C O M M I S S I O N E D R E P O R T

Commissioned Report No. 070

Study into landscape potential for wind turbine development in East and North Highland and Moray

(ROAME No. F02AA302)

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COMMISSIONED REPORT

Summary

Study into landscape potential for wind turbine development in East and North Highland and Moray

Commissioned Report No. 070 (ROAME No. F02AA302)
Contractor: Macaulay Land Use Research Institute and Edinburgh College of Art

BACKGROUND

The principal objectives of the Study were to:

- Make recommendations on an approach to be taken to conduct such an assessment with an analysis of its strengths and weaknesses.
- Assess the sensitivity of the landscape character to the siting of wind turbines.
- Assess the visual sensitivity of the landscape to the siting of wind turbines.
- Assess the potential cumulative visual impacts of turbines development within the study area.
- Classify the landscape of the study area according to its potential to absorb wind turbine development.

The analysis was at a strategic level and is not applicable at the level of an individual site which is the role of the relevant EIA. The study focused upon the landscape and did not take into account any other natural heritage issues such as habitat sensitivity, or technical considerations such as wind speed and connections to the electricity grid.

Four factors were used to derive the classification of landscape character sensitivity: landform; landform scale; land cover complexity; and land cover naturalness. Three factors were used to assess visual sensitivity: visibility of the landscape; nature of the viewing experience; and numbers of people viewing the landscape.

MAIN FINDINGS

- The visual sensitivity dataset illustrates that the areas that would be most sensitive to wind turbine developments are in the vicinity of towns and main roads, predominantly around coastal lowlands.
- The landscape potential maps (excluding the influence of landscape designations) show that the areas of greatest potential for large developments were scattered throughout the uplands and near the north coast between Tongue and Thurso.
- The areas with the lowest potential in the north were central Caithness, the land west of Tongue, west of Lairg, the coastal areas of Cromarty and the Black Isle. To the south the areas of low potential were around Inverness and the Moray coast, Strathspey and south west of Fort Augustus.

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Part 1: Main Report

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S.1 This study was commissioned by SNH in 2002 and carried out by the Macaulay Institute (MI) and the Edinburgh College of Art (ECA). A committee was formed to set the objectives and inform the methodology. It comprised of representatives from Scottish Natural Heritage (SNH), MI, ECA, the Moray Council and the Highland Council. This study was commissioned for use by SNH, The Highland Council, Moray Council and related bodies to help inform decision-making regarding windfarms. The field work for the study was carried out in the spring of 2003.

The principal objectives of the Landscape Potential Study for Wind Turbine Development in East and North Highland, and Moray were to:

1. Make recommendations on an approach to be taken to conduct such an assessment, with an analysis of its strengths and weaknesses.
2. Assess the sensitivity of the landscape character to siting of wind turbines.
3. Assess the visual sensitivity of landscape to the siting of wind turbines.
4. Assess the potential cumulative visual impacts of turbine developments within the study area.
5. Classify the landscape of the study area according to its potential to absorb wind turbine developments.

S.2 The analysis was at the strategic level and is not applicable at the level of an individual site, which is the role of the relevant Environmental Impact Assessment for any individual windfarm application. The outputs do not take into account other natural heritage issues (e.g. habitat sensitivity), or technical considerations such as wind speed and connections to the electricity grid. The methods used are, however, robust and repeatable, using quantitative materials to which qualitative assessments can be added.

S.3 The area of study was north and east Highland and Moray, covering a land area of 20,147 km^2 (approximately 25% of Scotland), excluding the offshore areas of the Pentland and Moray Firths.

Methodology

Landscape potential for wind turbine developments

S.4 The methodology used GIS-based Decision Support Tools (DSTs). These tools were calibrated and used with a high degree of professional landscape architecture theory and practice, backed up by calibration through fieldwork. The tools provided the framework for two parallel sequences of data collection and processing, which was carried out as a series of steps (Figure 1). The first sequence produced maps relating to landscape character sensitivity. The second sequence resulted in maps of visual sensitivity, based upon visual receptors such as roads, settlements and viewpoints. These two sets of maps were combined to produce a final series of maps showing the landscapes' potential for wind turbine development.

S.5 Use of DSTs enabled robust, rational and repeatable decisions to be made in situations of great complexity. This study required many factors to be considered. Some were

independent of each other, some partly dependent and some had greater significance than others. The DST approach allowed the interactions and weightings of each of the factors to be controlled and changed to test the implications of different assumptions about the data.

S.6 Figure 1 summarises the methodology. It shows the inputs that comprise the main factors used to derive a classification of the combined sensitivities of landscape to wind turbine development. These factors are grouped into Landscape Character Sensitivity and Visual Sensitivity. In addition, coarser grain maps of landscape unity and sense of place can be included or excluded in the final output (as overlays).

S.7 The four factors used to derive the classification of landscape character sensitivity were:
1. Landform complexity.
2. Landform scale.
3. Land cover complexity.
4. Land cover naturalness.

The factors were assessed using a scoring system that enabled computer-based analysis and subsequent map production. The digital representations of these four input datasets were calibrated by field observations to produce a landscape character sensitivity map. Weightings were used to allow differentiation between the sensitivity to small, medium and large wind turbine developments.

The categories Large, Medium and Small used throughout the report, relate to the size and number of turbines in a development as described in the "Guidelines on Environmental Impacts of Wind Turbines and Small Hydro-electric Schemes" (SNH 2001):
- Small – turbine developments of less than 10 turbines.
- Medium – developments from 10 to 25 turbines.
- Large – developments over 25 turbines.

The three factors used to assess visual sensitivity were:
1. Visibility of the landscape.
2. Nature of the viewing experience.
3. Numbers of people viewing the landscape.

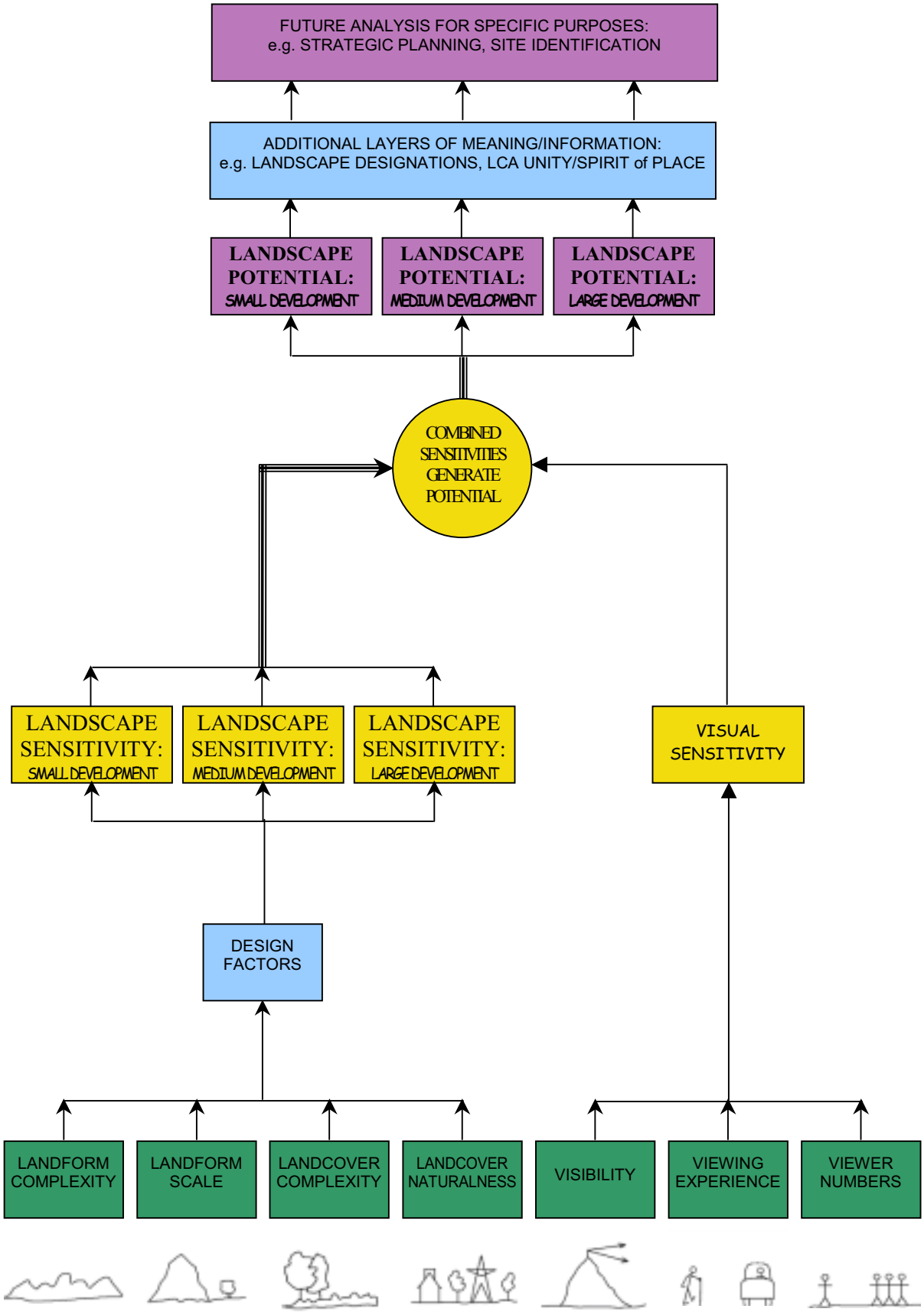
S.8 Baseline visibility of the landscape was derived from analysis of the terrain. Next, the visibility of the landscape from specific visual receptors, such as settlements, roads and viewpoints, was calculated and combined to produce a geographic model of the viewing experience. Finally, the visibility from roads was weighted according to estimated road usage and a dataset was derived to represent the number of people able to see the landscape.

S.9 The landscape character sensitivity and visual sensitivity maps were combined to produce three maps of landscape potential for wind turbine development (one for each size of development).

S.10 Landscape designations were identified: NSAs, AGLVs, the Cairngorms National Park, along with SNH Areas of Search for Wildland. Buffer zones of the visibility of land within the designations up to a distance of 10 km were created in the GIS. Weightings were applied to the designations and a lower weighting was used for the buffer zones and the SNH Areas of Search for Wildland. The resultant dataset may be used to re-assess the landscape potential for windfarms in the light of the designations and candidate areas of wildland.

S.11 Note: SNH's Areas of Search for Wildland are included in this study as a separate 'values' layer and should not be confused with Landcover Naturalness (see para S8 above) which is included in the main analysis to represent 'wildness' as part of the derivation of landscape character sensitivity (see Table 3.1).

Figure 1. Methodology flowchart.



Cumulative impacts

S.12 The assessment of potential cumulative visual impacts used Caithness and Moray as study areas and was performed in three steps:

1. identification of sensitive sites.
2. impacts according to ordering with respect to the road network.
3. sequences of views from the road network.

S.13 The assessment identified locations within each study area where views of multiple developments would be greatest, taking account of those developments for which planning approval existed. The output was overlaid on the datasets of landscape character sensitivity, visual sensitivity and landscape potential (for large turbine developments). This showed where the highest likelihood of cumulative visual impacts might arise taking account of the potential of the landscape to accommodate such developments.

S.14 In Moray, land that was calculated to have the highest likelihood of cumulative visual impacts was concentrated predominantly around the coast, with some areas inland principally to the west and north. Developments in the vicinity of Paul's Hill and south-west of Cairn Uish were found to have a high likelihood of contributing to cumulative visual impacts. There were no similar conflicts in the vicinity of Mains of Drummuir. In Caithness, the highest likelihood of cumulative visual impacts was concentrated the south-west and in the vicinity of Forss and Thurso to the north.

S.15 Near inshore areas were not considered in the analysis of cumulative visual impacts, but the same approach would be as valid inshore as for land areas.

S.16 It is recognised that more developments have been given planning approval since the analysis was conducted and that this may alter the geographic pattern of likely areas of cumulative visual impacts.

Results

General:

S.17 Predictably, the visual sensitivity dataset illustrates that the areas that would be most sensitive to wind turbine developments are in the vicinity of the towns and main roads, predominantly around the coastal lowlands.

S.18 The landscape potential maps (excluding the influence of landscape designations) show that the areas of greatest potential for large developments were scattered throughout the uplands and near the north coast between Tongue and Thurso. The largest single area of high potential is that in the Moray Firth, greater than 25 km from the coast.

S.19 The areas with the lowest potential in the north were central Caithness, the land west of Tongue, west of Lairg, the coastal areas of Cromarty and the Black Isle. To the south the areas of low potential were around Inverness and the Moray coast, Strathspey, and south-west of Fort Augustus.

Moray:

S.20 The areas of highest likelihood of cumulative visual impacts were found to be around the coast. The mountainous terrain leads to fragmented views and therefore less extensive areas of high likelihood than in Caithness.

S.21 In Moray, the areas with moderate or high landscape character sensitivity are predominantly inland, and coastal areas have low landscape character sensitivity. Visual sensitivity broadly shows the opposite pattern.

S.22 Areas of high likelihood of cumulative visual impact were found to coincide with areas of low potential for wind turbine development in coastal areas. However, some inland areas with a high cumulative likelihood also have a moderate to high potential for wind turbine development, particularly in the vicinity of Paul's Hill.

Caithness:

S.23 The areas of highest likelihood of cumulative visual impact were found to be in the south-west. They occupy land that is predominantly of moderate landscape potential for windfarms, with areas of high potential west of Altnabrec and high sensitivity in places such as Morven. Areas of high likelihood of cumulative visual impacts coincide extensively with areas of low visual sensitivity in the south-west of Caithness, but also include areas of high visual sensitivity north-west of Berriedale, and in the vicinity of Dounreay, Forss and Thurso.

S.24 The likelihood of cumulative visual impact was compared to the landscape potential for wind turbine development. Areas of high potential, where the likelihood of cumulative visual impact was not low or moderate, were located in the north-west of Caithness, and to a lesser extent in the south-east. Areas of high landscape potential, and high cumulative visual impacts were in the south-west of Caithness, between Strath of Kildonan and Boulfruich. However, there are also areas of low potential in the same vicinity such as Ben Alisky, Dounreay and Forss.

Outputs

S.25 This report is the main output of the study. Large format maps of landscape character sensitivity, visual sensitivity and landscape potential for wind turbine developments for the study area were produced for The Highland Council and The Moray Council.

Conclusions

S.26 The study has produced datasets describing characteristics of the landscape in east and north Highland and Moray that can be applied consistently across a wider area. These data can be assessed using expert interpretation with respect to their significance for wind turbine developments. The flexibility of the approach enables alternative models of landscape character sensitivity and visual sensitivity to be tested, producing maps of landscape potential for wind turbine development that are consistent, but which can be modified to reflect changes in the landscape content (e.g. more turbines), and the potential cumulative impacts that this could imply. However, it would be desirable to undertake greater sensitivity testing of the different scores and weightings used to assess the impact on the outputs at each stage.

S.27 The thresholds used in the derivation of areas of potentially high likelihood of cumulative visual impact can be altered to accommodate new circumstances, such as recent development approval, so that the assessment remains up-to-date for subsequent developments.

S.28 The digital datasets of the final outputs provide the user with additional sources to help in the consideration of proposals for turbine development.

ACKNOWLEDGEMENTS

Ack.1 The authors wish to acknowledge the contributions made by the members of the Steering Group, both with respect to the contents of the report, and their suggestions throughout the programme of work. Acknowledgement is also due to Dr Dick Birnie on aspects of the methodology.

Ack.2 Digital map data and turbine locations were provided by Scottish Natural Heritage, the Highland Council and Moray Council, and thanks are due to the members of staff who assisted in the provision and formatting of these data. The Ordnance Survey data was provided under licence (Licence number GD272825G 2001). Acknowledgement is also due to ERDAS (UK) Ltd, ESRI (UK) Ltd and Silicon Graphics whose software and hardware were used under licence for this work.

1 GENERAL INTRODUCTION

1.1 Objectives

1.1.1 This study was commissioned by SNH and carried out by the Macaulay Institute (MI) and the Edinburgh College of Art (ECA). This study was commissioned for use by SNH, The Highland Council, the Moray District Council and related bodies to help inform decision-making regarding those landscapes that are most able to accommodate windfarms. A committee was created to set the objectives and inform the methodology. It was comprised of representatives from SNH, MI, ECA, the Moray Council and the Highland Council.

1.1.2 The principal objectives of the landscape potential study for wind turbine development in east and north Highland, and Moray were:

1. To make recommendations on an approach to be taken to conduct such an assessment, including its strengths and weaknesses.
2. An assessment of the sensitivity of the landscape character to siting of wind turbines.
3. An assessment of the visual sensitivity within the study area to the siting of wind turbines.
4. An assessment of the potential cumulative visual impacts of turbine developments within the study area.
5. A classification of the landscape in the study area according to its potential to absorb wind turbine developments.

1.1.3 To achieve these objectives, the team developed tools for use as part of a Decision Support System (DSS), which were applied through the use of data analysis using a Geographic Information System (GIS). These Decision Support Tools (DSTs) were used with a high level of professional landscape architecture theory and practice, backed up by calibration through fieldwork.

1.2 Principles applied to the study

1.2.1 Landscape planning studies and reports frequently rely on expert opinion and, while the results may be sound, there can be some opacity in the methodologies and imprecision in the terminology. To avoid this problem, the guiding principles were that this study should be:

- Robust.
- Rational.
- Repeatable.

1.2.2 Robustness was required partly to ensure that the results are meaningful and also to ensure that the guidance developed through the study will stand up to scrutiny in a public inquiry. A rational basis was necessary for the methodology, choice of input data and the arguments presented to support the conclusions. The results must be repeatable to demonstrate that they are not dependent on personal views. Furthermore, terminology was clarified and made as precise as possible, with references to the relevant literature. Definitions of terms and acronyms are provided in Appendix I and Appendix II respectively.

1.2.3 The study was designed to follow the general principles of good practice contained in the Guidelines for Landscape and Visual Impact Assessment – the GLVIA – (IEMA & LI, Second Edition 2002), page 17, to:

- Clearly describe the methodology (Section 3).
- Use clearly defined and agreed terminology.
- Avoid generalisations.
- Be as impartial as possible.

- Draw upon the advice and opinions of others.
- Carry out consultations.
- Organise and structure the assessment.
- Openly acknowledge any deficiencies.
- Consider the "worst-case" situation.

1.3 Definition of key terms

1.3.1 Many of the terms used in this report have been defined or employed elsewhere in a variety of ways. To minimise confusion, the terminology used here was based, as far as possible, on the Guidelines for Landscape and Visual Impact Assessment (GLVIA 2002). The exceptions are terms that do not appear in the glossary to the GLVIA, in which case definitions were taken from "Elements of Visual Design in the Landscape" (Bell 1991) and the "Guidelines on Environmental Impacts of Wind Turbines and Small Hydroelectric Schemes" (SNH 2001). Some differences between these publications had to be resolved. The definitions of the main terms used throughout the report are as follows:

1.3.2 **Landscape character sensitivity**
Landscape character sensitivity is the degree of anticipated change in landscape character in response to a given type/magnitude of wind turbine development, derived in this study from analysis of landform complexity, landform scale, land cover complexity and land cover naturalness.

(An area of high landscape character sensitivity will show a greater change in landscape character to a given wind turbine developments than one of low landscape character sensitivity, and vice versa. Landscape character sensitivity is independent of landscape value. Hence, an area may be of high landscape character sensitivity and low landscape value, and vice versa).

1.3.3 **Visual sensitivity**
Visual sensitivity is a measure of the anticipated visual effect[1] in response to a given type/magnitude of wind turbine developments, as derived from analysis of specific visibility, and viewer criteria.

(An area of high visual sensitivity will have a greater change in appearance and visual amenity and/or affect a larger number of people, than one of low visual sensitivity, and vice versa. Visual sensitivity is independent of landscape value. Hence, an area may be of high visual sensitivity and low landscape value, and vice versa).

1.3.4 **Landscape potential**
Landscape potential is the combination of landscape character sensitivity and visual sensitivity.

1.3.5 **Landscape potential**
Landscape potential is the degree to which a geographical area[2] can possibly accommodate landscape character impacts and visual effects resulting from wind turbine development, without change that is considered to be unacceptable. Landscape potential must be interpreted in association with landscape value. A complete glossary is presented in Appendix A.I.

[1] Visual effect as defined in GLVIA, Institute of Environmental Assessment and The Landscape Institute, 2002. "Visual effects relate to the appearance (of these changes) and the resulting effect on visual amenity". (GLVIA Summary page – no page number)

[2] Landscape character area, or landscape character type. Capacity takes account of the designated value of the landscape, value as expressed by the predicted preferences of people who may experience the landscape, and value related to the presence of landscape icons.

1.4 Purpose of and approach to the study

1.4.1 Three underlying assumptions were made about the nature of the work:

1. This is a strategic level study. While it may be used to inform the selection of an individual site it is not intended to, and cannot, replace the Environmental Impact Assessment process.
2. The study does not take into account other natural heritage issues (e.g. habitat sensitivity), or technical considerations such as wind speed and connections to the electricity grid, which are addressed within either the Environmental Impact Assessment, or in consultation with the relevant planning authority.
3. The methodology is robust and repeatable, using quantitative materials to which qualitative assessments can be added.

1.4.2 The strategic approach to assessing the potential of the landscape character to accommodate wind turbine developments adopted in this study seeks to integrate four elements:

1. The sensitivity of landscape character to wind turbine development.
2. The degree of observer sensitivity to wind turbine development in any given landscape.
3. The anticipated design of any likely wind turbine development, i.e. the layout and scale of the windfarm, the design of turbines and the ways in which they can or cannot be fitted into landscapes of different characters.
4. The cumulative visual effect of the introduction of wind turbines into the landscape.

1.4.3 **The sensitivity of landscape character to wind turbine development**

This depends on the presence, to different degrees, of key components (landform complexity, landform scale, land cover complexity and land cover naturalness) that are specifically relevant to wind turbine location and layout. In this study, a number of aspects contributing to a wider understanding of landscape character, such as cultural historical associations or ecological interests, were omitted to enable focus to be placed upon the main visual factors, which formed the basis of the assessment. The results are presented as a neutral assessment, independent of the values placed on the landscape by those who experience it, or people's sensitivity to change, (dealt with under 'public acceptability', below). However, any judgement about sensitivity of the landscape character is inevitably based on some form of expert judgement. The current "Guidelines on Environmental Impacts of Wind turbines and Small Hydroelectric Schemes" (SNH 2001) were based mainly on the opinions of experts. Since the issue of wind turbines in the landscape is an evolving one, there were instances in this study where the authors disagree with some of the current published design guidance (both the SNH guidelines above and the GLVIA). Such cases are clearly stated with reasons.

1.4.4 **The degree of observer sensitivity to wind turbine development in any given landscape**

Sensitivity depends on the viewing location and its context, the expectations and activity of the observers and the importance (or value) of the landscape in the view (GLVIA 2002).

1.4.5 **The anticipated design of any likely wind turbine development, i.e. the layout and scale of the wind farm, the design of turbines and the ways in which they can, or cannot, be fitted into landscapes of different character**

Many other forms of development, such as planting of woodlands or house construction, can be designed to reflect character and to become an integral part of the landscape. Wind turbines, by contrast, are more standardised in their design, and flexibility is achieved by layout, numbers and density. Guidelines on siting, layout and choice of turbine are presented in the "Guidelines on Environmental Impacts of Wind Turbines and Small Hydroelectric Schemes" (SNH 2001), and these are used except where the authors disagree with these guidelines.

1.4.6 **The cumulative visual effect of the introduction of wind turbines into the landscape**
Multiple views of, or sequential exposure to, developments are considered by current guidance (GLVIA) to have a negative effect on the experience of the landscape by an observer. The order in which developments proceed to planning leads to different potential cumulative visual effects, such that an observer from a given location may experience different levels of cumulative exposure under different development scenarios.

1.4.7 Due to the strategic level of this study, it was not possible to assess every square kilometre of the landscape through fieldwork. The existing Landscape Character Assessments (LCAs) in SNH's national suite of LCAs provided intermediate data between the GIS-based analysis and the supporting field observations. Only the factors **landform complexity**, **landform scale**, **land cover complexity** and **land cover naturalness** were regarded by this study to be essential for the evaluation of landscape character sensitivity to wind turbines. By developing DSTs, a basis for linking elements of existing data using expert interpretation was possible, allowing the derivation of the four factors. The DSTs also allowed flexibility in the allocation of the relative weightings, enabling a user to explore alternative options that raise or lower the potential significance of data such as that represented by the LCA. These four factors were provided in the project brief and can also be found in the paper by Stanton (Stanton 1996) as well as the latest guidance from SNH (SNH 2001).

1.5 Geographical modelling

1.5.1 The analysis derived a landscape potential dataset for North Highland and Moray at a strategic level as well as maps of landscape character sensitivity and visual sensitivity. These datasets were combined to derive a map of landscape potential for windfarm development.

1.5.2 The landscape character and visual sensitivity datasets also provide a basis for analysing the likely cumulative visual impacts of wind turbine developments. This is demonstrated for the areas of Caithness and Moray. The outputs from the analysis of likely cumulative visual impacts enable a description to be made of the landscape visible from any given point, or section of road, in terms of the potential significance of the sequence of developments in obtaining planning approval.

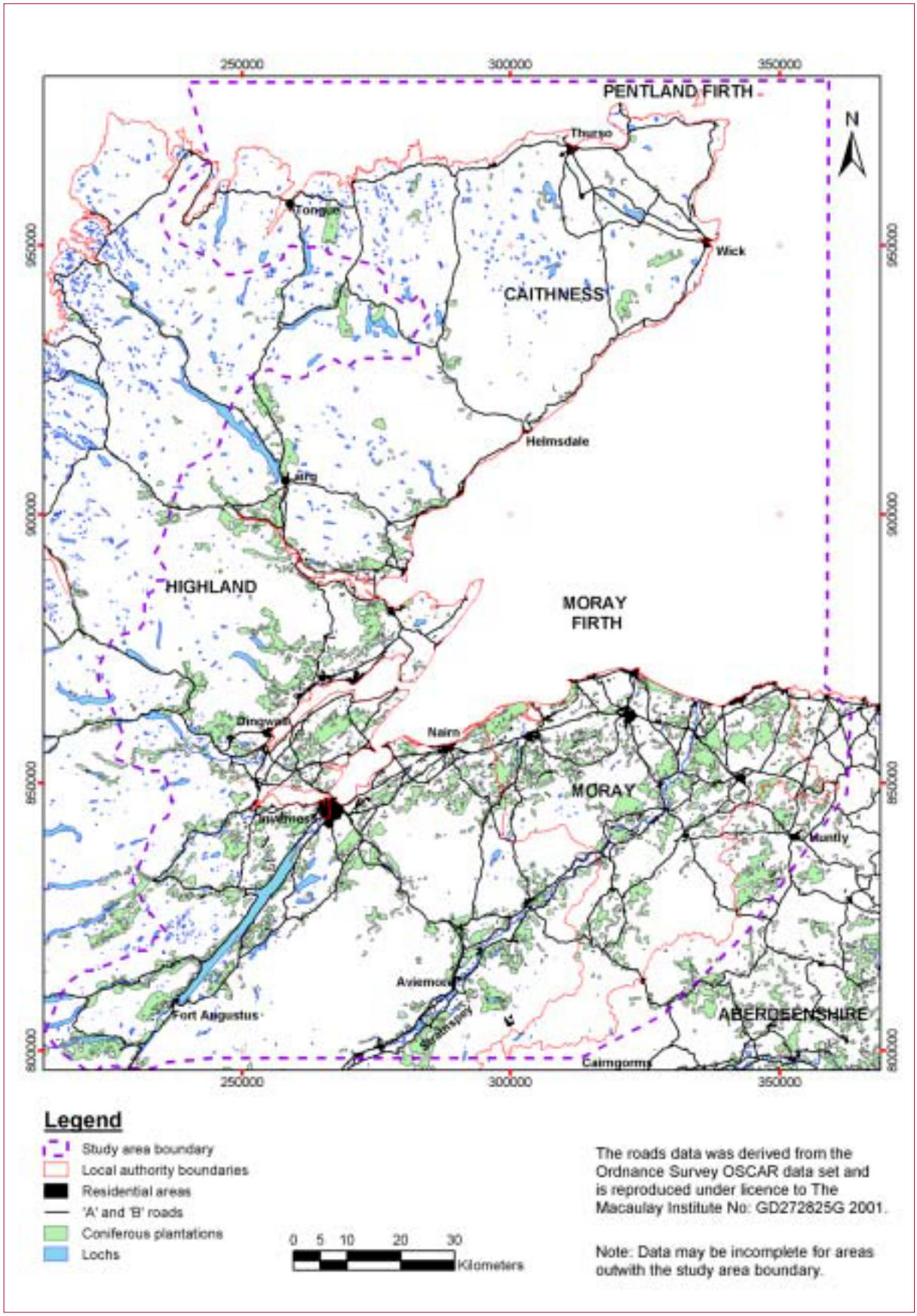
2 STUDY AREA

2.1.1 The extent of the study area was determined by the Steering Group. The factors considered in the identification and delineation of the extent of the area were to:

1. Include all of Moray Council.
2. Include all of the north coast, Pentland Firth and Moray Firth coastal area, from Loch Eriboll in the north-west to approximately Cullen in the south-east.
3. Include all of the sites for which there was an existing, or an outstanding proposal for a wind turbine development in the east and north Highland areas, as of the end of November 2002.
4. Draw the boundary to ensure that all relevant features are included.
5. Consider the factors that may impact upon the value of the study results to the members of the Steering Group (e.g. in informing them of potentially significant issues related to proposals for development).

2.1.2 Figure 2.1 shows the resulting area selected. This area was the basis for reporting the results of the study, and as a guide to the area within which field observations would be targeted. The land area of the study is 20,147 km^2 (approximately 25% of Scotland). This excludes the offshore areas of the Pentland and Moray Firths.

Figure 2.1. Study area.



3 OVERVIEW OF METHODOLOGY

3.1 Introduction

3.1.1 The methodology used GIS-based DSTs. The tools provided the framework for two parallel sequences of data collection and processing, which was carried out as a series of steps (Figure 3.1). The first sequence produced maps relating to landscape character sensitivity. The second sequence resulted in maps of visual sensitivity, based upon visual receptors such as roads, settlements and viewpoints. These two sets of maps were combined to produce a final series of maps showing the landscapes' potential for wind turbine development.

3.1.2 Use of a Decision Support System (DSS) enabled robust, rational and repeatable decisions to be made in situations of great complexity. This study required many factors to be considered. Some were independent of each other, some partly dependent and some had greater significant than others. The DSS approach allowed the interactions and weightings of each of the factors to be controlled and changed to test the implications of different assumptions about the data.

3.1.3 Development of the DSS had five phases, which are reported in Chapters 4, 5, 6, 7 and 8.

Phase 1 Spatial data (Chapter 4)

Phase 2 Analysis of landscape character sensitivity to wind turbines (Chapter 5)

Phase 3 Analysis of visual sensitivity (Chapter 6)

Phase 4 Mapping the landscape potential for wind turbine developments (Chapter 7)

Phase 5 Likelihood of cumulative visual impacts (Chapter 8)

An overview of each phase follows.

3.2 Phase 1: Spatial data (Chapter 4)

3.2.1 The inputs comprised a number of basic datasets relating to landscape character sensitivity and visual sensitivity. These included digital terrain and land cover data. Field observations enabled the data to be calibrated and the scoring system to be tested. Photographs were also taken to record the appearance of the landscape. The pre-processing of these data produced intermediate products, such as visibility levels of different land cover types, and inputs to the calculation of visual sensitivity, such as visibility from transport networks (*e.g.* roads and railways), viewpoints, and settlements.

3.3 Phase 2: Analysis of landscape character sensitivity to wind turbines (Chapter 5)

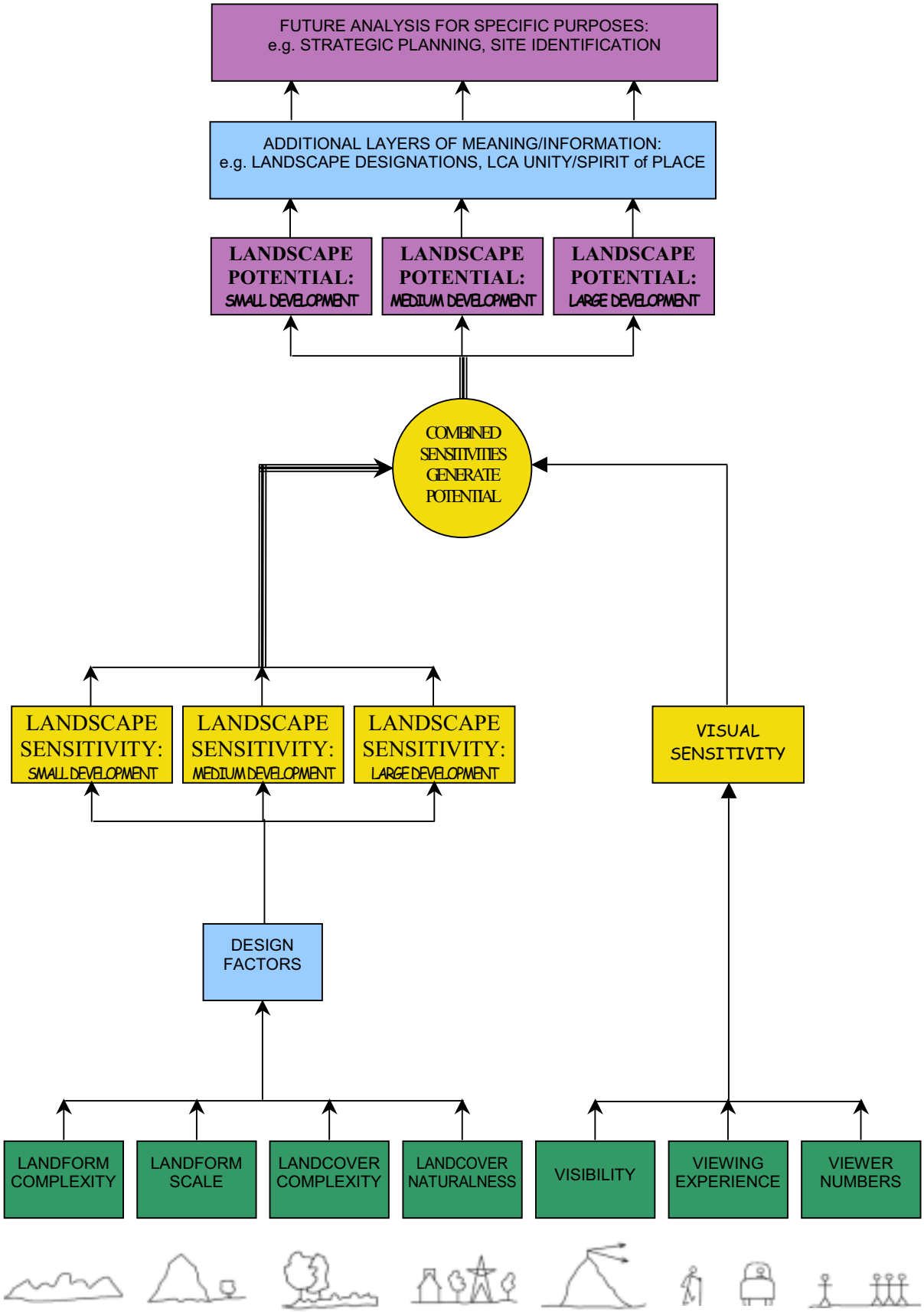
3.3.1 First, the digital elevation data were used to derive **landform complexity** and **landform scale**. The land cover data was used to derive **land cover complexity** and degree of **naturalness**. Together, these four factors are used to derive landscape character and contribute to the seven principal elements of wind turbine-related criteria listed in Table 3.1 (see also the four dark green boxes at the bottom left of Figure 3.1). The derivations were undertaken in a GIS and based on the expert opinion of the team supported by literature (especially Bell 1991). The processing of the data was undertaken in two sequences.

3.3.2 Secondly, these four factors were each subdivided into three classes e.g. landform complexity was divided into ‘very complex’, ‘moderately complex’ and ‘simple’. The subdivisions were scored (3=high; 2=med; 1=low) for their sensitivity to three sizes of windfarms (small, medium, large).

3.3.3 Thirdly, the four factors were weighted for their relative sensitivity e.g. landform complexity was regarded as being a more important determining factor for windfarm acceptability than land cover naturalness.

3.3.4 The scores and weightings were based upon expert judgement.

Figure 3.1. Methodology flowchart.



3.3.5 Table 3.1 shows how the project brief was interpreted to enable the derivation of GIS datasets that would allow analysis of landscape and visual sensitivity to wind turbine development.

Table 3.1. Factors in the project brief as applied to the study area.

FACTORS IN THE BRIEF	INTERPRETATION OF THE BRIEF	FACTORS USED IN THE STUDY	FIGURE
Landform complexity	The visibility of change in height.	**Landform complexity**: an analysis of the key attributes of landform.	5.6
Landform scale and openness	Openness is taken into account in terms of the extent of potential visibility across the landform.	**Landform scale**: an analysis of elevation range and the extent of terrain visibility.	5.10
Pattern and foci settlement	Foci are excluded because they are dependent on viewpoint, so not appropriate to be included in a strategic study. Landscape icons may incorporate certain aspects of landscape foci in another way.	**Land cover complexity**: landscape pattern is largely determined by the land cover, which in includes built structures, and is available for computer analysis.	5.14
Wildness	Currently such a dataset is not available, so an alternative (‘naturalness’), which does not convey exactly the same meaning, was used. The concept of wildness includes subjective, perceptual elements, not represented within the data.	**Naturalness**: this takes account of the main influences shaping land cover and the effect on this characteristic of the introduction of man-made objects.	5.18
Simplicity of the visual composition	Considered and discussed but not analysed quantitatively in the study. NOTE: some information has been retained in Appendix XI for the sake of completeness.	**Unity**: this considers the range of simple to complex visual compositions but also incorporates concepts such as integrity, harmony of pattern, visual confusion etc. Used within the predictive model of landscape value linked to the LCA data and in the digital data thus provided as dataset but not used in the analysis.	–
Rarity	Omitted from the analysis, as no dataset is immediately available for this factor.	None. Not used in the analysis	–
Spirit of Place	Recorded in field observations and linked to the LCA, not as a separate digital dataset.	Used within the predictive model of landscape value linked to the LCA data and in the digital data, again provided as dataset but not included in the analysis.	–

3.3.6 Landscape Unity was originally considered for inclusion. However, following further development of the methodology it became apparent that while landform and land cover data are available in GIS format and can be analysed successfully, landscape unity cannot. Although expert assessment is feasible, the number of samples available from fieldwork prevented a satisfactory degree of robustness in the data and so this factor was omitted from the analysis at this stage. The field observations are provided as attributes of a digital dataset for use in the GIS (see Figure 3.1).

3.3.7 Spirit of Place was also originally considered for inclusion. However, it presented problems because it varies much more locally than could be detected by field survey. Instead, features identified, by the expert opinion of team members, as being likely to present strong indicators of a spirit of place, referred to as "landscape icons", were identified from the GIS data. These provide extra levels of anticipated sensitivity of the landscape to the introduction of wind turbines but need to be assessed at the level of the EIA for particular developments, rather than at the strategic level of this study. Like Landscape Unity, Spirit of Place can also be queried in the GIS digital dataset of the field observations.

3.3.8 A dataset of landscape character sensitivity was developed by associating the data for landform complexity, landform scale, land cover complexity and naturalness with the landscape's ability to accept different scales of wind turbine developments. The weightings agreed by the Steering Group are shown in this report.

3.3.9 The output was a series of maps showing relative degrees of sensitivity to three different sizes of wind turbine development (small, moderate and large).

3.3.10 Alternative sets of weightings were tested to show the flexibility of the approach in accommodating the emphasis of different factors, as determined by expert opinion or consultative approaches.

3.4 Phase 3: Analysis of visual sensitivity (Chapter 6)

3.4.1 Analysis of visual sensitivity was conducted using GIS data to represent visual receptors (i.e. roads, railways, settlements, viewpoints, etc.) calibrated and tested in the field. This analysis used data on the visibility of the landscape, the number of viewers and the nature of the viewing experience.

3.5 Phase 4: Mapping the landscape potential for wind turbine developments (Chapter 7)

3.5.1 The landscape character sensitivity dataset was combined with that of visual sensitivity to form a combined dataset and map. The result was subjected to additional refinement using data on the degree of impact of potential developments, which are also checked against the field notes.

3.5.2 Landscape designations (NSAs, AGLVs, and the Cairngorms National Park) together with SNH Areas of Search for Wildland were considered to represent certain assessments of value of the landscape. These were retained as separate layers of information which were added to the maps of landscape potential for wind turbine development.

3.6 Phase 5: Likelihood of cumulative visual impacts (Chapter 8)

3.6.1 An evaluation of the likelihood of cumulative visual impacts from new developments was performed using the areas of Caithness and Moray as study areas. The evaluation was based on their proximity and position in relation to the location of viewers, and the combinations of views of development sites with respect to factors associated with sensitivity, such as naturalness and land cover complexity. The methodology used existing developments, proposed developments and randomly distributed observer points to identify areas in which developments may have a significant cumulative visual impact on the surrounding landscape. Examples were run to show the effects of development ordering on sites in Caithness and Moray.

4 PHASE 1: SPATIAL DATA

4.1.1 Methods for the compilation, analysis and representation of digital data using Geographic Information Systems (Burrough and McDonnell 1998) were used in the analyses to produce the maps of potential for, and sensitivity to, wind turbines. These were combined with landscape evaluation following guidelines such as those of Scottish Natural Heritage (2002a) and The Countryside Agency (2002) in the assessment of landscape character (Institute of Environmental Assessment and The Landscape Institute 1995).

4.1.2 This study's methodology draws upon work on the strategic assessment of visual impacts of wind turbines (e.g. Miller et al. 2002; Miller and Morrice 2001), and reports on the landscape character by Fletcher (1998), Land Use Consultants (1999), Ferguson McIlveen (1999), Richards (1999), Stanton (1998) and Turnbull Jeffrey Partnership (1996; 1998).

4.1.3 The data were represented in a raster format for processing but, as they originate from different sources, scales and resolutions, a single dataset was selected as a base to which the others were co-registered for consistency. The dataset used was the Ordnance Survey raster backdrop (Ordnance Survey 2002b), to which the Digital Terrain Model (DTM) (Ordnance Survey 2002a) with a spatial resolution of 50 m x 50 m was registered, and all other datasets processed to the same spatial resolution. All other datasets were then transformed to a similar resolution and position.

4.1.4 Descriptions of all of the spatial datasets used in the subsequent analysis, their limitations, and examples of the outputs are reported in Appendix III.

5 PHASE 2: ANALYSIS OF LANDSCAPE CHARACTER SENSITIVITY TO WIND TURBINE DEVELOPMENT

5.1 Introduction

5.1.1 Four main factors were used to derive a classification of the sensitivity of landscape character to wind turbine development for the study area:

- **landform complexity**
- **landform scale**
- **land cover complexity**
- **land cover naturalness**

5.1.2 Landscape unity was considered but not used in the main analysis. It was, however, reserved as a possible aid to the interpretation of the final output map, in the form of a digital dataset. Details on landscape unity and its assessment are contained in Appendix XI. At the site level, a number of additional issues need to be addressed in relation to the sensitivity of a site to the layout of wind turbines. Some of these issues are addressed in Appendix X.

5.1.3 The four factors were each subdivided into three classes. Each class was assigned a score which was then weighted using a system of numerical coding. This system provided a practical and repeatable tool for dividing data into different classes that can be assessed with respect to their likely sensitivity to the siting of wind turbines.

5.1.4 The approach is different from early uses of scoring which somewhat crudely applied scores to compare different things in assessments of landscape value, for example the so-called 'Fines System' or 'Manchester Method' (Fines 1968). These systems were used to allocate quasi-objective numbers on un-calibrated subjective measures. In the approach used in this study, the scores relate to sections along continuous scales of variability enabling the scales to be split into discrete steps.

5.1.5 The key test in developing a score-based system is how those numbers relate to each other and whether using them in arithmetical combination can be deemed to be valid. The scores used in this study were not arbitrary; they were based on the application of the design and landscape assessment guidance, calibrated by the field assessment. There was also the question of weighting of the scores. If it was considered that each factor (**landform complexity** etc) would have an equal effect on landscape character sensitivity, then each would be weighted the same. The scores were thus weighted to account for the differences in the factors. The assigned weightings are shown in blue in Table 5.1 below.

5.1.6 The choice of the number of steps in the scoring system was based on:

- The existence of any real and clear breaks or step-changes in the data. It is desirable to use natural breaks where possible. These were identified from initial testing of the datasets and were used to select the thresholds between classes.
- Expert judgement to define categories where such breaks in the data were unclear.

5.1.7 The categorisation of steps was calibrated by field observations to verify its validity, and to check that the steps were evident on the ground and capable of being identified consistently by several different assessors.

5.1.8 Although any continuum can be sub-divided into classes there is a limit to how many are capable of being determined on the ground (i.e. visually) and, practically, how many are useful in the final data analysis. Too few classes may be too crude a representation of the data, and risk losing subtlety at the boundaries between categories, with scope for large

degrees of transition open to debate. For this study, three classes were adopted for each category. The choice was an adaptation of experience gained from successfully applying similar assessment methods (Forestry Commission 2000). During the field testing of the work reported by the Forestry Commission (2002), using a large number of sample viewpoints, it was found that assessors were able to judge the categories consistently.

5.1.9 Table 5.1 summarises the scorings for each of the reclassified input factors (shown in green) and their relative weightings (shown in blue). These are multiplied together to give final values (shown in red) which were then used as inputs to the development of the final landscape potential dataset in Section 7. The four main factors are described in more detail in the following sub-sections. The categories Large, Medium and Small in Table 5.1 and elsewhere, relate to the size and number of turbines in a development as described in the "Guidelines on Environmental Impacts of Wind Turbines and Small Hydro-electric Schemes" (SNH 2001):

- Small – turbine developments of less than 10 turbines.
- Medium – developments from 10 to 25 turbines.
- Large – developments over 25 turbines.

5.1.10 A high score equals a high sensitivity. For example, a score of three (coloured green) in the first row of Table 5.1 indicates that very complex landforms and moderately complex landforms are highly sensitive to large wind turbine developments. A simple landform has a low sensitivity and scores one.

Table 5.1. Figures for inputs to landscape character sensitivity dataset for three types of turbine development (value in brackets is initial score).

A) Large turbine developments			
Factor	*Factor classification*		
Landform complexity:	*Very complex*	*Mod complex*	*Simple*
Weighting = 3	(3) **9**	(3) **9**	(1) **3**
Landform scale:	*Small scale*	*Medium*	*Large*
Weighting = 3	(3) **9**	(2) **6**	(1) **3**
Land cover complexity:	*Complex*	*Mod complex*	*Simple*
Weighting = 2	(3) **6**	(3) **6**	(1) **3**
Naturalness:	*Mainly natural*	*Mixed*	*Mainly man-made*
Weighting = 1	(3) **3**	(2) **2**	(2) **2**
B) Medium turbine developments			
Factor	*Factor classification*		
Landform complexity:	*Very complex*	*Mod complex*	*Simple*
Weighting = 3	(2) **6**	(2) **6**	(1) **3**
Landform scale:	*Small scale*	*Medium*	*Large*
Weighting = 3	(3) **9**	(1) **3**	(1) **3**
Land cover complexity:	*Complex*	*Mod complex*	*Simple*
Weighting = 2	(3) **6**	(1) **2**	(1) **2**
Naturalness:	*Mainly natural*	*Mixed*	*Mainly man-made*
Weighting = 1	(2) **2**	(1) **1**	(1) **1**
C) Small turbine developments			
Factor	*Factor classification*		
Landform complexity:	*Very complex*	*Mod complex*	*Simple*
Weighting = 3	(1) **3**	(1) **3**	(1) **3**
Landform scale:	*Small scale*	Medium	*Large*
Weighting = 3	(2) **6**	(1) **3**	(1) **3**
Land cover complexity:	*Complex*	*Mod complex*	*Simple*
Weighting = 2	(2) **4**	(1) **2**	(1) **2**
Naturalness:	*Mainly natural*	*Mixed*	*Mainly man-made*
Weighting = 1	(1) **1**	(1) **1**	(1) **1**

5.2 Landform complexity

5.2.1 The complexity of the landform's topography is important because it has major implications for the acceptability of wind turbines, being one of the main determinants of character and a feature that can readily be analysed. Topographic complexity can be measured by analysing the degree of variability of the digital elevation data. Different areas can be compared at the same scale of resolution to generate zones with different degrees of complexity.

5.2.2 The measures tested to assess landform complexity are a combination of:

- levels of detail to be considered when undertaking the field observations.
- a measure of terrain variation (standard deviation of the elevation) which *approximates* to the fractal dimension of the complexity of the contours in any given unit area (Bell 2000). (An alternative would be the fractal dimension itself, which is a measure of the degree of deviation of a line, such as a contour line, from straight, or the deviation of a surface, such as land, from flat. A very winding line has a high fractal dimension, as does a very complex landform. However, contour data were not available to the project for the entire study area).

Figure 5.1(a). Plan views showing increased degrees of landform complexity, based on the pattern of contours.

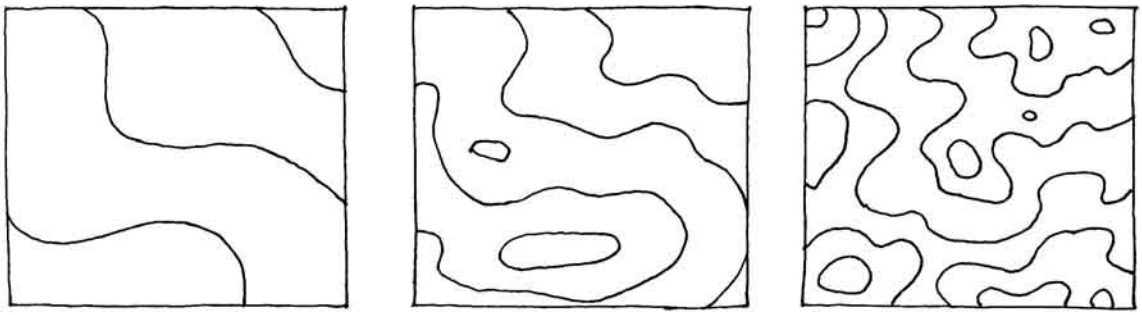
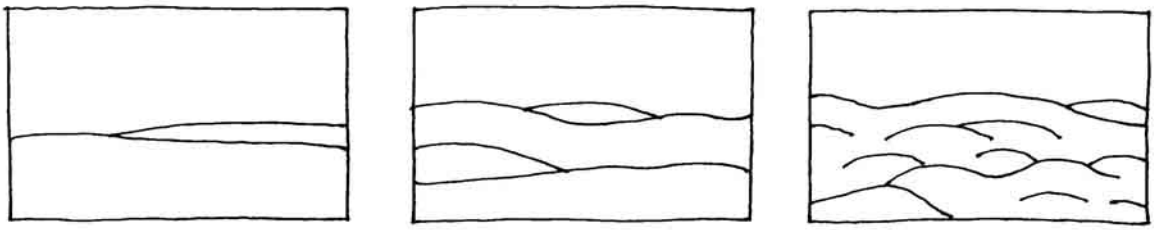


Figure 5.1(b). Perspectives showing increasing degrees of landform complexity.



5.2.3 The literature suggests that complex landforms are less able to cope with wind turbine development because the position of turbines in relation to the landform structure tends to create visual confusion and disharmony as well as a lack of balance (Stanton 1996; SNH 2001; Bell 1991). This is exacerbated by the fact that **landform complexities** are often not visible over longer viewing distances, so that any relationship of turbine to topography tends to be lost. This problem does not occur in simpler landforms where there is also more flexibility to site the turbines.

Figure 5.2(a). A short distance view of turbines sited on a complex landform.

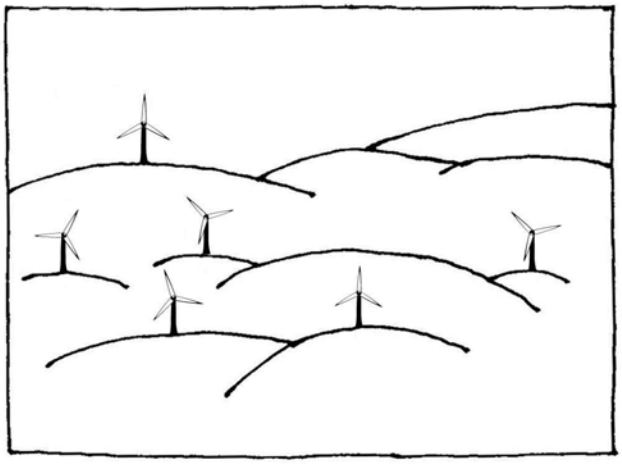
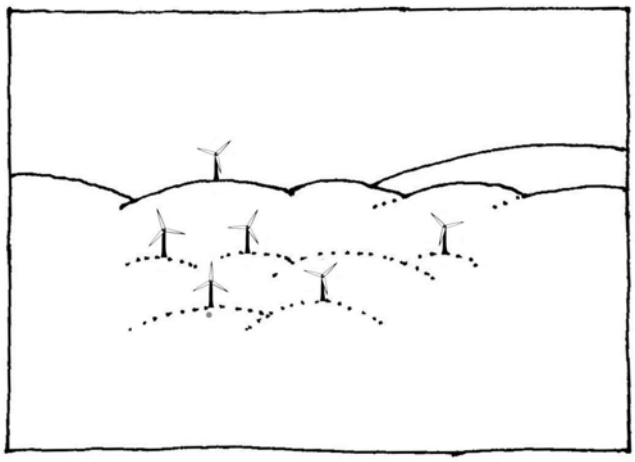


Figure 5.2(b). With a more distant view the landform complexity is less pronounced so that the turbines appear less well anchored into the landscape.



5.2.4 The capability of a given landform to accept different sizes or numbers of turbines will vary and the general points described above need to be refined because:

- the options for variation in turbine layout are fewer in a large development, leading to greater potential for unresolved unity between turbine and landform.
- the pattern created by large numbers of turbines tends to have a greater potential for visual conflict with the underlying landform than that created by small numbers.

5.2.5 Figure 5.3 illustrates a derivation of **landform complexity,** which is the result of the DTM (terrain data) analysis using a 2 km radius window, which represents the variability across large structures. A similar analysis was carried out at a smaller radius to identify the distribution of smaller features as they contribute to the complexity of the landform, but it was agreed by the team that this grain of information would be omitted as it was not relevant at the strategic level.

5.2.6 An alternative interpretation of the complexity of terrain data could include other factors that represent relevant information, such as the presence of rock features, which would increase the apparent complexity of the landforms. However, this is also dependent upon the viewing distance from the feature, and at a strategic level this level of detail is probably not significant.

5.2.7 The lowest level of **landform complexity** is in the area of Caithness, the level coastal areas of Moray and the Black Isle and Cromarty. There are also some areas of low complexity further inland, such as that north-west of Lairg, and in Stathspey. The Cairngorms and western parts of the study area show greater variation. Sections of cliffs and narrow valleys, such as the coastal areas north of Tongue, were also measured as being complex in character.

5.2.8 The dataset shown in Figure 5.3 was regrouped into three classes of landform complexity, the output of which is shown in Figure 5.4. For the remainder of the study, the results in Figure 5.4 were used as the representation of **landform complexity**.

Figure 5.3. Landform complexity as derived from variation in the Digital Terrain Model.

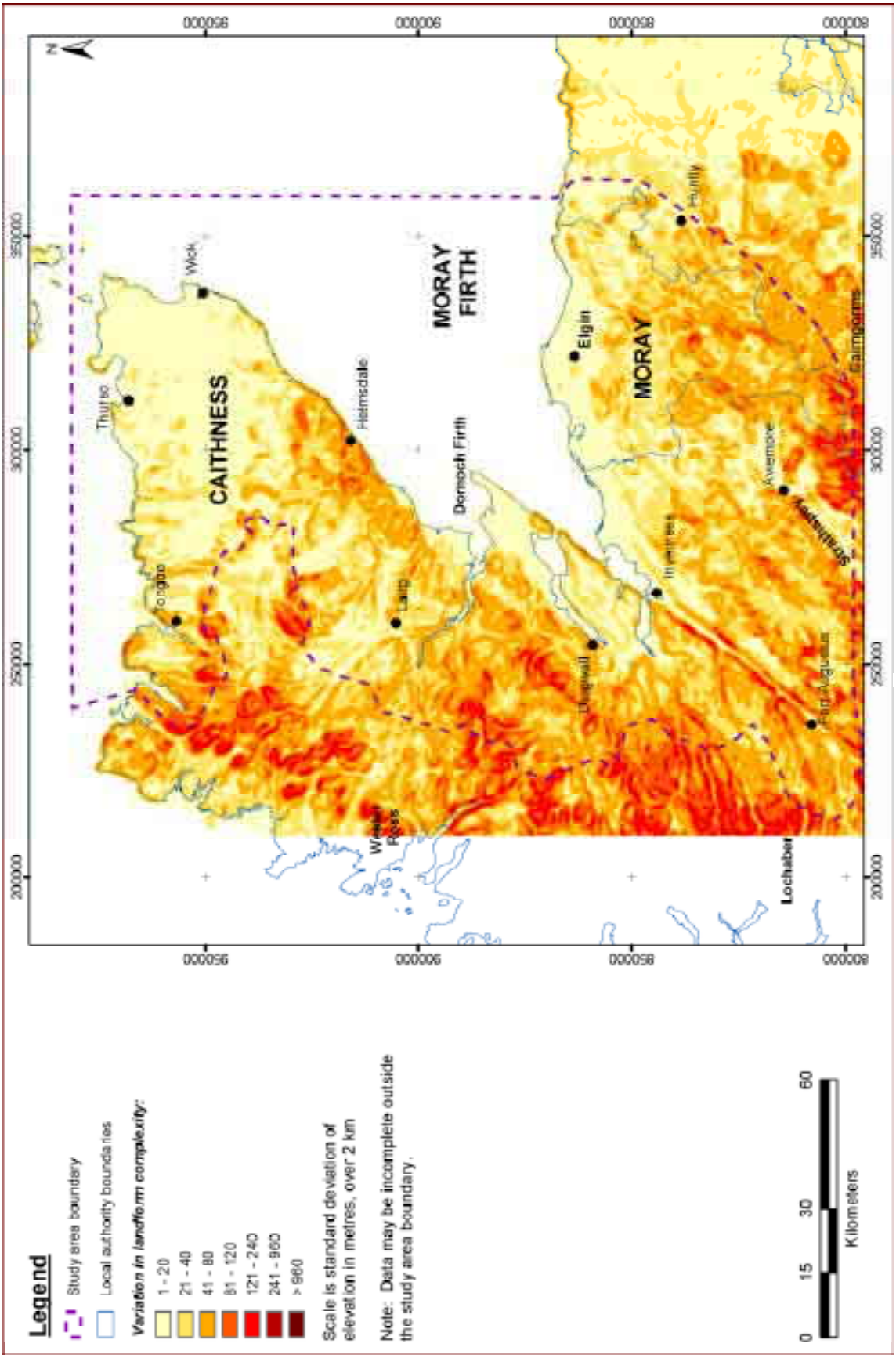
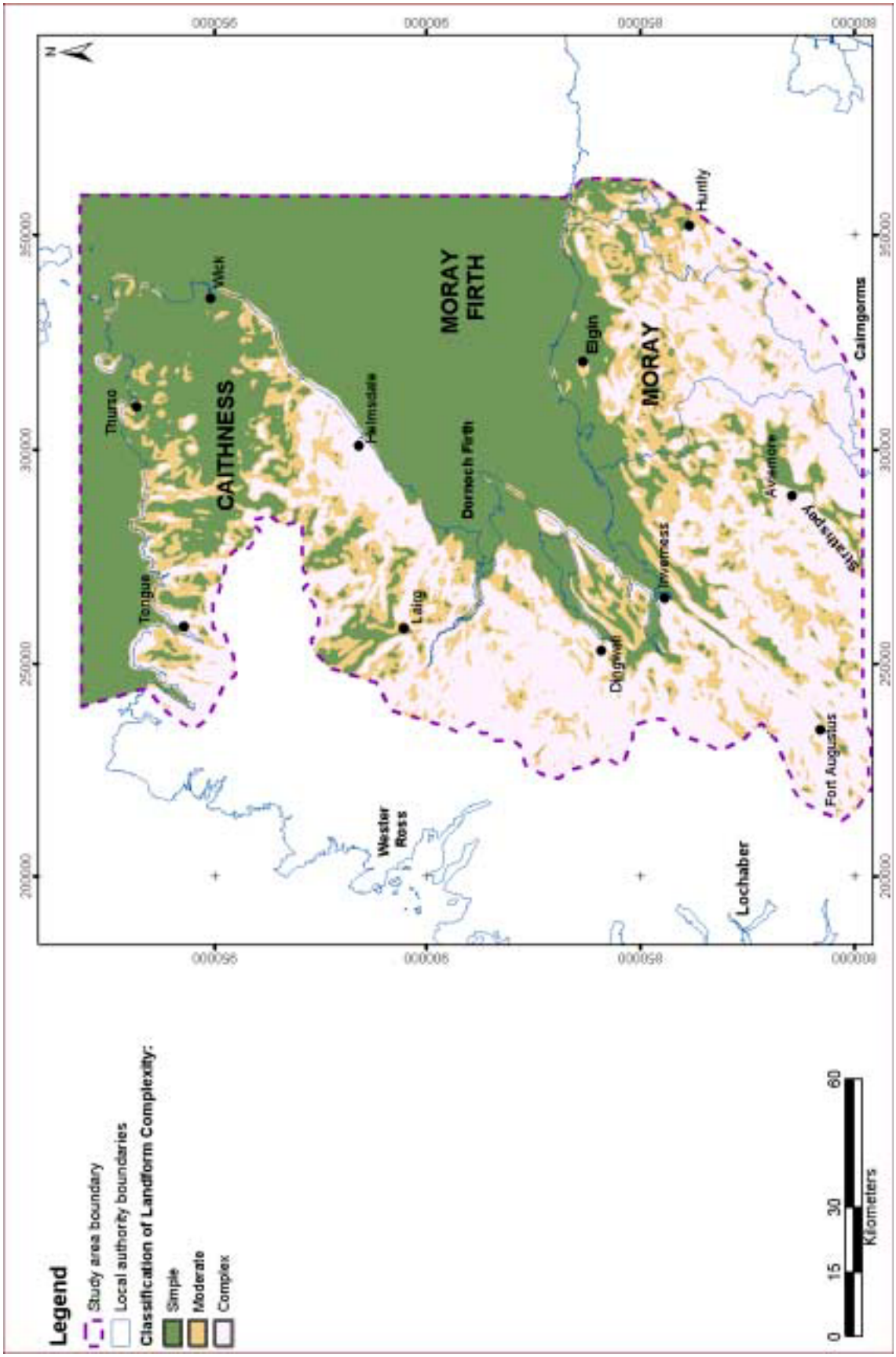


Figure 5.4. Classification of landform complexity, derived from the variation in the Digital Terrain Model.



5.3 Landform scale

5.3.1 **Landform scale** relates both to the magnitude of the landform (measured in relation to the size of a human figure or to a structure of known dimension) and to the potential visible extent of the landform. A flat, open plain which permits extensive views into the far distance and or a mountain which dwarfs the human figure are both examples of large scale landforms. The perceived scale also depends on the position of the viewer. For example, the landscape may appear to be at a larger scale if viewed from hill summits compared to from valley bottoms. Relative magnitude is the main dimension of scale and can be derived from the digital elevation data by measuring the range of elevation. Potential visibility can be derived by analysing the area visible.

Figure 5.5. A large-scale landscape of massive relief dominates the viewer, although the perception of scale varies between valley bottom (smaller) and mountain summit (larger).

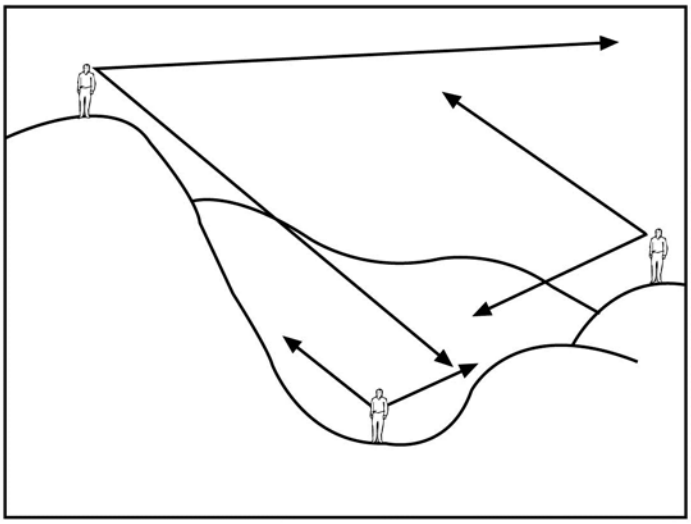
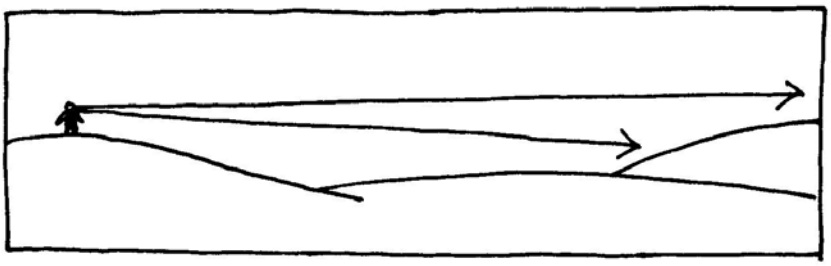


Figure 5.6. A large-scale landscape defined by openness and distance of views.



5.3.2 In this study **Landform scale** in the vicinity of the observer is derived from the combination of two factors:

- the extent of the view.
- the range in elevation that may be considered to be dwarfed by, similar to, or greater than, man-made features.

5.3.3 Datasets representing these two factors were derived from the DTM to represent landform scale across the study area:

- the viewshed for each 50 m x 50 m cell.
- the elevation range within this viewshed.

5.3.4 Figure 5.7 shows the output from the analysis of data on elevation range and terrain visibility which sought to produce classes that are similar in characteristics (i.e. areas within which the extent of visible area and range in elevation are similar) by statistical classification. Initially, the dataset was grouped into twenty classes (see also Appendix A.IV). Figure 5.8 shows the final output for landscape scale.

5.3.5 The twenty classes were re-grouped into a three-class scheme. An example of the histograms of the range in elevation and extent of visibility is shown in Appendix IV. The input classes were allocated to output classes based upon the comparison of the field observations with the histograms.

Figure 5.7. Input datasets for derivation of landscape scale.

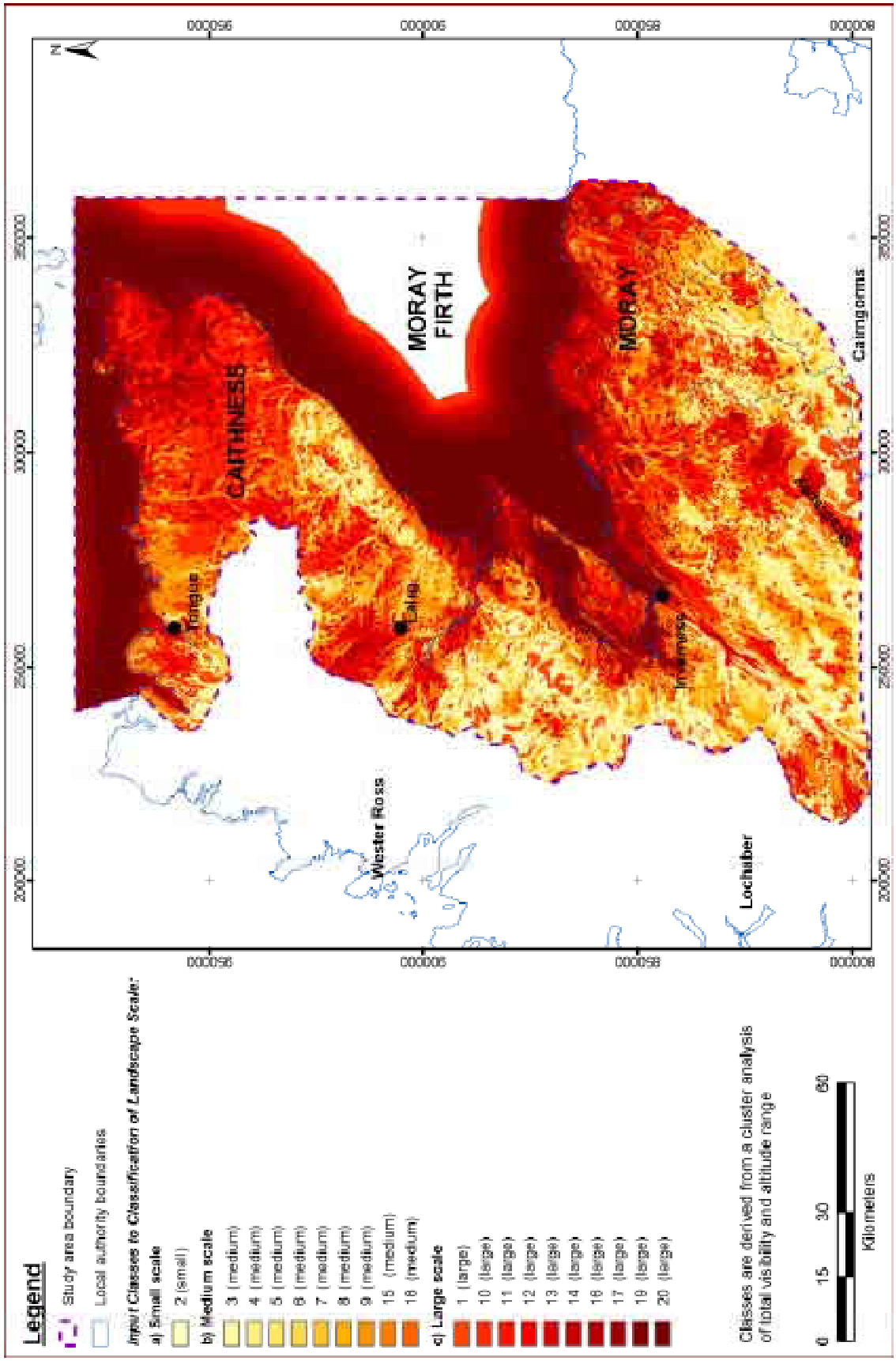
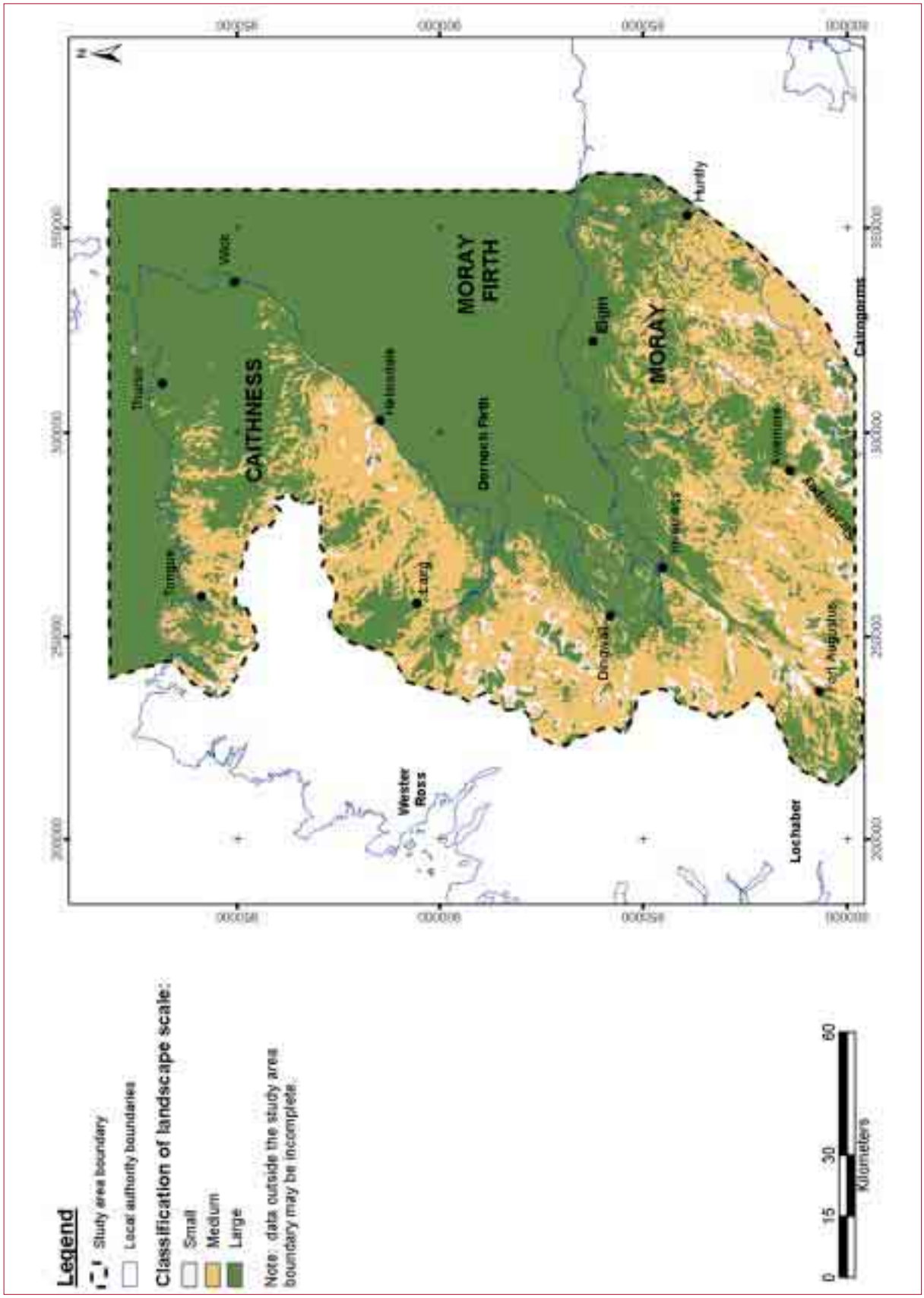


Figure 5.8 Final classification of landscape scale.



5.3.6 Figure 5.8 shows that the areas characterised as being of a small scale comprise a low proportion of the study area, are predominantly found to be away from the coast and are associated with steeply sided glens and hills. This class is mainly found in the Cairngorms and western parts of the study area, but includes areas alongside Loch Ness and narrower glens in Sutherland. Some parts of the coast, along the north-west of the Moray Firth, contain some areas of hill plateaux and are also classified as small scale.

5.3.7 The larger scale landscapes dominate the coastal areas, Caithness, Strathspey, and areas to the north of Lairg. They are also extensive in the upland areas of Moray, dissected by moderate scale landscapes that follow the patterns of drainage associated with the glens. However, some areas of narrow glens are also identifiable as being of a large scale, such as the sides of Loch Loyal, where the range in elevation is sufficiently great to dwarf any existing man-made features (e.g. electricity pylons). The offshore area was coded as being large scale.

5.3.8 The effects of scale on the capacity of the landscape to absorb turbine development varies according to the size of the development. Larger-scale landscapes are better able to absorb turbines because they tend to dominate man-made structures, even the largest turbines. However, turbines can dominate a small-scale landscape. See Figures 5.9 and 5.12.

5.4 Land cover complexity

5.4.1 Land cover refers to the types of vegetation cover, including semi-natural vegetation, woodlands, agriculture, and build features. The approach taken to the classification of **land cover complexity** was based upon an analysis of the visibility of digital land cover data, namely the Land Cover of Scotland 1988 dataset (LCS88) (MLURI 1993). **Land cover complexity** was assessed by analysing the number of different land cover types within the view at any given location.

5.4.2 The analysis of **land cover complexity** used three derived datasets:

- the total number of different classes of land cover visible from any location.
- a combined dataset in which all of the basic data were represented.
- the percentage of each class visible from each 50 m x 50 m cell.

5.4.3 These datasets were then compared with the field observations of land cover (see Appendix A.III.XIII). Account was taken of the field notes and the factors that influenced the recording of land cover complexity (number of classes; and proportions of the view occupied by classes). No measure was made of the contribution of distance from the observer to each land cover type, and thus no measure made of the effect of viewing perspective on the proportions of the land cover classes in the view. Table 5.2 lists the land cover class groupings that were used.

Table 5.2. Details of inputs to calculation of land cover complexity.

Land cover classes
Agriculture (no rock, no trees)
Coniferous woodland
Semi-natural woodland, broadleaved woodland, and scattered trees
Rough and smooth grasslands and dunes
Heather moorland (no rock, no trees)
Bracken (no rock, no trees)
Peatland and montane (no rock no trees)
Inland water
Sea
Settlements and developed rural land
Cliffs + scattered rock

5.4.4 Figure 5.9 shows the distribution of the total number of land cover classes visible from any one location. This figure highlights areas in the wider glens and straths, the coastal areas, the northern and central areas of Caithness and much of upland Moray as comprising views of complex land cover. However, the percentage of classes correctly identified in the field observations did not correlate well with the total number of land cover classes actually present. So, comparisons were made with percentage cover of classes and the total number of classes to determine thresholds that would imply dominance of any one class, or combination of classes. This summarised the number of classes to three (Table 5.3).

5.4.5 The rules used in deriving **land cover complexity** relate to the field observations, in which overall view dominance by any one class was recorded as simple, as was the presence of a very few classes. The land cover in the view was recorded as complex where there was a presence of many classes (generally greater than seven).

5.4.6 The results of the classification are shown in Figure 5.10. The areas of lowest land cover complexity were found to be in the coastal zones, dominated by sea views, but including areas of agriculture land in Caithness, Cromarty and the Black Isle, and some of the peatlands in Caithness. Much of the Monadhliath Mountains were also classified as simple in comparison to the complex classification of Strath Nairn to the west. The simple land cover class also includes most large settlements and some of the larger inland lochs.

Figure 5.9. Total number of land cover classes visible from each location.

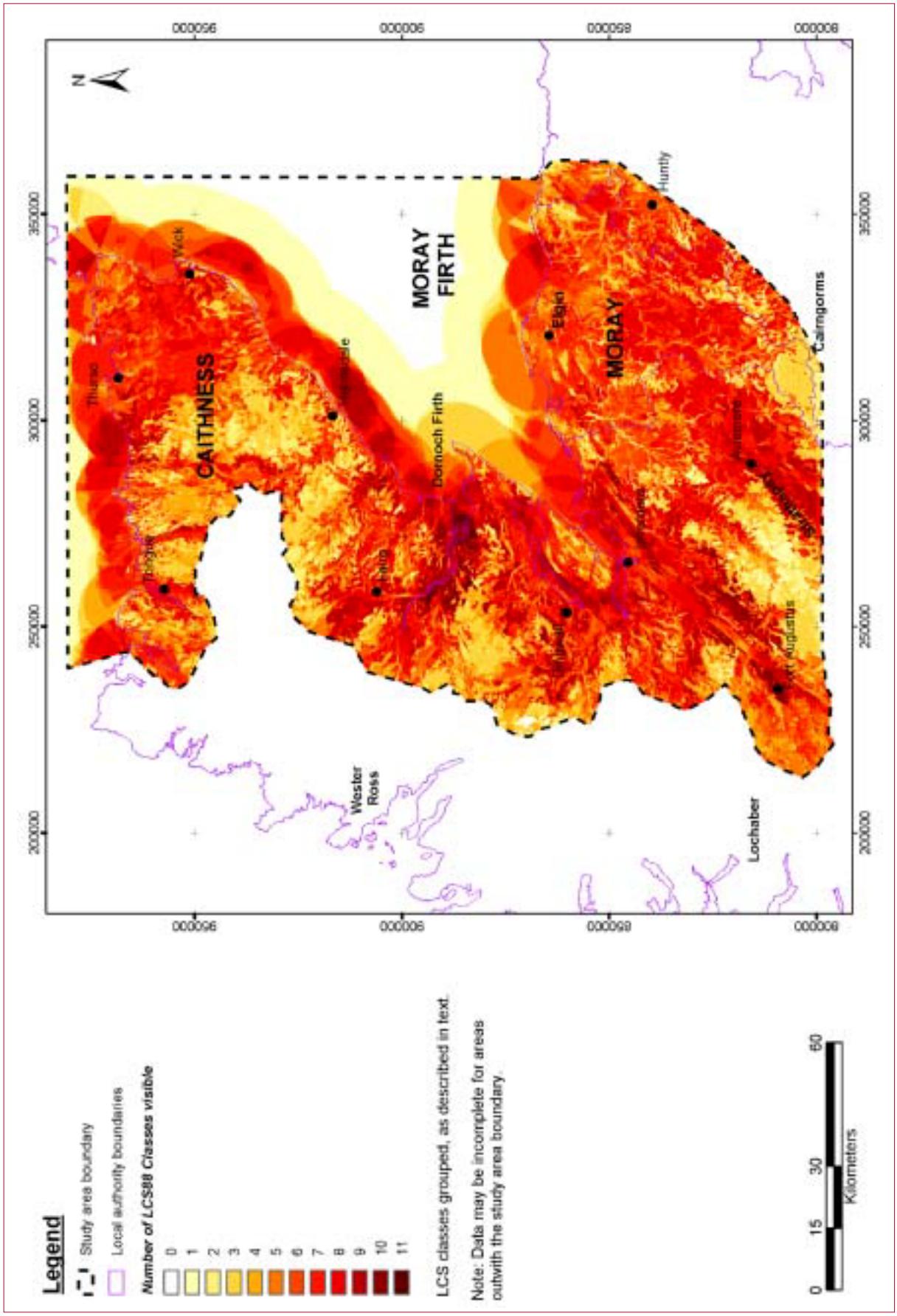


Table 5.3. Summary of the classification of land cover complexity.

Class	Description
Very complex	No visible class occupies > 25% of the view OR (No visible class occupies > 40% of the view AND More than 7 classes are visible)
Moderately complex	Remaining classes
Simple	Any one class occupying >= 75% of the view OR (Any one class occupying < 75% of the view AND <= 3 classes visible)

5.4.7 The complex land cover class incorporates most of the narrower glens, and many (but not all) of the mountainous and upland areas. In such areas, the presence of scattered rock and trees, plus small groups of fields and evidence of small settlements, will contribute towards the high score. Similarly, in western Caithness, the forestry classes, together with rock, peatland, inland water and grasslands, contribute towards a high score.

5.4.8 The interpretation of this factor is potentially difficult. Land cover affects landscape character sensitivity to wind turbine development in several ways. While more complex vegetation patterns, especially woodland elements, can help to screen, mask or distract attention from turbines, they can also cause visual competition with them (SNH 2001), while built structures, especially those with vertical forms, may contrast too strongly. Simpler patterns allow the turbines to be seen more cleanly and with less confusion to the eye. Generally, large wind turbines tend to produce most visual disruption in the more complex land cover classes, while smaller developments are easier to absorb. It must be stressed here that the decision rules are somewhat broad in the context of **land cover complexity**, so that it remains important to judge individual developments in the context of the site, since the nature of the land cover complexity may have a significant effect on the landscape character sensitivity and potential for turbine development.

5.4.9 Figures 5.15(a) through 5.15(c) provide illustrations of the three land cover complexity classes together with the visual implications for inclusion of turbines within an area of each class.

Figure 5.10. Land cover complexity.

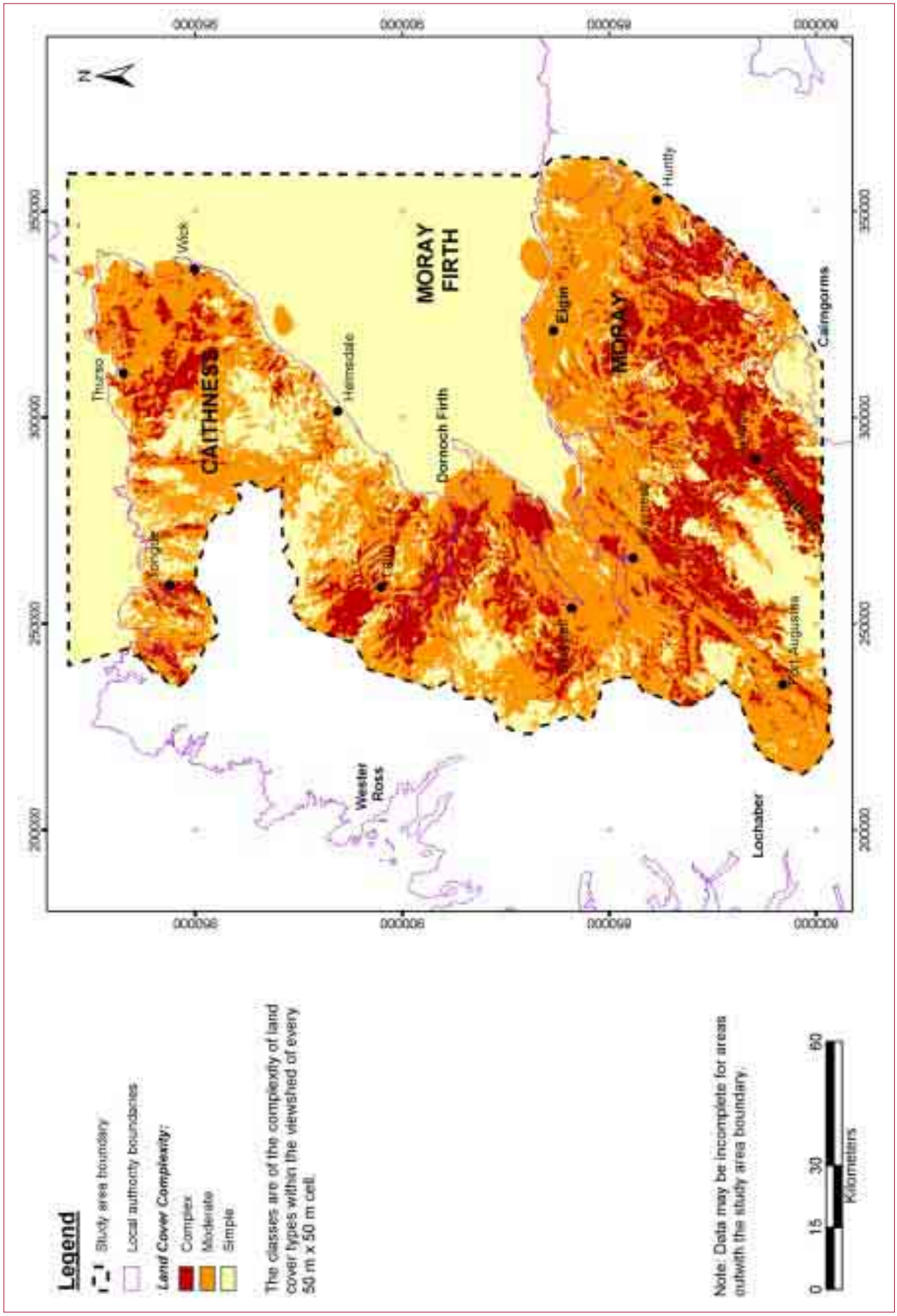


Figure 5.11(a). A series of plan views showing increasing degrees of land cover complexity based on the amount of different land cover type per unit area.

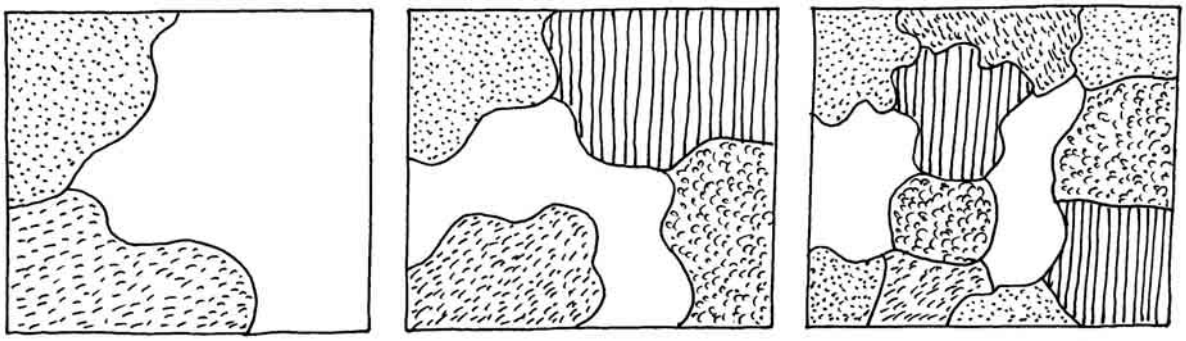
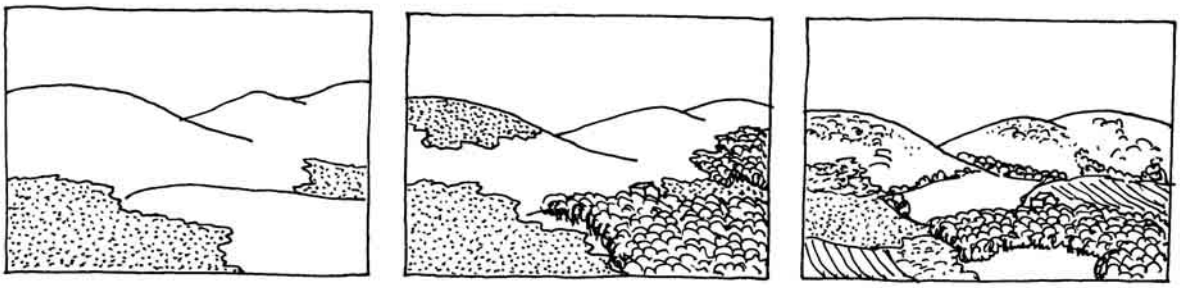


Figure 5.11(b). A series of perspectives showing increased land cover complexity.



5.5 Naturalness of land cover

5.5.1 Introducing wind farms into landscapes dominated by natural land cover can be more difficult than into those of mainly human origin because turbines are large, man-made industrial installations, which contrast strongly with natural or semi-natural qualities. The issue is also connected with the size of the development, since a large wind turbine development may produce a sense that a formerly natural landscape is now dominated by man-made elements, whereas a small wind turbine development may not affect the apparent balance to the same degree. Conversely, turbines added to a landscape of largely human origin may visually interact with other features to disrupt unity or to affect the perception of scale. However, it can be argued that it is easier to admit further man-made elements into a landscape already affected by human activity as long as the unity and scale are appropriate. See Figures 5.16(a) through 5.16(i).

Figure 5.12(a). A landscape where the land cover pattern is perceived as wholly natural in origin: upland heath, bracken, native woodland, water, rock and bog.

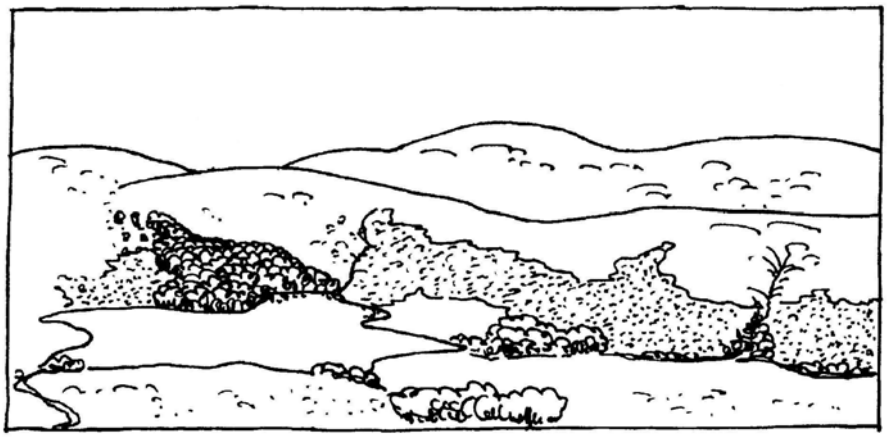


Figure 5.12(b). A landscape where there is a roughly equal division between land cover of natural and man-made origin.

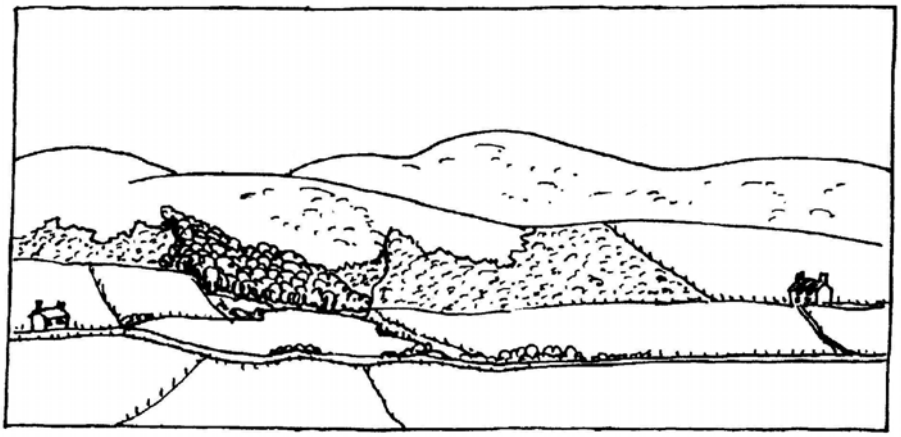
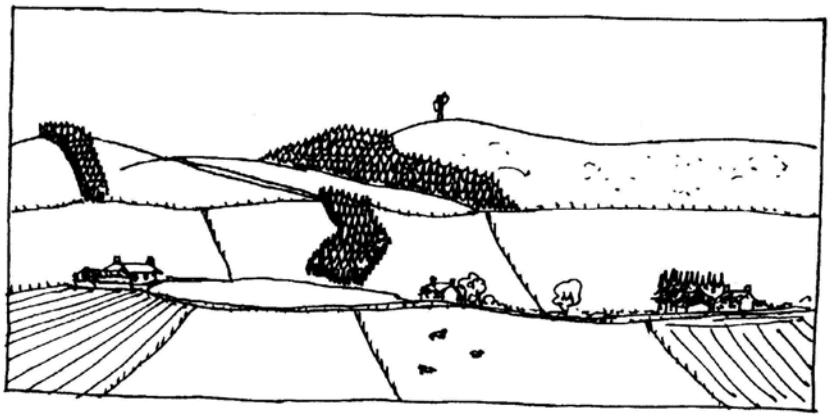


Figure 5.12(c). A landscape where the land cover pattern is wholly of human origin: crops, managed grassland, plantation forest, roads and buildings.



5.5.2 The degree of **naturalness** can be assessed by comparing the proportions of semi-natural land cover with those of types of human origin (for example, the areas of semi-natural montane or moorland vegetation visible compared to that of cropland or settlement). As with **land cover complexity**, the Land Cover of Scotland 1988 dataset (LCS88) (MLURI 1993)

provided the basis of the land cover data, and the analysis was carried out using the visibility of the relevant land cover types, as described in Appendix A.III.II.

5.5.3 Land cover classes were categorised as 'mainly natural' or 'mainly man-made' (Table 5.4). The categorisation recognised that, in LCS88, classes that were identified as mosaics will contain overlap between what is described as natural and non-natural classes, with respect to land cover naturalness. Errors in land cover interpretation in the compilation of the dataset will also have an impact on the accuracy of the representation of naturalness from this, or any other, land cover dataset.

Table 5.4. Details of inputs to calculation of naturalness.

Mainly natural land cover origin	Mainly human origin
Semi-natural woodland and scattered trees (all rough grassland, or heather moorland classes, in which there were scattered trees, but moorland excluded areas of muirburn and rock)	Agriculture (including arable and improved pasture)
Rough grassland (excluding scattered trees and rock)	Coniferous woodland (including recently felled and new plantations)
Cliffs and scattered rock (excluding any evidence of heather muirburn)	Heather moorland with burning
Inland water	Smooth grassland
Sea	Settlements and developed rural features
Bracken (excluding rock and scattered trees)	Peatland (commercial extraction)
Peatland (excluding workings) and montane vegetation	
Heather moorland (excluding muirburn, scattered trees and rocks)	

5.5.4 Using the classification shown in Table 5.4, two datasets were derived that represented 'percentage natural' and 'percentage non-natural' for every point in the landscape. The two datasets were compared to ensure that the totals were 100% for every point, and checks made to address any errors. Figure 5.13 shows the outputs from this processing. The dataset on percentage naturalness was compared with the field observations and thresholds selected of 30% and 70% for the derivation of the three-class output shown in Figure 5.14.

5.5.5 The areas of the high levels of naturalness are typically at the higher elevations (such as Cairngorm, the Monadhliath Mountains, and north-west Sutherland). However, they also include the large tracts of peatlands in western Caithness and coastal sections of Sutherland. The inclusion of the sea within the natural land cover class also leads to a strong influence in coastal areas, with dominance of this class in areas such as the Moray coastline, central Caithness and the Black Isle and Cromarty.

5.5.6 The sea itself is categorised as being almost always natural, but the inner waters of the Beauly, Cromarty and Dornoch Firths are influenced by the surrounding land cover types, and thus are coded as being of mixed natural and human origin, and mainly human in those areas furthest from the Moray Firth coast. These latter areas are identified as 'Kyles, firths and sea lochs' in the relevant LCA reports (e.g. Stanton 1998).

5.5.7 Areas of low levels of naturalness are dominated by intensive agricultural landscapes such as those of north Moray, the Black Isle and central Caithness. The urban areas of Inverness, the Cromarty Firth and parts of Strathspey also influence the impression of the land cover as being dominated by human activity.

Figure 5.13. Percentage natural land cover.

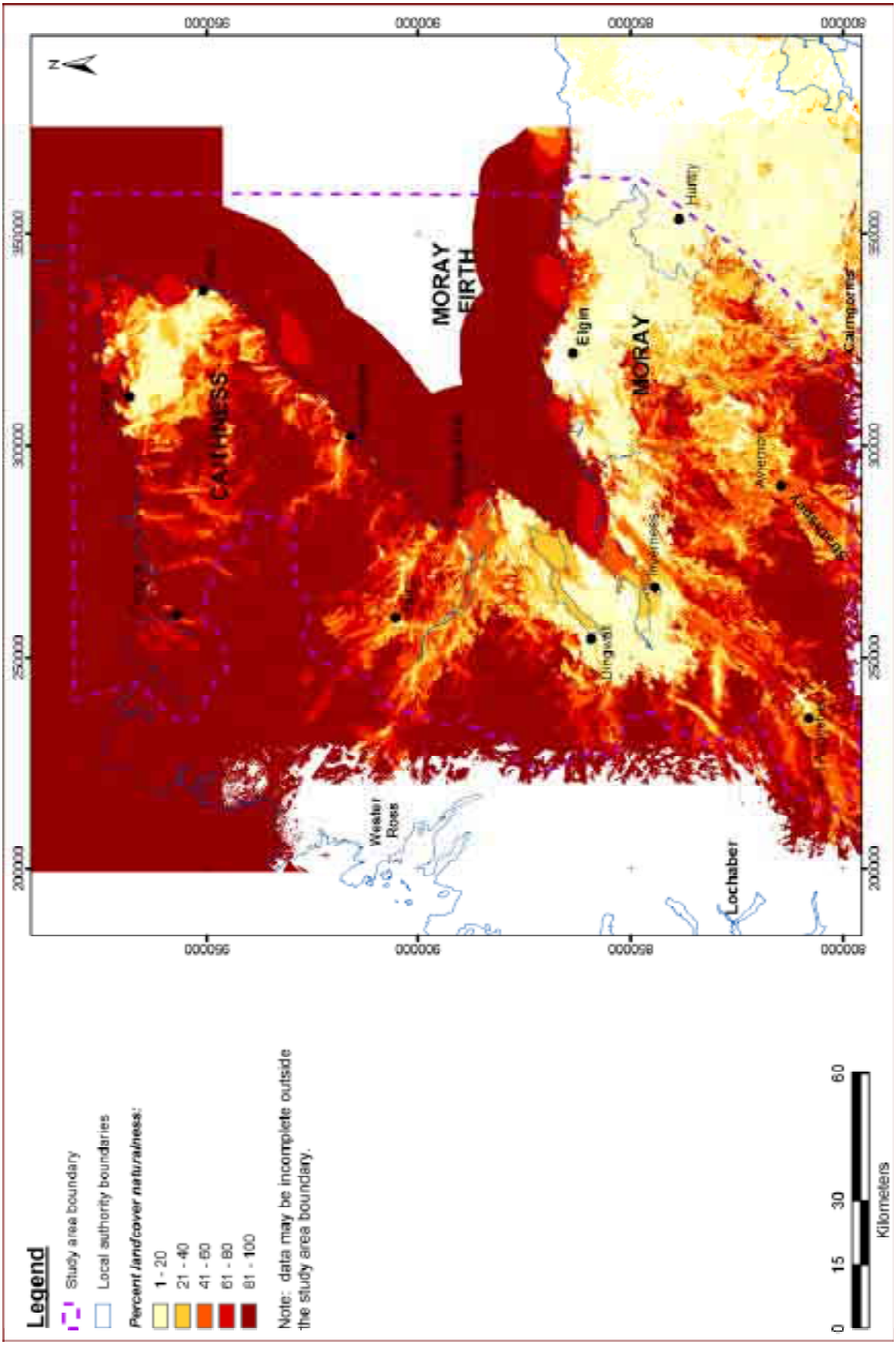
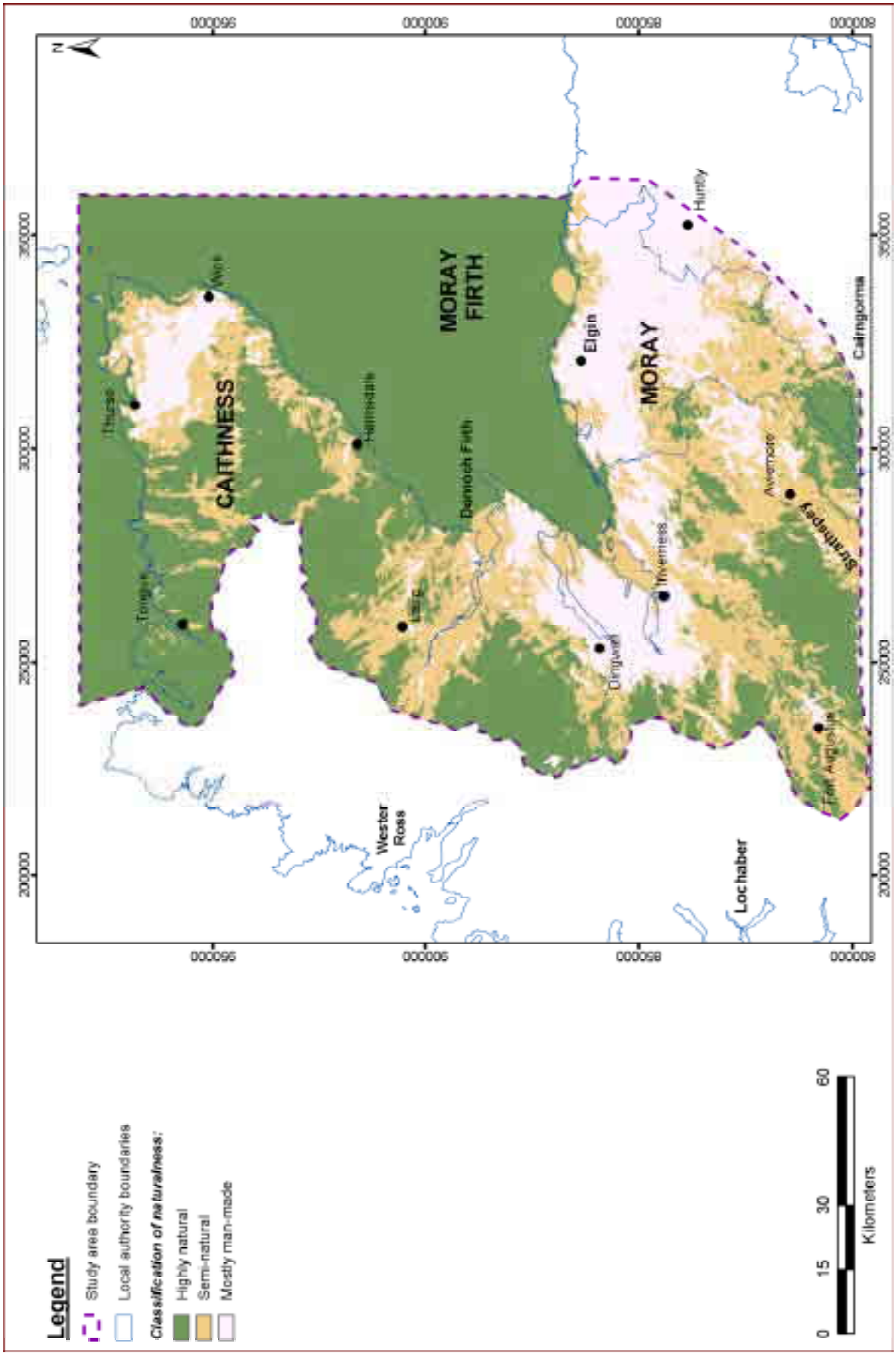


Figure 5.14. Classification of naturalness.



5.6 Development of the datasets and maps of landscape character sensitivity for each size of wind turbine development

5.6.1 In the description of each of the contributing elements of landscape character sensitivity to wind turbine developments presented in Phase 2, the relevance and potential significance of each to accept wind turbine development was discussed. From this, scores were used to evaluate each character class in terms of its anticipated sensitivity to wind turbine developments, based upon the size of the wind turbine development. The rules were then applied using the layers of digital data to produce a map showing different degrees of sensitivity, using the scores as per Table 5.1.

5.6.2 Totalling the scores for each category and then recoding them into the three-category classification provides a simple rule-based approach suited to the creation of the dataset representing landscape character sensitivity.

5.6.3 Figures 5.15 to 5.17 show classifications of landscape character sensitivity recoded into a three-class scheme. Figure 5.15 shows landscapes with a low landscape character sensitivity in many of the lower lying parts of the study area, including much of northern and central Moray, the Black Isle, Cromarty and central Caithness. The areas with higher landscape character sensitivity are spread across the area, in valley bottoms and upland areas (e.g. the Cairngorms and Monadhliath Mountains). The areas of high character sensitivity also include the hill plateaux to the north-west of the Moray Firth, in Sutherland. The moderate landscape character sensitivity class includes the coastal fringe, and inland areas of open moorland (e.g. in the vicinity of Altnaharra, Caithness, west of the Causeymire road, and smaller upland areas throughout Moray, Strathspey and Easter Ross).

5.6.4 Figure 5.15 shows the landscape character sensitivity to large wind turbine developments. The landscapes that are most sensitive in the northern part of the study area are north-west of Dingwall, east of Lairg and west of Tongue. Areas of higher sensitivity lie to the south of the study area, including central and southern Moray, land south-west of Inverness, and to the south-east of Aviemore. In comparison to the spatial pattern of the areas of high landscape character sensitivity, those with the lowest sensitivity tend to be concentrated in Caithness, the Cromarty area, the coastal areas of Moray, and in mid-Strathspey.

5.6.5 Landscape character sensitivity to medium sized developments (Figure 5.16) show the most sensitive areas to be the same areas of north-west of Dingwall and south-east of Aviemore that were highlighted for the large developments, but with an area at the southern end of Loch Ness also identified. The areas of moderate sensitivity are located on valley sides, particularly in Moray, alongside the A9 south of Inverness, Strath Nairn and the eastern side of Loch Ness, and towards the north in the area between Dingwall and Lairg. The areas of highest sensitivity lie on the higher and sloping land. Moderate sensitivity areas occupy open sloping land, such as that of Strathspey, south of Inverness, and in the vicinity of Lairg.

5.6.6 Figure 5.17 (small wind turbine developments) show a consistently low level of sensitivity across the entire area.

Figure 5.15. Classification of landscape character sensitivity for a large turbine development.

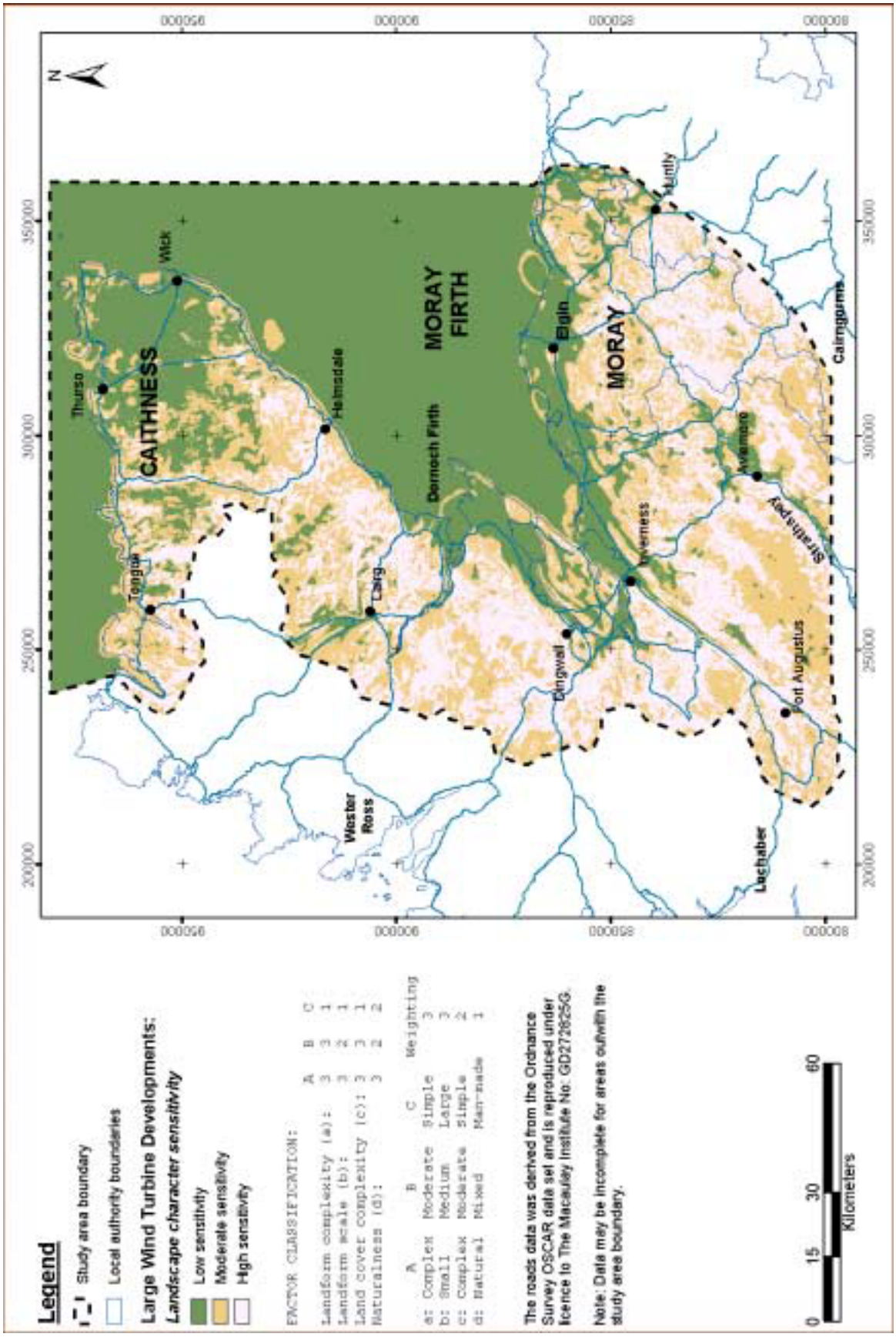


Figure 5.16. Classification of landscape character sensitivity for a moderate turbine development.

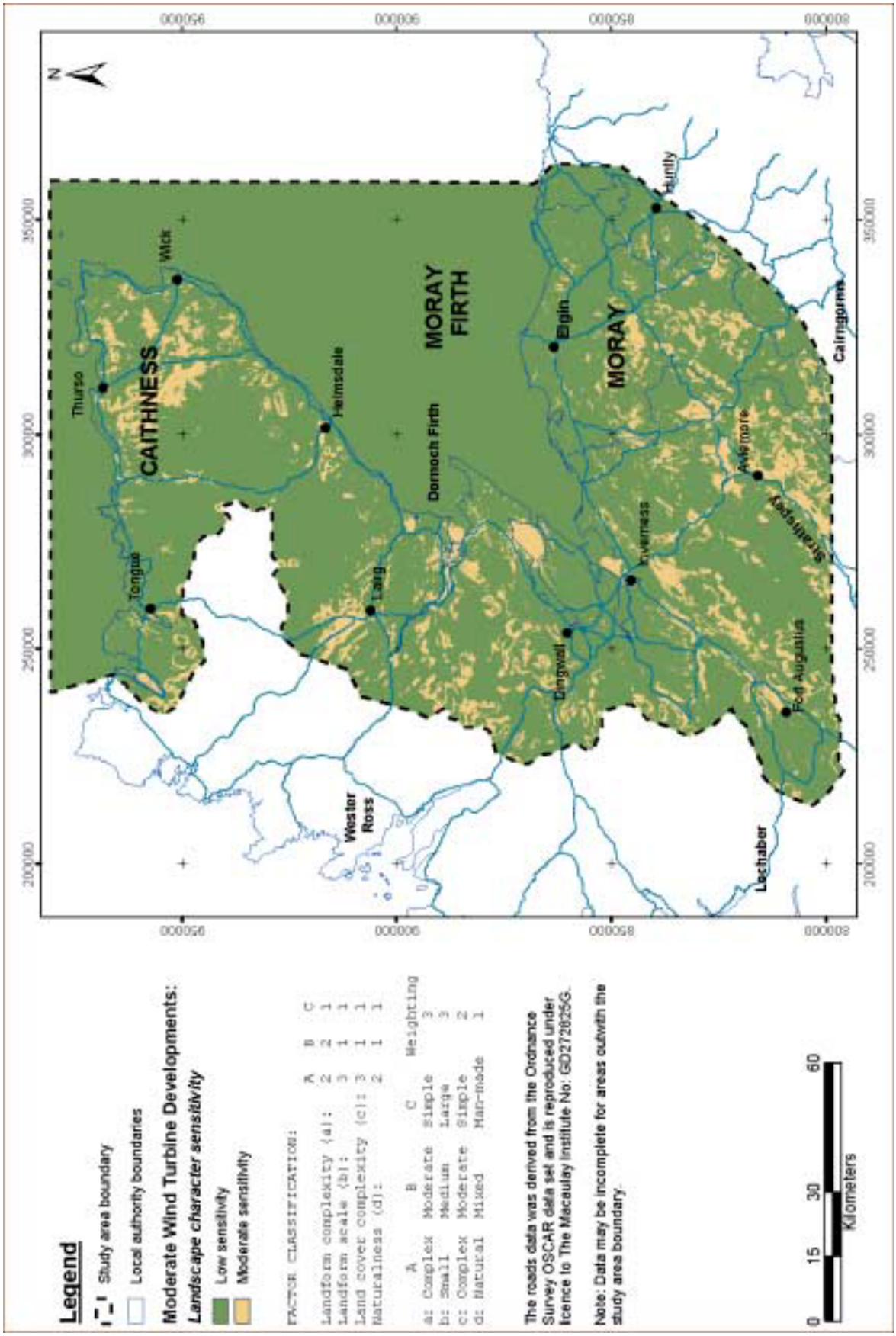
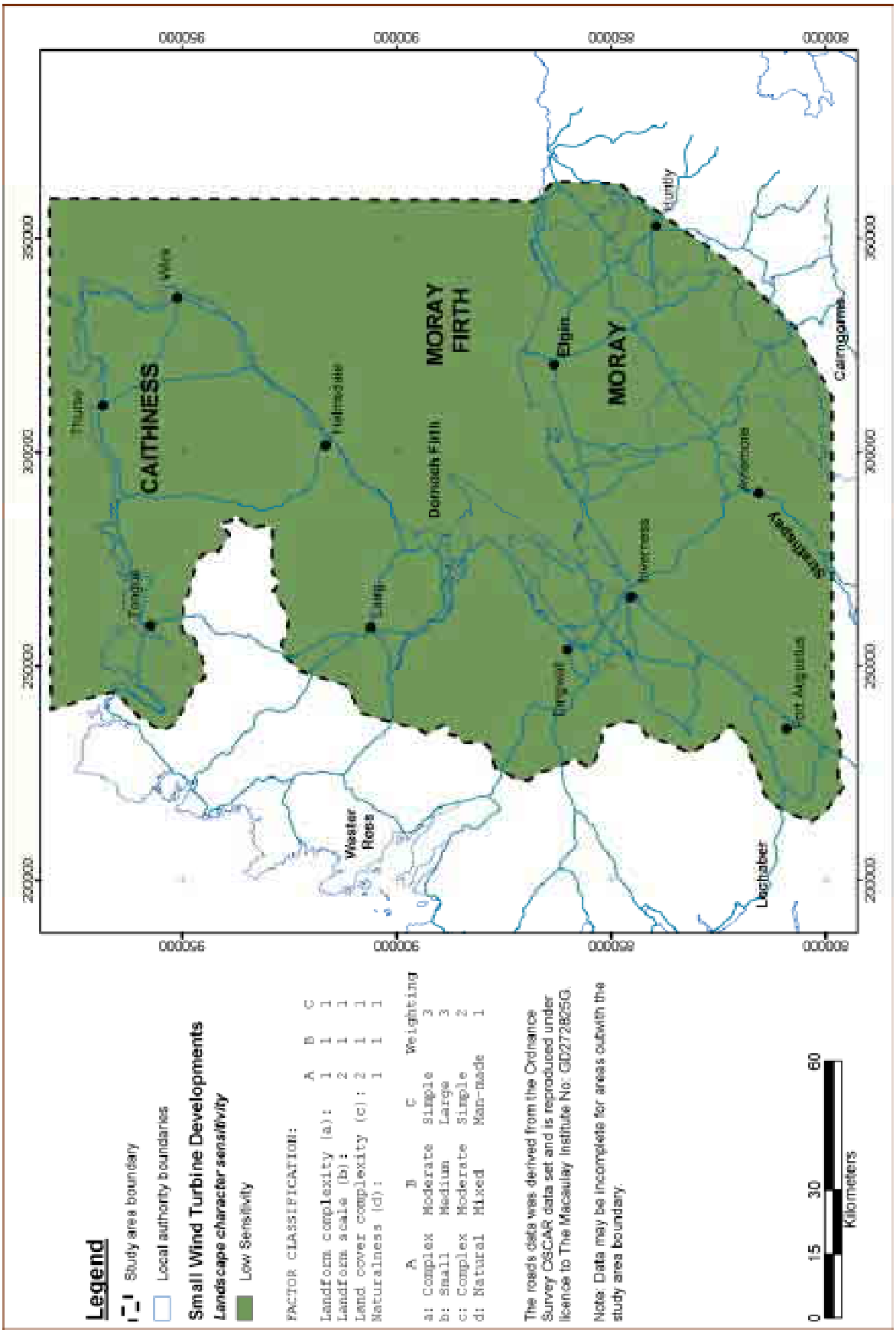


Figure 5.17. Classification of landscape character sensitivity for a small turbine development.



6 PHASE 3: ANALYSIS OF VISUAL SENSITIVITY

6.1 Introduction

6.1.1 The second major group of factors is visual sensitivity. The first is landscape character sensitivity: see Phase 2 Chapter 5. The factors assessed were:

1. visibility of the landscape.
2. nature of the viewing experience.
3. numbers of people viewing the landscape.

6.2 Visual sensitivity

Visibility of the landscape

6.2.1 The potential extent of the visibility of any location in the landscape, and the extent of its visibility, can be calculated using analysis of an elevation model, from which a map of visibility can be assembled. This is the same as the sum of the visibility of all land cover classes at every 50m x 50m cell, which formed the basis of the calculation of naturalness (Section 5.5). Figure 6.1 shows the total visibility dataset for the study area, and Figure 6.2 shows it reclassified into a three-class map (low, medium and high visibility). As noted elsewhere, this analysis took no account of the intervention of individual features, such as buildings, and should be considered to be a strategic level dataset. It is suitable for use at the resolution of the database for most interpretations.

6.2.2 Figures 6.1 and 6.2 both show that the areas of highest visibility are on the open valley sides, such as those of Strathspey and south-west of Inverness. They also show high values for the coastal areas where views are open to the water and facing slopes, such as in the vicinity of Dornoch and the Cromarty Firth.

6.2.3 The areas with the lowest levels of visibility are those in narrow valley bottoms, or the upland plateaux, where the total area of view occupied by the land surface is minimal. These areas also include land obscured by more dominant features, such as hillsides that rise steeply to one side of the observer. Therefore, the higher parts of concave valley slopes also show up as being of lower visibility, where there are few opportunities of views on the opposite side of the valley.

6.2.4 The pattern of visibility in the inshore coastal waters becomes progressively more consistent at distances away from the influences of the coast. Therefore, consideration can be given to the visual sensitivity of offshore structures from offshore sites. However, this remains a weakly tested aspect of the modelling, and takes no consideration of the variability in the views that may be available from small craft.

6.2.5 According to the practice of dividing the data into three categories, the total visibility of the terrain has been scored according to Table 6.1, the output from which is presented in Figure 6.2. The thresholds have been selected at intervals of one third of the maximum score, reflecting absolute levels of terrain visibility across the area. The thresholds have been selected at intervals of one third of the maximum score, reflecting absolute levels of terrain visibility across the area.

Figure 6.1. Map of total landscape visibility.

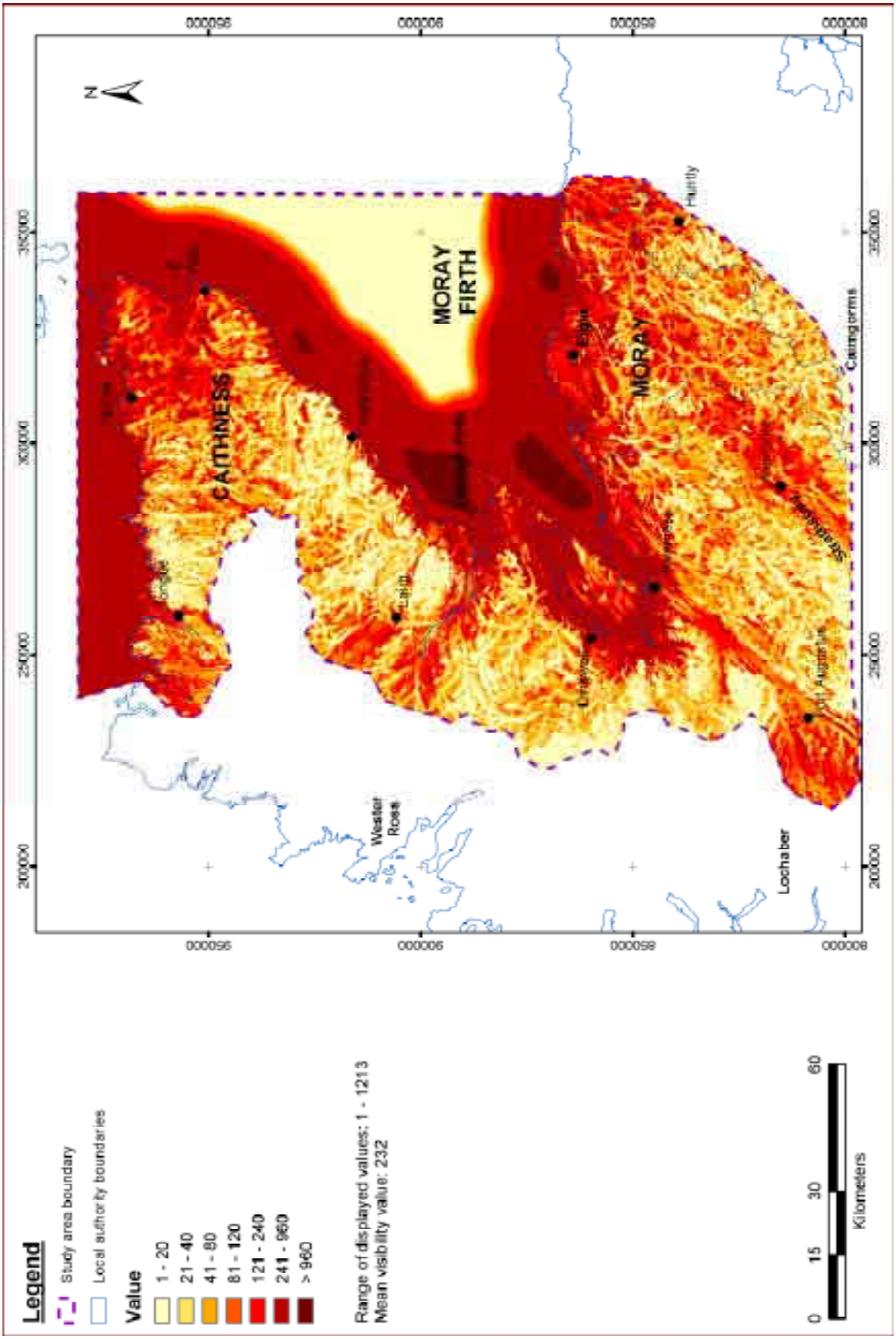


Figure 6.2. Classification of total landscape visibility.

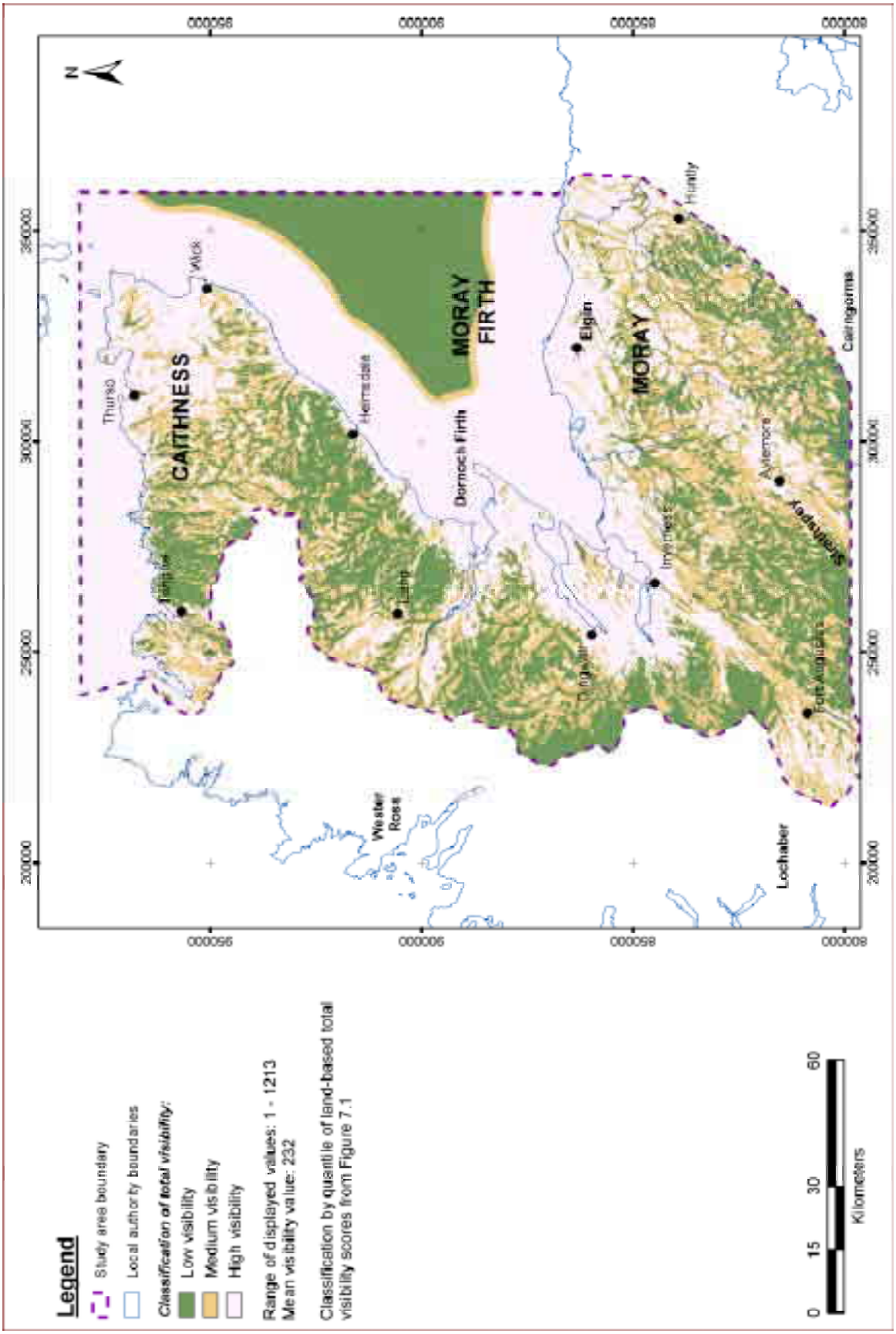


Table 6.1. Criteria for assessment of landscape visibility.

Criterion	Score
High terrain visibility	3
Moderate terrain visibility	2
Low terrain visibility	1

6.2.6 Moisture in the air reduces clarity of viewing such that increasingly distant scenes are progressively less visible. This varies over the seasons and according to weather conditions. The limit to the calculation of visibility for the terrain and land cover data was selected to be 10 km because of the computational constraints of processing the visibility of the landscape elements for every cell within the study area, while ensuring that the resolution of the visibility levels was consistent with those of the other datasets (i.e. 50 m x 50 m). However, distances for the computation of the visibility of the turbine developments and seaward views were selected as 25 km.

6.2.7 Table 6.2 shows the viewing distances from observers under different viewing conditions (e.g. sea level to sea level, and hill top to sea level), taking account of earth curvature, but not atmospheric conditions.

Table 6.2. Theoretical viewing distances with respect to heights of observer.

Height of observer (m)	Height of object (m)	Distance (nautical miles)	Distance (km)	Example
1.8	100	25.1	46.4	Man-made structure
1.8	50	18.6	34.4	Man-made structure
1.8	1.8	5.9	10.9	Two observers of equal height and elevation
1.8	0	3.0	5.5	Observer on beach

6.2.8 Linear routes present a continuous series of ever changing views of which some are more significant than others when experienced by travellers. For example, views where a road passes over a summit, views on the outside of bends, or views framed by valley sides could all be likely to be considered to be more significant than others. Viewing the landscape also takes time – views that last for 3 to 5 seconds or longer may make an impact, whereas those that last for much less time may be barely noticed. The computer analysis of visibility along roads identifies where the most extensive views are obtained assuming a constant rate of travel. However, the analysis does not explicitly calculate the time of exposure of any given view.

6.2.9 Data on visibility from roads, viewpoints (e.g. roads, long distance footpaths, Munros, Corbetts, settlements etc.) were incorporated in the GIS-based visibility analysis. The derivation of the visibility from these types of viewpoints used datasets that extend beyond the boundary of the study area.

6.2.10 Table 6.3 summarises the total length of the transport network for each class of road, the railways, ferries and the Long Distance Routes, and the number of Ordnance Survey viewpoints, Munros and Corbetts, from which visibility calculations were undertaken. These calculations were undertaken for points across northern Scotland, and not restricted to the extent of the study area. This retained some flexibility in the definition of the study area, and it takes account of landscape features and viewpoints the viewsheds of which extend beyond the boundary of the current study area.

Table 6.3. Summary of lengths of road network and number other types of viewpoint for which processing was undertaken.

Viewpoint	Length or Number of Features
Length of Trunk Roads (km)	905.5
Length of 'A' Roads (km)	461.8
Length of 'B' Roads (km)	1 283.5
Length of Minor Roads (km)	176 438.0
Length of Railway Line (km)	598.1
Length of Long Distance Routes (km)	241.8
Number of Munros	284
Number of Corbetts	220
Number of Ordnance Survey view points	35

6.2.11 The derivations of the visibility of views from the types of points noted above have been combined to produce a dataset which represents the visibility of the landscape. There are a number of options available for combining the data on these points, reflecting the total area visible from each type of viewpoint, the extent of visibility from each type of viewpoint (e.g. a higher score from roads), or a weighting of the two.

6.2.12 Figures 6.3 and 6.4 show the output from two options for combining the viewpoint types to input to a visual sensitivity dataset:

1. a simple addition of the number of different types of viewpoint that offer a view of each part of the landscape.
2. a combination based upon level of visibility from each type of viewpoint, interpreted by a 'rule-base'.

6.2.13 The approach adopted was to use a simple sum of viewpoint scores from each source of data i.e. option 1. The outputs from such calculations were then classified according to being 'visible' or 'not'. The weightings of types of viewpoints (of both landscape and visual receptors) then rely upon look-up tables such as those presented in Table 6.4. However, the opportunity is available for refinement of these data with respect to the levels of visibility available from each type of viewpoint, and the rule-based approach to enable the targeting of specific view types. In future, such a refinement could be tested by reference to focus groups, or public questionnaires.