable slopes. Although the popular conception that geological processes are very slow may well be valid in some cases, it is important to appreciate that in some processes, for example, coastal or fluvial erosion, certain types of mass movement and rock weathering or softening, can be relatively rapid. In the cases of coastal erosion and weathering, rates of change can be predicted and incorporated into the plan.

A. Fulton (London School of Economics) replies: Whilst I agree with Dr Cripps's observation that many geological processes are relatively rapid, the problem of identifying the point at which the evolution of a geological process becomes an impact on a planning strategy remains. Without detailed records and monitoring of processes the long-term behaviour of a given process and its likely evolution over time cannot be accurately judged. Few planning systems take this into account and the lower tiers of government in many societies (including Great Britain) have neither the fiscal nor manpower resources to implement monitoring programmes except where an impact is imminent or where a process has already caused losses.

Planning timescales are often quite short and do not coincide, except by chance with the threshold events of geological processes. Any attempt to reconcile these two very varying areas of interest in land use development requires some attempt at studying both the planning process and geological processes and establishing linkages between the two based on accurate information.

Written contributions

J. C. Cripps (University of Sheffield) writes: Would Messrs Venter & Gregory please clarify the extent to which the high risk zones identified for road P45-1 (Fig. 2) depend on the intersection of sinkholes by a borehole? What borehole spacing was used and what size are the sinkholes?

Also, have the authors attempted to relate the risk assessment of Table 1 to the severity of the subsidence? Reference is made to the fact that 20% of road P45-1 is expected to settle more than 100 mm and this corresponds to the length of road classified as high risk (Fig. 5).

Finally, would it be possible to derive coatings for this problem by weighting the remedial and other costs by the probability that various amounts of settlement will occur?

B. J. Gregory (Kirk, McClure and Morton) replies: In general, the classification of an area as high risk does not depend on intersecting a sinkhole by a borehole. This is because, under dewatering conditions, the risk primarily derives from the formation of new sinkholes and so the problem is to identify those areas where the geological conditions are conducive to their formation. There is also a high risk from renewed subsidence of palaeo-sinkholes. These features, which date from the late Tertiary or Quaternary periods, were filled in with red aeolian and water-borne sands and clays and are difficult to identify from gravity surveys due to minimal density contrasts between the infill material and the general overburden. However, where identified, such features are classified as high risk and indeed the two narrow southernmost high risk zones on road P45-1 (Fig. 2) are so classified because exploratory boreholes intersected suspected palaeo-sinkholes.

The position of exploratory boreholes was selected on the basis of gravity anomalies and features identified from gravimetric surveys conducted along the road centrelines. The results of these surveys, carried out with station intervals of 10 m, were used to produce a model of the bedrock topography, albeit an 'average depth' model. The boreholes were not positioned on a set pattern and their spacing varied from in excess of 1 km down to 10 m.

The size of sinkholes varies considerably from a few metres up to 100 m in diameter with the majority in the range of 10 to 30 m. They pose a considerable threat to life. For example, in 1962 a sinkhole engulfed a three-storey crusher plant at the West Driefontein mine with the loss of 29 lives, and in 1964, at Blyvooruitzicht, two houses disappeared with the loss of 5 lives.

The risk categories summarized in Table 1 relate to sinkhole occurrence and, therefore, are not directly related to the severity of subsidence discussed elsewhere in the paper as surface movements associated with sinkholes are in terms of metres, even tens of metres. Although 20%

of road P45-1 is classified as high risk it is expected that less than 0.1% of the road will, in reality, be affected by sinkholes once the effects of dewatering have diminished (see data summarised on Fig. 3). However, both the length of road classified as high risk and that expected to settle in excess of 100 mm are about 20%. That these are of the same order of magnitude is not unexpected as the presence of soft compressible wad below the water table is not only one of the factors conducive to the formation of sinkholes but is also that portion of the soil profile that will settle most as dewatering progresses. It is considered fortuitous and coincidental that they agree so closely.

Finally, it is not possible to derive costings for this problem by relating costs to the probability that various amounts of settlement will occur because damage caused to the road is related to differential settlement rather than the magnitude of the total settlement. For example, in the Bank Compartment on the main road to Carletonville, stretches on the road have settled uniformly and severe damage is restricted to narrow zones where tenson cracks have developed at the margins of the settlement. The problem is not primarily a question of cost, the aim being to minimise risk to people using the public roads. That is why the various alternative solutions described were identified and assessed before a decision was taken, in consultation with the State Co-ordinating Technical Committee for Sinkholes, to proceed with grouting as a preventative stabilization measure prior to the start of dewatering.