the uncertainty in travel distance and /or travel direction should be modelled as shown in the example presented in Table C8.

Table C8: Example of modelling uncertainty in travel distance and the probability of spatial impact ($P_{(S:H)}$).

Travel Distance Range metres	Estimated Probability the Travel Distance will be in this Range	Probability of spatial impact ($P_{(S:H)}$) assuming the element at risk is 32 metres below the landslide
<20	0.2	0
20 to 30	0.6	0
30 to 40	0.2	0.2
	Total 1.0	Total 0.2

The probability values could be further modified by the conditional probability associated with travel direction, where this is appropriate. For example, if a rockfall is assessed to have a variety of possible trajectories, only some of which will result in spatial impact on the element at risk, then application of the conditional probability for the trajectory would be applied to the travel distance probability.

C6 CONSEQUENCE ANALYSIS

C6.1 ELEMENTS AT RISK

No further comment.

C6.2 TEMPORAL SPATIAL PROBABILITY ($P_{(T:S)}$)

Roberds (2005) gives a detailed account of how to estimate temporal spatial probability where the elements at risk are mobile. AGS (2000, 2002) Appendix E gives details for the case of traffic travelling on a road.

For most assessments involving persons at risk in a building, the practitioner should make an estimate of temporal spatial probability based on the use of the building. This should include assessment of the probability of non-evacuation which may be used as a conditional probability. The landslide velocity and possibility of forewarning of the landslide failure will be relevant considerations.

The assessment may need to be based on a regulator's notional occupancy for a dwelling, not necessarily the client's proposed occupancy. For example, a client may wish to build a holiday house with relatively low occupancy factors (particularly for the time of year most likely to have a landslide event). However, a subsequent owner may be occupying with an average family on a fulltime residential basis. The later occupancy would be more critical and should be adopted for assessment purposes for the development.

C6.3 EVALUATION OF CONSEQUENCE TO PROPERTY

C6.3.1 Estimate the extent of damage likely to property arising from each of the landslides

The assessment of vulnerability and damage to property is subjective, and there is little published information. The Practice Note Appendix F has some data but note that for property this represents the judgements of those doing the study and is not a record of actual vulnerability. There are some general points which should be considered:

- Landslides which move slowly (particularly those with a near planar, horizontal surface of rupture) may cause little damage to structures on the landslide, though those structures which are on the boundaries of the landslide will experience differential displacement.
- For stuctures on the landslide, the rate of movement is less important for damage to the structures, except insofar as it affects the time rate of damage, than it is for loss of life.
- For stuctures below the landslide, the velocity of the landslide has a major effect on the damage and hence vulnerability. Hence structures which are near the toe of a landslide which will travel a long distance are likely to experience a high velocity impact and will suffer extensive damage (high vulnerability), and structures which are near the limit of the travel (or run-out) of the landslide will experience low velocity impact by only part of the landslide mass and will probably suffer "minor" damage (low vulnerability).

- It will sometimes be appropriate to consider vulnerability of a small part of the element at risk. For example, a room in a house which may be affected by a small landslide such as rock fall, may have a vulnerability of 1.0, whereas this may represent only a proportion of the value of the house as a whole.
- The proportion of a structure damaged is unlikely to represent the same proportion of the value of the structure. For example, damage to 10% of structure may represent 50% of the value of the structure.

C6.3.2 Estimate the indicative cost of the damage

The direct cost of damage to the structure is not the Total Cost to the owner if a landslide occurs. The Practice Note details the costs to be considered to derive an estimate of the Total Cost.

For many risk assessments it will be sufficient to estimate the costs approximately for example by using published construction cost guides which are relatively inexpensive (such as Rawlinson's, Cordell's, Reed's or similar). However, the practitioner is not a quantity surveyor and caution should be used in providing broad brush guesstimates on which legal decisions may be made and enforced. All cost estimates should be well documented and referenced using up to date industry sources appropriate to the location and types of costs involved.

Experience using the qualitative terminology in AGS (2000) Appendix G indicated that evaluation of the meaning of the description of the consequences to property can be subject to wide interpretation. In an effort to narrow the interpretation, de Ambrosis and Mostyn (2004) suggested use of estimates of the cost of damage as a more objective measure so as to limit disputes of interpretation of the description. The Practice Note definition builds on that proposal. Assessment of the consequences to property has been normalised as the Total Cost relative to the Market Value of the property under consideration. AGS recommends adoption of this updated approach using a semi-quantitative method as presented in Appendix C of the Practice Note.

There may be some situations where the regulator will require the risk from all landslide hazards to be brought to tolerable risk levels as part of the remedial works in the event of a landslide on a property. Regulators who will take this approach should make it clear to Practitioners doing risk assessments in their area.

For Practice Note Appendix C, the consequences scale has been adjusted in conjunction with appraisal of the risk categories as discussed in Appendix CC. It is considered that the adopted consequence scale is preferable to the order of magnitude scale in de Ambrosis and Mostyn (2004) as the Appendix C scale enables a more workable subdivision of risk in the Medium and Major categories (10% to 100% consequences) and shifts the descriptors towards the higher consequences, which is more realistic.

There is an obvious limitation in application of the method if the practitioner is not experienced enough to appreciate the civil engineering and structural engineering implications of particular landslide events. However, as consequences are an essential input to risk evaluation, this limitation has to be addressed and may require assistance ffom other experts, such as civil or structural engineers (as appropriate) or quantity surveyors for refinement of cost estimates.

C6.3.3 Estimate the market value

No additional comments.

C6.3.4 Consider the resulting Consequence classification, such as using Practice Note Appendix C, and implied accuracy of the above estimates.

No additional comments.

C6.4 EVALUATION OF CONSEQUENCES TO PERSONS

The assessment of vulnerability to persons is subjective and there is little published information. The Practice Note Appendix F has some data but note that except for the data in Finlay et al (1999) this represents the judgements of those doing the study and is not a record of actual vulnerability. There are some general points which should be considered:-

- For persons below the landslide, the velocity of the landslide has a major effect on the vulnerability. Persons who are near the toe of a landslide which will travel a long distance are likely to experience a high velocity impact and will have a high vulnerability and persons who are near the limit of the travel (or run-out) of the landslide will experience low velocity impact by only part of the landslide mass and will have a lower vulnerability.
- Persons who are in buildings which collapse totally have high vulnerability.
- Persons who are in buildings are less vulnerable than those in the open unless the building collapses.

- Persons in vehicles are less vulnerable than those in the open. Their vulnerability depends on the volume and velocity of the landslide. Experience in Hong Kong (Finlay *et al.,* 1999) indicates that rapid landslides of only a few hundred cubic metres are likely to result in death of the occupants of the vehicle.

It should be noted that whether a person will evacuate from the path of the landslide is covered in temporal spatial probability, not in vulnerability.

C7 RISK ESTIMATION

Standards Australia (2004) HB436:2004 discusses the types of risk analysis which may be summarized as:

- *Qualitative analysis*: "uses words to describe the magnitude of potential consequences and the likelihood that those consequences will occur. These scales can be adapted or adjusted to suit the circumstances, and different descriptions may be used for different risks"
- *Semi-quantitative analysis*: "qualitative scales, such as those described above are given values. The objective is to produce a more expanded ranking scale than is usually achieved in qualitative analysis, not to suggest realistic values for risk such as is attempted in quantitative analysis."
- *Quantitative analysis*: "uses numerical values (rather than descriptive scales used in qualitative and semi-quantitative analysis) for both consequences and likelihood using data from a variety of sources. The quality of the analysis depends on the accuracy and completeness of the numerical values and the validity of the models used."

Appendix G of AGS (2000) presented an example of qualitative terminology and risk matrix that was considered to be suitable for use in landslide risk assessment for property. AGS (2000) recognized that alternative schemes may be used, provided they are defined. As previously noted, AGS (2000) has now been superseded by the Practice Note.

C7.1 QUANTITATIVE RISK ESTIMATION

Reference should be made to Lee and Jones (2004) for a number of examples of risk calculations for a variety of scenarios. Some examples are also given in Roberds (2005) and other invited papers in the same volume. Such examples may be useful for deriving an appropriate model to enable suitable risk estimates.

C7.2 SEMI-QUANTITATIVE AND QUALITATIVE RISK ESTIMATION FOR RISK TO PROPERTY

In the context of risk assessments for residential development with submission to a regulator, adoption of a common preferred qualitative terminology should be mandatory as stipulated in the regulator's policy. If the practitioner considers an alternative scheme to be preferable for a particular hazard/situation, then adoption of this alternative must be justified by detailed documentation of the reasons.

There is considerable benefit to the regulator and the practitioner to use a common terminology. Comparison between different sites and between different practitioners is facilitated. Whilst there may be an inherent difference in assessment between practitioners (for example as shown by Baynes *et al.*, 2002), adoption of a common terminology will facilitate understanding and calibration between practitioners. Use of a scheme developed for a specific site or case makes cross comparisons difficult or confusing.

Although the Practice Note Appendix C scheme uses qualitative terminology to communicate and/or summarise the assessment of risk to property, it is in essence a quantitative scheme since it relies on the best estimates of the likelihood and consequence for the analysis. Risk to life should only be considered quantitatively and the adoption of semi-quantitative methods is considered to be inappropriate.

C7.3 RISK MATRIX FOR PROPERTY LOSS

The preferred Risk Matrix for Property presented in the Practice Note Appendix C has been derived primarily for residential development. It may also be appropriate to apply the scheme to other development,or situations/consequences. If the scheme is modified, or an alternative adopted, then full discussion of the justification and basis for the alternative scheme should be given.

A number of alternative qualitative scales for Likelihood, Consequences and resulting risk matrices and assigned risk levels were examined before deriving the final scheme in the Practice Note. Further discussion is given in Appendix CC of the considerations involved.

The main considerations were:

- The use of the annualised cost of damage to help allocate the risk categories.