Appendix A

Assessment of Cliff Recession Potential

Appendix A Assessment of Cliff Recession Potential

A.1 Introduction

This appendix provides a brief description of the approach taken to assessing cliff recession potential along the West Dorset, Weymouth and Portland coast, and the results of this assessment.

A.2 Methods and models

Reliable projection of cliff recession is fundamental to many aspects of coastal planning.

In recent years, significant progress has been made in developing methods to investigate and predict cliff instability and erosion. Important developments have been the recognition of different types of cliff behaviour (e.g. regular retreat, sudden change and episodic landslide events) that can be recognised along the coast as discrete cliff behaviour units; the use of historical maps and orthorectified (i.e. map accurate) aerial photographs in a GIS to derive accurate historical data that can underpin future projections of change; and the use of probabilistic approaches to address uncertainty in the cliff recession process (Table A-1).

Table A-1 Summary of recent work on coastal erosion projection (after Moore et al. 2010)

Date	Study title	Description	Sponsor
1994-2001	Investigation and Management of Soft Rock Cliffs (Lee and Clark 2002)	Summarises methods of prediction of recession rates and erosion control techniques. Defines the concept of cliff behaviour units. Developed analytical methods for predicting cliff recession rates for the wide variety of CBU types.	MAFF
2000-2002	Futurecoast	Regional-scale study of the coast of England and Wales by Halcrow to inform the 2nd round shoreline management planning. Provided a robust geomorphological framework for conceptualising coastal evolution. Included a database of cliff behaviour units for England and Wales with details of sensitivity to climate change and cliff recession potential.	Defra
2005-2006	Risk assessment of coastal erosion (RACE)	Halcrow-led project to develop a robust probabilistic method for assessing the hazard and risk of coastal erosion. Supported by the Futurecoast cliff database, strategic coastal monitoring programmes and risk-based inspections. Five techniques are developed with increasing degrees of sophistication and data input, ranging from expert judgement to probabilistic cliff recession prediction.	Defra
2006-2012	National coastal erosion risk mapping (NCERM)	Halcrow project that maps lengths of coastline susceptible to cliff instability and erosion from natural processes while taking account of the possible impacts of climate change and coastal defence policy and management. The project has developed innovative web-based software utilising the methods developed by RACE.	EA

While it is accepted that climate change will lead to an increase in the rate of erosion, due to sea level rise causing waves to break higher up the beach and cliff more frequently, and increased levels of winter rainfall triggering more frequent landslides; the relationship between climate change and cliff recession is poorly understood. This is primarily due to a lack of long-term empirical datasets that link historical cliff recession rates with projected climate change and sea level rise (Moore *et al.*, 2010; Lee, 2011). Consequently, future projections generally use probabilistic methods to estimate the full range of potential climate change impacts.

A.3 Key terms

Important terms that are used in this report are defined here:

- **Coastal erosion** is a process driven by wave and tidal energy at the coast which is dissipated by frictional drag associated with the scour, mobilisation and transport of sediments by tides and waves. Where coastal hinterlands and backshores are elevated relative to sea level, the action of waves and tides will erode and undercut the base of cliffs which will develop a characteristic morphology and profile reflecting their geological composition, structural form and evolution.
- **Cliff instability** involves slope failure and mass movement of a coastal slope or cliff and may result in deposition of debris on the beach and foreshore. Some landslides are very large and extend a considerable distance inland, offshore and deep below beach level and care must be taken to ensure their true extent is recognised. Cliff instability and erosion is a four stage process involving detachment of particles or blocks of material, transport of this material through the cliff system, its deposition on the foreshore and its removal by wave and tidal action.
- **Cliff recession** is the landward retreat of the cliff profile (from cliff toe to cliff top) in response to cliff instability and erosion processes. It is not a simple or uniform process in space or time and depends on a variety of factors that control the rates of detachment and transport. Long-term rates of historical change can give an indication of future behaviour, but short-term data are likely to be misleading.
- **Cliff behaviour units** (CBUs) provide an important framework for the investigation and management of cliffs (Lee and Clark, 2002, Moore *et al.*, 1998). Each CBU includes the foreshore, the cliff top and the processes that act upon them, all of which can have a significant influence on cliff instability and recession behaviour (Figure A-1). Diagnostic CBUs in order of their relative complexity, are as follows:
  - **Simple cliff face systems**: a single sequence of inputs from falls or slides leading almost directly to foreshore deposition. There is usually a steep cliff face, narrow degradation zone and rapid response to toe erosion. This type of cliff will fail as a result of toe erosion and undercutting, so relative sea level rise (RSLR) is the main forcing parameter. Examples include the sandstone cliffs of Burton Cliff, Burton Bradstock and East Cliff, West Bay.
  - **Simple landslide systems**: a single sequence of inputs and outputs with variable amounts of storage. A marked degradation and storage zone is

usually apparent affording limited buffering against toe erosion. This system will be affected by erosion of the landslide toe and excess groundwater in the slide zone; therefore both sea level and rainfall are key forcing parameters of equal importance. Examples include the protected cliffs of Wyke Regis on the northwest shore of Portland.

- **Composite cliff systems**: partly coupled sequences of contrasting simple sub-systems, typically comprising inter-bedded hard and soft rocks. Around the coast of England and Wales composite cliffs are formed where hard cap rocks are underlain by clay-rich strata giving a distinct steep upper cliff face and a tendency for high magnitude, low frequency failures. Composite cliffs are sensitive to changes in toe erosion and groundwater where soft rock occurs above hard rock. Examples include many of the hard-rock capped cliffs of Portland.
- **Complex cliff systems:** strongly coupled sequences of scarp and bench sub-systems, each with their own inputs, storage and outputs of sediment. The output from one system forms a cascading input to the next resulting in close adjustment of process and form with complex feedbacks. The sub-system storage results in significant buffering against the immediate effects of toe erosion, although elevated groundwater levels can trigger major events that can transform the behaviour of the whole system (e.g. major mudsliding episodes), therefore groundwater is the main forcing parameter in the short-term. The impact of toe erosion occurs over much longer timescales of 100s or 1000s of years and consequently toe protection measures alone will not prevent headscarp recession due to sub-aerial slope degradation. Examples include Black Ven, and the East and West Weare cliffs of Portland, Dorset.
- **Relict cliff systems:** sequences of pre-existing landslides susceptible to reactivation and exhumation by coastal erosion operating over long timescales of many hundreds to a thousand years. They include abandoned cliffs and slopes formed by ancient landslides that have the potential to become reactivated by toe erosion and or excess groundwater levels. An example is the Undercliff to the west of Lyme Regis.

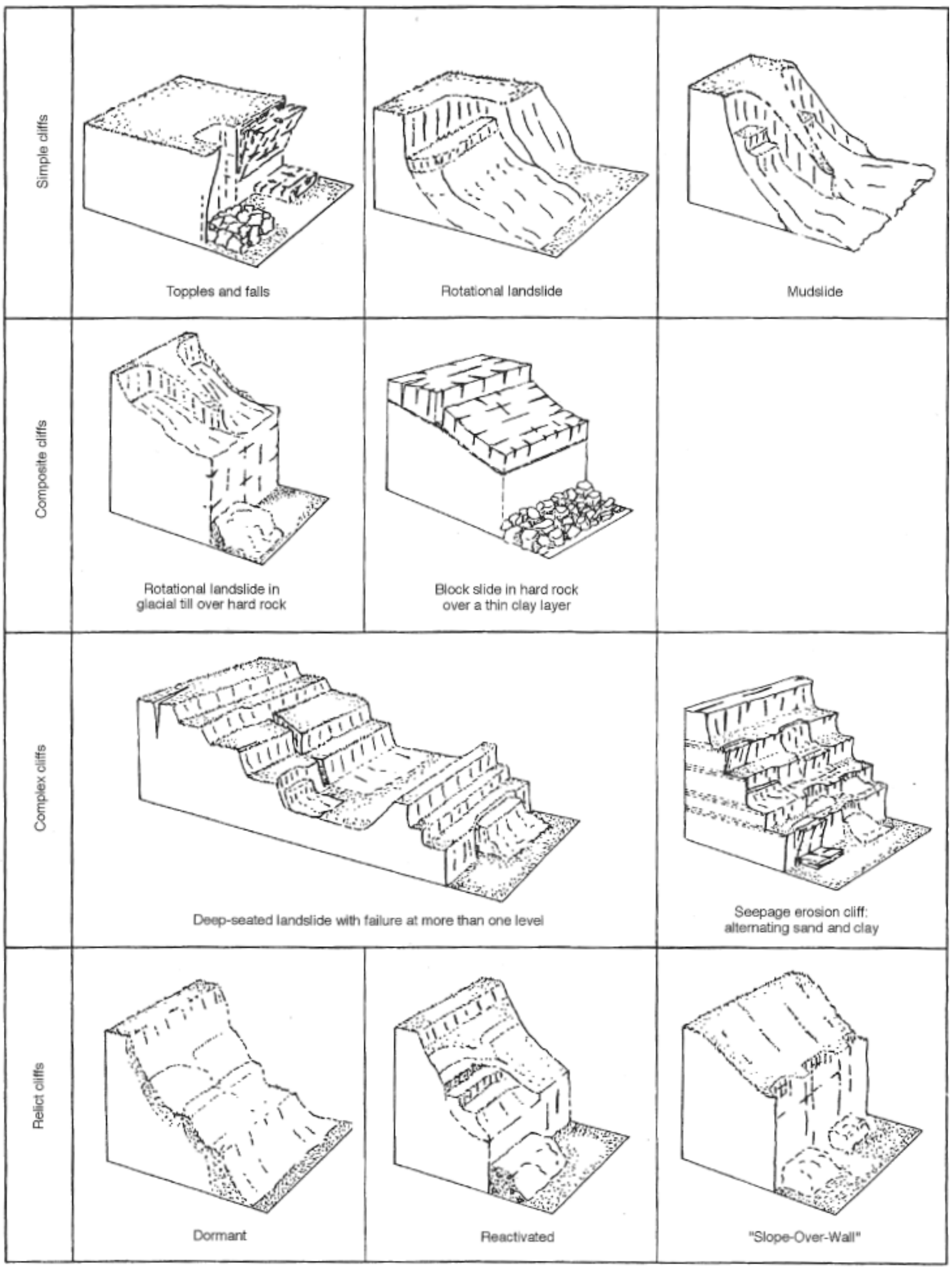


Figure A-1 CBU types (after Lee and Clark, 2002)

A.4 The National Coastal Erosion Risk Mapping (NCERM) project

The National Coastal Erosion Risk Mapping (NCERM) project was undertaken by Halcrow for the Environment Agency and uses coastal erosion concepts and models first developed for Futurecoast. Its aim is to publish robust and consistently-derived projections of coastal erosion in the public domain, as a component of the Agency's 'What's in your backyard' web pages.

NCERM uses a methodology that combines projections of historical coastal recession rates to determine future erosion losses over timescales of 20, 50 and 100 years. It accounts for coastal management policies as defined in shoreline management plans and assuming a scenario of no active intervention to simulate the natural behaviour of cliffs. Projections are provided for stretches of coast that are sub-divided into a series of cliff behaviour units. Where defences are present, NCERM always takes 55 years as the maximum residual life for defences in line with Defra guidance. NCERM assumes that following the failure of defences and re-activation of erosion the recession rate will initially accelerate. The acceleration takes place until the receding coastline 'catches up' with the point that it would have reached if it had been undefended and allowed to erode naturally. Following this, coastline recession will continue at the normal predicted rate for the epoch under consideration. This is a realistic interpretation of the likely response of a coastline which has been defended for a long time becoming re-exposed to marine processes, although there are limited case studies of this process.

Over each time period, results are presented that show 5%, 50% and 95% probability losses from erosion, which account for uncertainty associated with cliff recession processes and impacts of climate change and sea level rise. The default cliff recession data on which projections are based are taken from the Futurecoast project (Halcrow, 2002) and historical data held in current shoreline management plans (SMP2). However, prior to public release, a comprehensive validation process was undertaken allowing local authorities to review, and where necessary update, the historical cliff recession rates.

NCERM recognises three types of coastline:

- **Erodible Coasts** that have simple cliffs or landslides that behave in a predictable manner, which can be assessed using NCERM.
- **Floodable Coasts** that are low lying areas identified by Environment Agency flood maps. They are not subject to erosion and are not covered by NCERM. Floodable coasts are not considered further in this methodology.
- **Complex Cliffs** that behave in a non-linear way with multi-tiered landslides that are difficult to predict through simple extrapolation of historical recession rates. Complex cliffs and relict cliffs are not covered by NCERM and require more careful analysis on a case-by-case basis.

The classification of CBUs in NCERM is summarised in Table A-2.

Table A-2 Classification of CBUs in NCERM

CBU type	NCERM classification
Simple cliffs and landslides	Erodible Coast, covered by NCERM
Composite cliffs	Erodible Coast, covered by NCERM
Complex cliffs	Complex Cliff, not covered by NCERM
Relict cliffs	Complex Cliff, not covered by NCERM

NCERM therefore provides the necessary cliff instability and erosion data to underpin estimates of future cliff recession potential associated with Erodible Coast CBUs (i.e. simple cliffs, simple landslides and composite cliffs). The outputs of NCERM were published in April 2012 and are freely available to Local Authorities. The published outputs from NCERM comprise erosion bands for 20, 50 and 100 years at 5%, 50% and 95% probabilities, with current SMP management policies in place for each time period (i.e. hold the line, managed retreat and no active intervention), and also assuming a scenario of no active intervention to simulate the natural behaviour of cliffs.

For Complex Cliff CBUs (i.e. complex cliffs and relict cliffs), a site-specific expert review of cliff behaviour is required to underpin projections of future potential cliff recession losses. This assessment requires information on historical relationships between climate, sea cliff erosion and headscarp recession. For many of the larger complex cliff systems, data is available from Futurecoast, published papers or information held in Local Authority records. However, it is likely that information on complex cliffs will be limited and it is possible that new studies will be required to derive accurate projections of future cliff instability and erosion. The use of existing data to estimate future behaviour of complex cliffs and the scope of site-specific studies are described in Section A.5.2.

A.5 Estimating recession potential

Recession potential has been estimated for each CBU along the West Dorset, Weymouth and Portland coast in one of the following ways, depending upon the CBU type.

A.5.1 Simple cliffs, simple landslides and composite cliffs

The NCERM data has been used directly for CBUs defined as simple cliffs, simple landslides of composite cliffs (refer to Section A.4).

No further assessment has been made as the NCERM data has only recently been published following extensive validation with local authorities to ensure the data is as accurate as possible.

The data presented in the risk maps is for the 5% probability scenario in 20, 50 and 100 years. This means that within the risk zone, part(s) of the cliff top are expected to experience recession back to the landward boundary of the zone, though it is uncertain as to how much of the cliff will receded to this limit in the stated time-scale.

A.5.2 Complex cliffs

Detailed, site-specific information on historical landslide behaviour is available for the Lyme Regis/Charmouth and Portland Harbour north-west shore coastlines. These data have been used to determine recession potential estimates for complex cliffs along the coast. For other stretches of the coast, where site-specific data of historical behaviour of complex cliffs are unavailable, data held in Futurecoast on the expected magnitude and frequency of recession events have been used.

The steps taken to estimating recession potential based upon the Futurecoast data is shown in Figure A-2. In summary, the approach is as follows:

1. Recession potential is estimated by multiplying magnitude of each event by its frequency.
2. The magnitude of each event is assumed to be 5m, 25m and 50m for low, medium and high activity cliffs respectively. These magnitudes are based on expert judgement.
3. The frequency of each event, based on expert judgement, is assumed to be:

- For events that occur every 1 to 10 years = 20 events in next 100 years
- For events that occur every 10 to 100 years = 5 events in next 100 years
- For events that occur every 100 to 250 and 250 to 1000+ years = 1 event in next 100 years.

4. 5 and 95% probabilities are derived by adding/subtracting 20% from the central (50%) projection.

5. If the SMP policy is for HTL over the next 100 yrs, headscarp recession is assumed to be 50% of the central projection. This recognises that toe erosion will be halted (by continued defence of the toe), but that other effects, such as system lags or elevated groundwater levels, may continue to promote instability.

6. 20 and 50 year projections are simply derived by factoring down the 100yr projection.

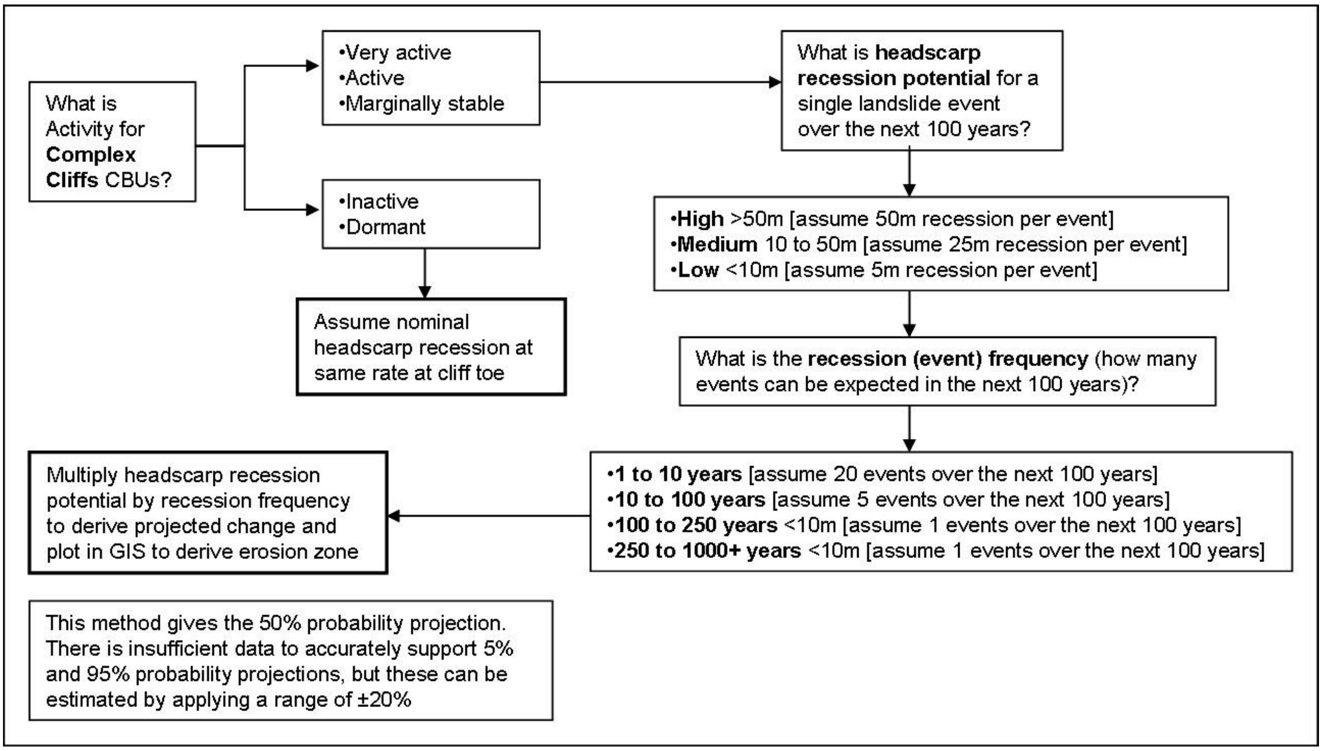


Figure A-2 Approach to estimating cliff recession in complex cliff areas using Futurecoast data.

A comparison of the results from detailed assessments from Lyme Regis/Charmouth and Portland Harbour north-west shore with projections derived from Futurecoast shows that Futurecoast method is somewhat precautionary, with cliff recession projections being in the order of c. 20% greater. However, as this data is to be used for planning guidance, a precautionary assessment of the potential areas affected is recommended.

The methodology is also precautionary in that it assumes that 'marginally stable' cliffs will be active over the next 100 years, as a result of the impacts of climate change. This means change is projected at Portland and Ringstead Bay (towards White Nothe).

Appendix B

Geotechnical Appraisal Report Template

Appendix B Geotechnical Appraisal Requirements

B.1 Approaches to the investigation of coastal land instability

Ground investigations are undertaken to determine site specific geology, geomorphological processes and the geotechnics of erosion or instability problems in an area.

The approach to geotechnical investigations can vary, and there is a range of national standards, technical documents and general literature that provide guidance for the geotechnical investigation of instability problems in the UK. However, Chapter 4 of the *Cliff Instability and Erosion Management in Great Britain: A Good Practice Guide*(Halcrow, 2011b) provides a concise overview of the most appropriate approaches for investigating coastal land instability, including the use of early warning and monitoring systems and the value of ground stability (a.k.a. geotechnical appraisal) reports in ensuring that appropriate expert assessment and evaluation of land stability has been considered in producing development proposals (refer to Section B.2).

B.2 Suggested structure and content of Geotechnical Appraisal Reports

Geotechnical Appraisal Reports prepared to support a planning application are recommended to broadly adhere to the following structure (from Halcrow, 2011b):

1. **Introduction:** a statement indicating for whom the work was done, the nature and scope of the investigation, its general location, its purpose and the period over which it was carried out.
2. **Description of History:** a detailed description of the site based on observations made by a Competent Person (i.e. a chartered geomorphologist, geologist or engineer with experience of coastal cliffs and landslides) during a site reconnaissance. It should be referenced to a plan of the site showing national grid co-ordinates and to a scale no smaller than 1:2,500. Use of GIS is recommended to manage spatial data.
3. **Investigations:** information consulted during the course of the desk study should be referred to and listed as an appendix. Fieldwork should be described and full records of boreholes, trial pits or other exploratory methods included as an appendix and their locations shown on a plan. Site tests and laboratory tests and methods should be similarly described and their results included.
4. **Ground Conditions:** descriptions of the ground conditions found during the investigation and an interpretation of their relevance to the stability of the site and surrounding area. Anomalies in any of the data collected should be pointed out. The following items should be discussed, where appropriate: geological conditions, hydrogeology, history of past events and ground movement rates, soil and rock properties, other factors e.g. coast protection.
5. **Evaluation of Stability:** the stability of the site and relevant adjacent area should be evaluated with respect to the proposed development and the assessment of ground conditions. Where stability calculations are carried out, the method of analysis should be stated. The stability calculations should

demonstrate both the existing factors of safety and, where appropriate, the factors of safety that would be created by the proposed development and any associated stabilisation measures. It is expected that particular attention should be paid to the gradients of cut slopes and fills, drainage measures, retaining structures, failure mechanisms and the design criteria applied.

6. **Conclusions and Recommendations:** the Competent Person should summarise the main conclusions of the investigation and list the recommendations to ensure both the long-term stability of the site (taking account of the anticipated life of the development) and also in the short term whilst construction proceeds. It is expected that particular reference will be made to matters such as: the avoidance of fills near the crest of steep slopes, restrictions on the depth of excavation at the toe of steep slopes, the maximum length of trenches excavated along the contours of steep slopes at any one time, avoidance of septic tanks and soakaways, provision of flexible jointed pipes capable of sustaining small movements without leakage, provision for free drainage of groundwater, minimising drainage diversions and their lining where site conditions require them.

B.3 Geotechnical Appraisal Report Declaration Form

Alongside the Geotechnical Appraisal Report, the following declaration form should also be submitted (from Halcrow, 2011b):

Site Name	Site Address	Development Management Area
Category	**Question**	**Answer: yes / no / ? / n/a**
A) Competent Person	• Has a Competent Person or Geotechnical Specialist prepared the report?	
	• Does the Competent Person or Geotechnical Specialist operate a Quality System which meets the requirements of BS EN ISO9001?	
	• Does the Competent Person or Geotechnical Specialist have a minimum of £1m Professional Indemnity Insurance?	
B) Site History	• Has the site been affected by past ground instability?	

	• Is the site located within or adjacent to any instability features?	
C) Site Inspection	• Has a detailed site inspection been carried out?	
	• Does the site and adjacent land bear any geomorphological evidence of past or incipient ground instability?	
	• Does the site or neighbouring property bear any evidence of structural damage or repairs that might be associated with ground instability?	
D) Geotechnical Desk Study	• Have any previous ground investigation reports and/or borehole records from the site been consulted?	
	• Is the information consulted and referred to sufficient to quantify the ground behaviour constraints, which could affect the stability of the site?	
E) Ground Investigation	• Has a ground investigation been carried out and have the results been submitted in support of this application?	
	• Did the investigation identify the presence of sub-surface shear zones and low strength compressible soils at the site?	
	• Is the information sufficient to quantify the ground behaviour constraints, which could affect the stability of the site?	
F) Stability Assessment	• Is the information in B, C, D and E (where applicable) adequate to assess the stability of the site and adjacent land?	
	• Can ground instability reasonably be foreseen within or adjacent to the site within the design life of the proposed development, allowing for any deterioration of ground conditions caused by the development itself?	
	• Can instability be reduced to a reasonable level through cost-effective mitigation and stabilisation measures that would be environmentally acceptable?	
G) Mitigation Measures	• Have mitigation measures been proposed with respect to ground instability issues?	
	• Have these been designed to reduce the effects of actual or potential instability to a reasonable level?	

	• Is it possible the mitigation measures may have an adverse effect on the stability of other, adjacent sites (for example by affecting groundwater drainage in the area)?	
H) Name, Qualifications and Signature of Person Responsible for the Geotechnical Appraisal Report	**Full Name:** **Qualifications:** **Signature:** **Company Represented (if applicable):**	

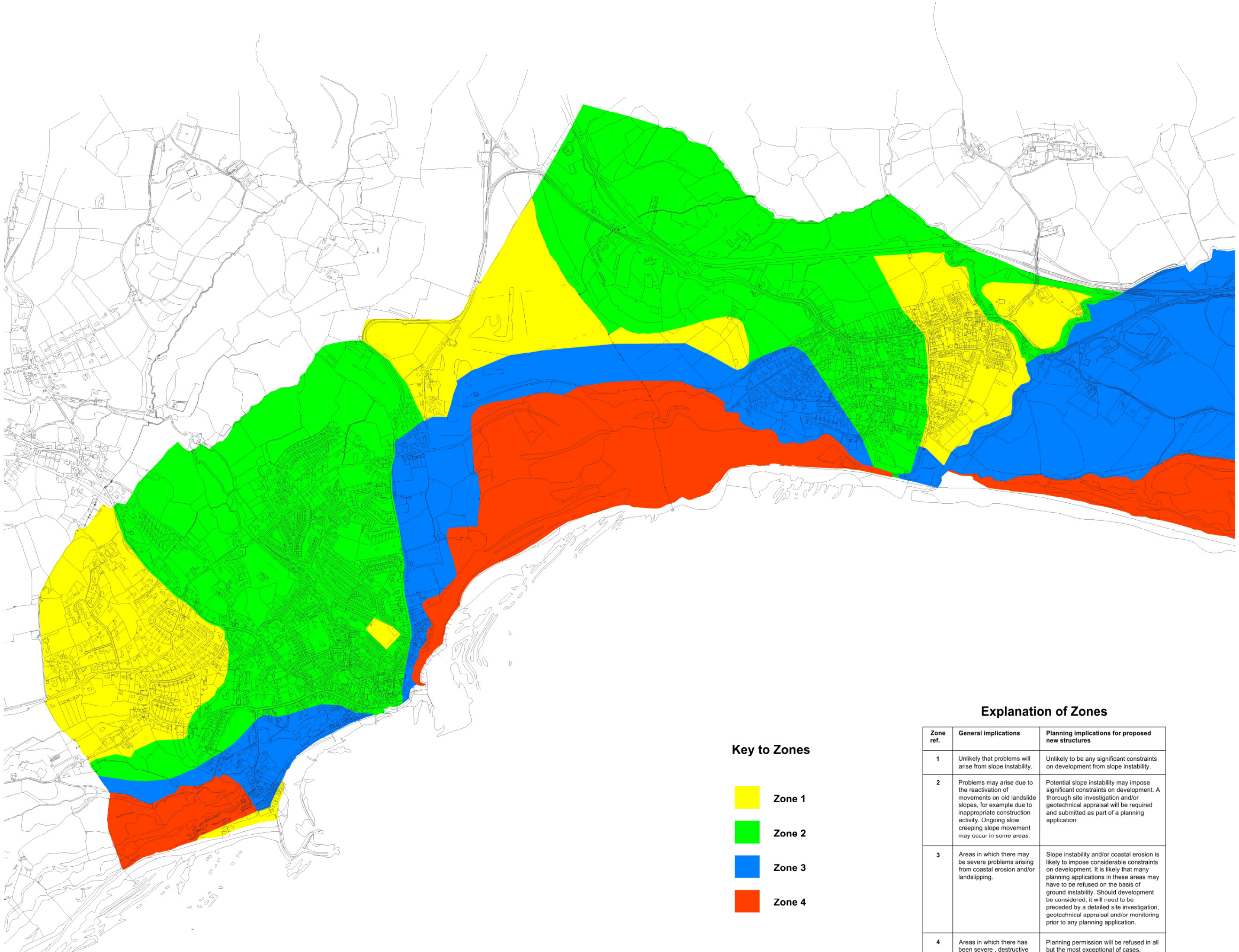
Appendix C

Zonal Mapping of Instability

Appendix C Zonal Mapping of Instability

The mapping in this appendix shows zones of varying land instability at Lyme Regis and Charmouth, as prepared by High-Point Rendel (2004) for West Dorset District Council. This has been reviewed alongside other available data in developing this coastal risk planning guidance and, based on this review, is considered to be appropriate for continued use for development management.

No other similar zonal mapping of instability is available at the present time for the rest of the West Dorset, Weymouth and Portland coast that is the subject of this coastal risk planning guidance.



Explanation of Zones

Zone ref.	General implications	Planning implications for proposed new structures
1	Unlikely that problems will arise from slope instability.	Unlikely to be any significant constraints on development from slope instability.
2	Problems may arise due to the reactivation of movements on old landslide slopes, for example due to inappropriate construction activity. Ongoing slow creeping slope movement may occur in some areas.	Potential slope instability may impose significant constraints on development. A thorough site investigation and/or geotechnical appraisal will be required and submitted as part of a planning application.
3	Areas in which there may be severe problems arising from coastal erosion and/or landslipping.	Slope instability and/or coastal erosion is likely to impose considerable constraints on development. It is likely that many planning applications in these areas may have to be refused on the basis of ground instability. Should development be considered, it will need to be preceded by a detailed site investigation, geotechnical appraisal and/or monitoring prior to any planning application.
4	Areas in which there has been severe , destructive landslipping and/or coastal erosion in recent historical times.	Planning permission will be refused in all but the most exceptional of cases.

The purpose of this map is to provide information on the likely degree of constraint on development due to slope instability at Lyme Regis and Charmouth. The map is based on the most up to date data available at the time of preparation (September 2003). The principal criteria on which the location and extent of the different map zones have been based are as follows:

1. The underlying geology, inferred from boreholes and geological mapping

2. The form and steepness of the ground and geomorphological mapping

3. Knowledge of previous incidents of slope instability

4. The proximity of actively-eroding cliffs or river banks.

Whilst sufficient information exists to make reasonable judgement of the extent of each of the zones, rigorous systematic studies of ground behaviour, covering the whole of the Lyme Regis and Charmouth area, have not yet been carried out. The maps should therefore be regarded as interim, to be progressively updated as more information becomes available, and ultimately to be replaced by the findings of comprehensive studies.

The map is intended to give guidance on slope instability constraints only, and not on other geological hazards, such as soft ground or high groundwater table.

Where the map indicates that potential slope instability may impose constraints on development, a geotechnicial investigation and/or appraisal will need to be carried out, and a report submitted prior to, or as part of, the planning application. This work should be carried out by a suitably-qualified professional consultant proficient in ground engineering. The report should consider slope instability issues specifically, and should demonstrate that the development would be carried out without adverse effects on the safety or serviceability of either the development itself or the surrounding land and structures, both in the permanent case and during construction.

Revision	Amendments / Revisions	Checked	Date
2	Change in Zone 3 and 4 boundary near Pine Walk and edits to text	MS	Oct 04
1	Change in Zone 1 and 2 boundaries near Lyme Regis Golf Club	MS	Sept 03

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Preliminary Slope Instability Guidance Map

for Lyme Regis and Charmouth

Drawn by : NB	Checked by : GMD	Approved by :
Date : October 2004	Scale : 1:7500	
Drawing File Reference : (WDDC)\\lymesrv\lymeDWG\WDLS001 (HPR)\1584-Figure2.dwg		
Drawing Number : Figure 2		Rev. : 2

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