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NATURAL ENVIRONMENT RESEARCH COUNCIL

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**Centre for  
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NATURAL ENVIRONMENT RESEARCH COUNCIL

**The use of LCM2000  
to provide improved definition of the  
FEH catchment descriptor URBEXT  
in Northern Ireland  
Stage 1 – Evaluation of mapping**

Report to Rivers Agency

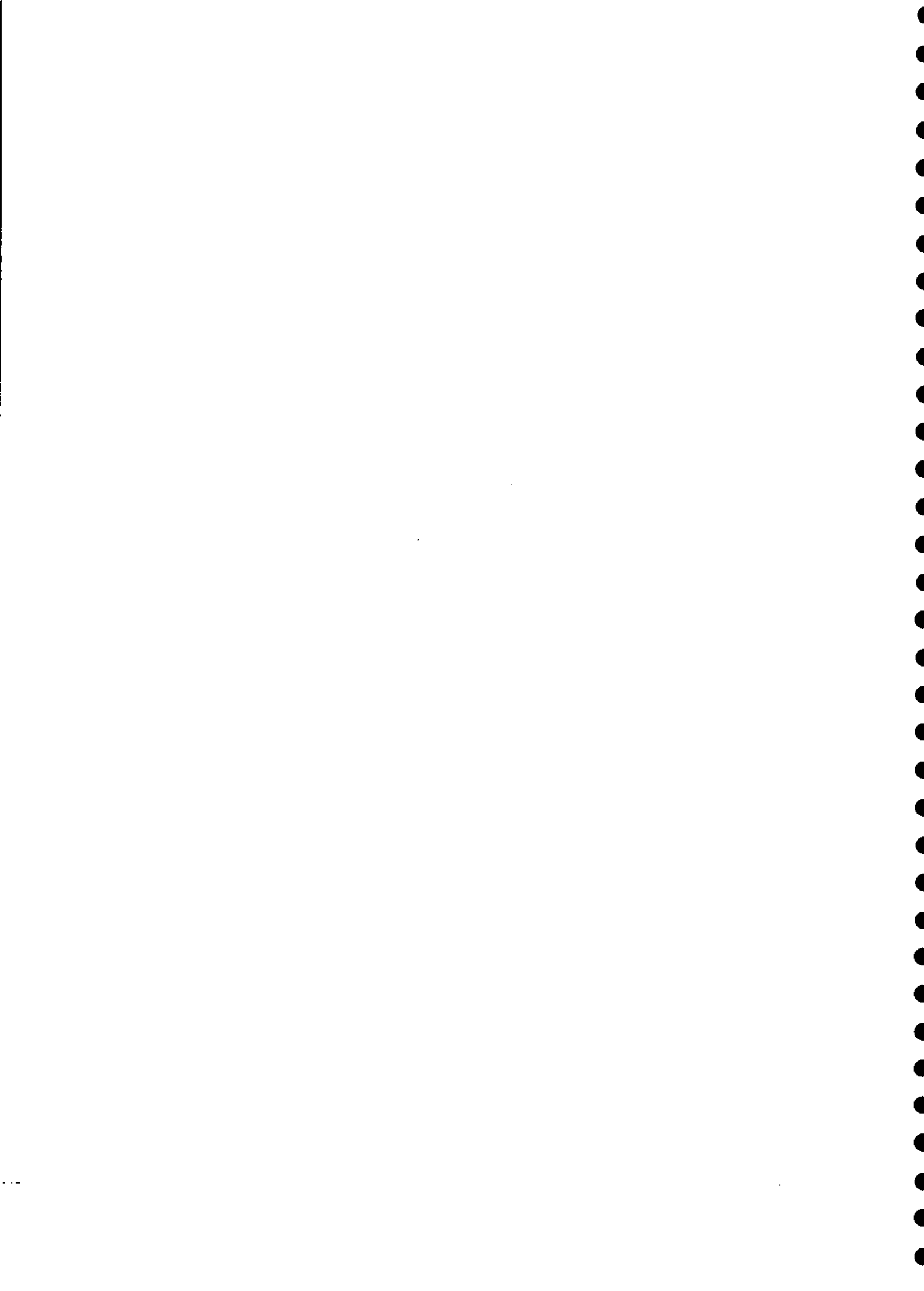
A C Bayliss & H N Davies

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## EXECUTIVE SUMMARY

A key catchment descriptor in the use of Flood Estimation Handbook (FEH) procedures is URBEXT<sub>1990</sub>. This index describes the extent of catchment urban and suburban land cover, and in Great Britain (GB) was based on data taken from the CEH Land Cover Map (LCMGB), but since the data did not extend to Northern Ireland (NI), alternative land cover mapping was used there. The European Community programme for the Coordination of Information on the Environment (CORINE) produced land cover mapping that included NI and this provided a basis for indexing catchment urban extent. The CORINE data were of poor resolution compared to the LCMGB and an adjustment factor was required to produce approximations of URBEXT<sub>1990</sub> that were broadly equivalent to those computed for GB. In addition, the CORINE mapping used was based on satellite imagery taken between 1989 and 1990 and for some catchments now gives an inaccurate picture of the extent of built-up areas. Urban and suburban mapping from Land Cover Map 2000 (LCM2000) should be evaluated since the initiative provides an opportunity for the indexing of catchment urbanisation to be brought up to date, for index values to be consistent with those used in GB, and based on land cover data of a higher resolution.

This report gives details of the work carried out under funding from the Rivers Agency, Department of Agriculture and Rural Development (DARD) for Northern Ireland. The primary objectives of the research are to thoroughly evaluate appropriate outputs from LCM2000, apply refinement procedures to the land cover data where necessary and report on the suitability of the data in deriving an update to values of the FEH catchment descriptor URBEXT<sub>1990</sub>. Following appraisal of the findings described in this report, and subject to funding, a second stage would see the derivation of updated values of URBEXT computed and these made available to FEH users through the release of a new version of the FEH CD-ROM. The production of a new CD-ROM would also allow the inclusion of improvements to the Digital Terrain Model (DTM) that underpins the derivation of FEH catchment descriptors.

The report begins by describing the importance of catchment descriptors in the FEH procedures (Chapter 1). They provide a method for estimating key variables at ungauged sites and in judging catchment similarity when 'pooling' flood peak data. They are also used to identify permeable and urbanised catchments for which FEH provides additional procedures. In the case of the latter the catchment value of URBEXT is pivotal to the adjustments made. The URBEXT<sub>1990</sub> values provided on the FEH CD-ROM for NI are now out of date and based on low resolution data, and need to be updated if suitable data can be found.

Chapter 2 gives details of outputs from LCM2000 and how 25 m raster data were generalised to a 50 m resolution to be consistent with the DTM used in the derivation of FEH catchment descriptor values. It also identifies three LCM2000 Subclasses; namely Suburban, Urban and Inland Bare Ground, as likely to be the most appropriate in defining the extent of built-up areas.

The evaluation of the mapping of built-up areas by LCM2000 is described in Chapter 3. The tools used in the appraisal comprise GIS and mapping software, Ordnance Survey

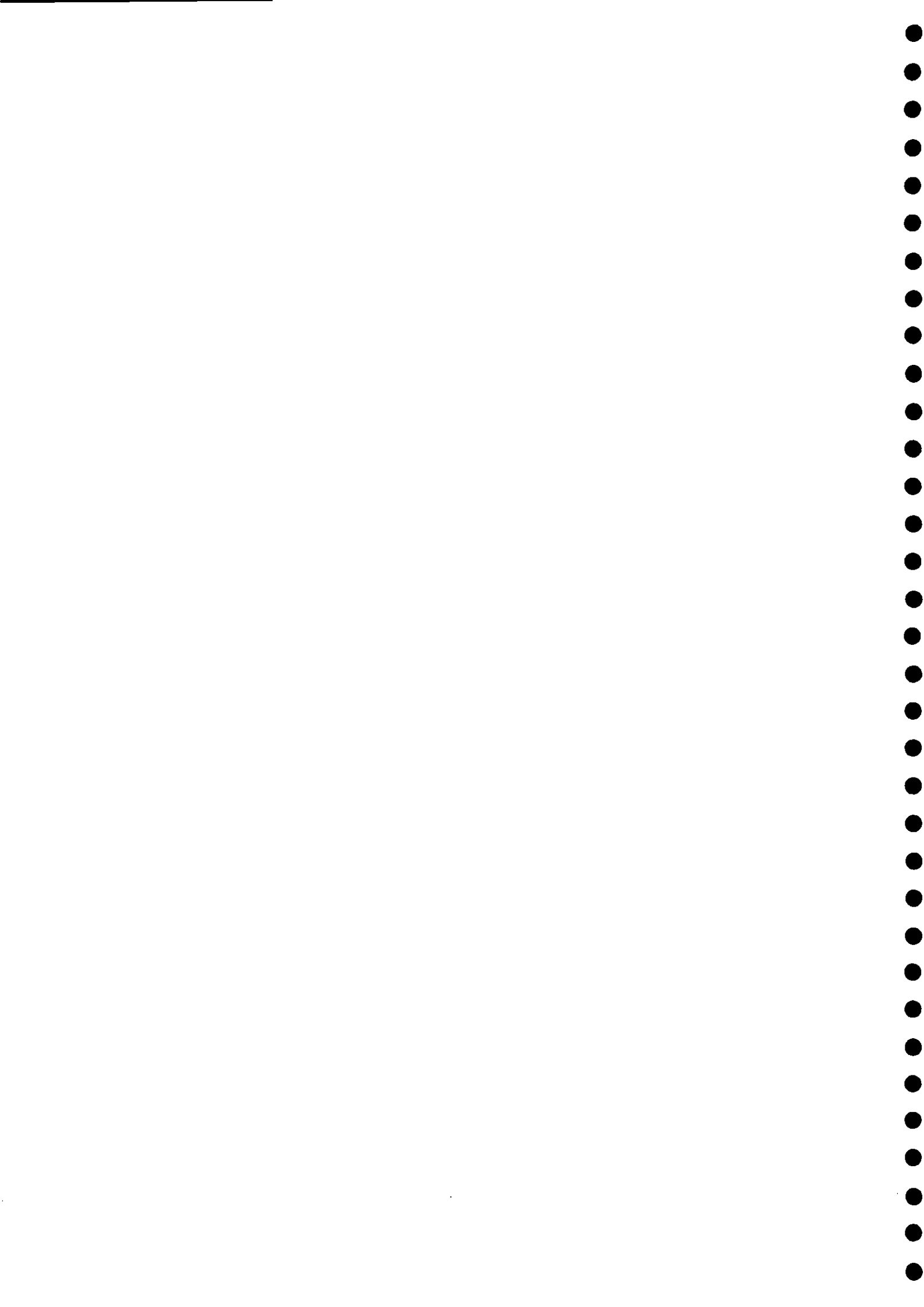
(OS) mapping and digital settlement outlines. The settlement polygons are themselves evaluated before use and some amendments to the dataset are made. The evaluation finds that there is exaggeration of the extent of Suburban and Urban land cover in rural areas that needs addressing before the data can be used. It also concludes that the Subclass Inland Bare Ground maps land cover relevant to indexing urban extent within settlement outlines, but not elsewhere.

Chapter 4 describes the procedures used to refine the LCM2000 land cover data that define built-up areas. The Development Limits supplied by the DARD Planning Service provide the basis for a mask where Urban, Suburban and Inland Bare Ground land cover that falls outside the mask is rejected. Assessment of the result of the rejection and reclassification procedures shows that overall their application produces a refinement of the mapping of built-up areas by LCM2000.

Finally, in Chapter 5, the report concludes by summarising the research carried out under Rivers Agency funding. The key recommendations made by the authors are that the refined land cover data be used to derive updated values of catchment urban extent, that this descriptor be known as URBEXT<sub>2000</sub>, and that these new values be made available to FEH users through the release of a new version of the FEH CD-ROM.

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# **1. INTRODUCTION**

## **1.1 FEH catchment descriptors**

The Flood Estimation Handbook (FEH) procedures (IH, 1999) have largely superseded those described in the Flood Studies Report (NERC, 1975) as the standard methods for estimating flood frequency in the UK.

Derivation of catchment characteristics for use in the Flood Studies Report (FSR) procedures involved time-consuming manual extraction of information from paper maps. An innovative approach to defining descriptor values for the FEH employed a Digital Terrain Model (DTM) to define catchment boundaries automatically, which were subsequently superimposed on digital spatial datasets. Descriptor values are supplied to users on the FEH CD-ROM along with a geographical interface to aid catchment selection. This approach is seen to be a major advance in flood frequency estimation.

Catchment descriptors quantify physical and climatological characteristics (Bayliss, 1999) and play an important role in the Handbook methodologies. Relationships established between descriptors and key variables, such as the median annual flood (QMED), provide techniques for producing flood frequency estimates at ungauged sites. Descriptor values are used in the judgment of catchment similarity when, for example, there is a requirement to 'pool' flood peak data (Robson & Reed, 1999). They are also used to identify permeable and urbanised catchments for which the FEH provides additional steps to the procedures.

## **1.2 Indexing urban extent**

Urbanisation will often have considerable influence on the downstream flood regime and, without amelioration, be likely to increase flood volumes and reduce response times. Consequently, consideration of this effect is an important part of flood frequency estimation procedures and definition of the extent of catchment urbanisation crucial to producing a 'best estimate'.

Guidance following publication of the FSR in 1975 advised users to estimate the urbanised fraction of the catchment using a hand-drawn catchment boundary overlain on an Ordnance Survey (OS) 1:50 000 scale map. The production of a digital Land Cover Map of Great Britain (LCMGB) that included classes defining urban and suburban areas (Fuller *et al.*, 1994), by the then Institute of Terrestrial Ecology (now CEH Monks Wood), meant that the FEH could consider an automated approach to defining catchment urbanisation. The LCMGB was used as a basis for defining URBEXT in England, Wales and Scotland, but the mapping did not extend to Northern Ireland (NI).

During the FEH research programme digital land cover data for Ireland were available through the European Community programme for the Coordination of Information on the Environment (CORINE). The CORINE classification included a number of land

cover classes that appeared to be synonymous with the LCMGB classes urban and suburban. The CORINE dataset has a minimum mappable unit of 0.25 km<sup>2</sup>, which meant many small rural settlements were not represented, and conurbations were depicted in a generalised way. Equivalent CORINE classes were used to define catchment URB<sub>CORINE</sub> values in NI but these are inconsistent with the URBEXT values computed for GB. [In addition to the difference in resolution, the discrimination between urban and suburban areas in the CORINE dataset was found to be unreliable. As a result the development of an URBEXT index consistent with that used in GB, where the influence of the suburban element was reduced by applying a weight of 0.5, was not possible in NI]. Consequently an adjustment was applied to URB<sub>CORINE</sub> values (Bayliss & Scarrott, 1999). This procedure does provide a way for automatically defining URBEXT values in NI but they are based on low-resolution data and are inappropriate for use on small catchments.

Currently, FEH users carrying out a study using a catchment in Northern Ireland are recommended to treat the URBEXT values provided on the FEH CD-ROM as indicative and, as an alternative, manually calculate combined urban and suburban land cover from Ordnance Survey 1:50 000 mapping. As a second stage in the procedure, the map-based value is converted to URBEXT, using the relationship provided in the Handbook.

The urban and suburban land cover used in the derivation of URBEXT in GB is based on satellite imagery taken around 1990. Since the extent of catchment urbanisation is likely to change through time, it is important that index values are 'dated'. URBEXT values given for gauged catchments in Volume 5 of the Handbook, and made available for over 4 million ungauged sites on the FEH CD-ROM, describe urban and suburban development around 1990. That is made clear by use of a subscript (i.e. URBEXT<sub>1990</sub>). The approximations of URBEXT for catchments in Northern Ireland, based on CORINE data, also take on the 1990 subscript. The quantification of catchment urban extent given by index values of URBEXT<sub>1990</sub> is now clearly out of date. FEH users currently employ pragmatic solutions to update catchment values of URBEXT<sub>1990</sub> where necessary and reasonably expect that any new national land cover dataset be considered for use.

The release of urban and suburban mapping from Land Cover Map 2000 (LCM2000) provides an opportunity to bring the indexing of catchment urbanisation up to date and, since mapping is UK wide, produce URBEXT values for NI which are consistent with those produced for GB. LCM2000 data are of a higher resolution than provided by the CORINE classification and additionally, the former uses an advanced parcel-based classification methodology, which is seen to have a number of advantages over the pixel-based procedures used in 1990. The use of LCMGB urban and suburban data in defining URBEXT in GB was only possible after the use of a refinement procedure involving the overlay of settlement polygons taken from OS mapping. It is important therefore, that data from LCM2000 are evaluated in a rigorous way before using them to define URBEXT for catchments in Northern Ireland.

## **2. LAND COVER MAP 2000**

### **2.1 Introduction**

Countryside Survey 2000 (CS2000), which covers both Great Britain and Northern Ireland, provides information about the habitats and landscape of the UK countryside. A key component of the survey is Land Cover Map 2000 (LCM2000) which complements the detailed, sample-based, field surveys of CS2000 (Fuller *et al.*, 2002a). LCM2000 seeks to both update and upgrade the Land Cover Map of Great Britain (LCMGB) of 1990 (from which the urban and suburban mapping used to define values of URBEXT<sub>1990</sub> was taken).

LCM2000 is a digital map of land cover based on satellite imagery taken principally between 1998 and 2000. The satellites record spectral reflectances from the Earth's surface on a grid of approximately 25 m × 25 m cells (pixels). LCMGB used a pixel-based approach which may lead to a speckled appearance, be misleading, and result in poor quality mapping - for example, where pixels of grass are shown within a field of wheat. Additionally pixels on the boundary between areas of uniform land cover are from multiple surface types and may give spurious results (Smith & Fuller, 2000).

Processing of satellite data for LCM2000 addressed these issues by using a parcel-based approach. Image segmentation built around 'seedpoints' was used to identify land parcels in the pixel-based images (a detailed account of which is given by Fuller *et al.*, 2002b). Post-segment generalisation gave parcels with a minimum mappable unit of half a hectare (5 000 m<sup>2</sup>). A geographical information system (GIS) was used to record boundaries between the pixel-based segments using digital line work, thereby creating a vector version of the dataset with a range of attribute data held for each of the resultant land parcels.

### **2.2 Outputs and formats**

#### **2.2.1 Introduction**

LCM2000 is a land cover classification comprising 72 class Variants, combined into 26 Subclasses and in turn into 16 Target classes and 10 Aggregate classes. Subclasses were also combined to simulate 20 Broad Habitats of the UK Biodiversity Action Plan (see Table 2.1). LCM2000 is provided as several different product versions.

#### **2.2.2 Vector database**

Data are provided as polygons (land parcels) with each parcel linked to a set of attributes. The standard level of detail supplied (known as Level 2) provides the 26 LCM2000 subclasses. Level 3 gives class detail down to the 72 Variant level but may not be of consistent quality throughout the UK. The standard output format is as ArcView shape files.

**Table 2.1 LCM2000 Subclasses and their relation to the Target classes and Broad Habitats (from Fuller *et al.*, 2002a)**

BH	LCM Target class	LCM Subclasses
22. Inshore sublittoral	Sea / Estuary	Sea / Estuary
13. Standing water/canals	Water (inland)	Water (inland)
20. Littoral rock	Littoral rock and sediment	Littoral rock
21. Littoral sediment		Littoral sediment
		Saltmarsh
18. Supra-littoral rock	Supra-littoral rock and sediment	Supra-littoral rock
19. Supra-littoral sediment		Supra-littoral sediment
12. Bogs	Bogs (deep peat)	Bogs (deep peat)
	Dwarf shrub heath (wet / dry)	Dense dwarf shrub heath      Open dwarf shrub heath
10. Dwarf shrub heath	Montane habitats	Montane habitats
15. Montane habitats	Broad-leaved wood	Broad-leaved / mixed woodland
1. Broad-leaved woodland	Coniferous woodland	Coniferous woodland
2. Coniferous woodland	Arable and horticultural	Arable cereals
4. Arable & horticultural		Arable horticulture
		Non-rotational horticulture
5. Improved grassland	Improved grassland	Improved grassland
	Neutral / calcareous	Setaside grass
6. Neutral	semi-natural / rough	Neutral grass
7. Calcareous	grasslands	Calcareous grass
8. Acid	Acid grass and bracken	Acid grass
9. Bracken		Bracken
11. Fen, marsh and swamp	Fen, marsh and swamp	Fen, marsh, swamp
17. Built up areas, gardens	Suburban and urban	Suburban/rural developed
		Continuous Urban
16. Inland rock	Inland Bare Ground	Inland Bare Ground
20. relevant BHs	16 target classes	26 target/subclasses

### 2.2.3 Raster dataset

The data have been derived from the vector database and are available at two resolutions, 25 m and 1 km. The former provides the appropriate LCM2000 Subclass for each 25 m square and the latter the dominant Subclass and Aggregate class.

### 2.2.4 Choice of data and format

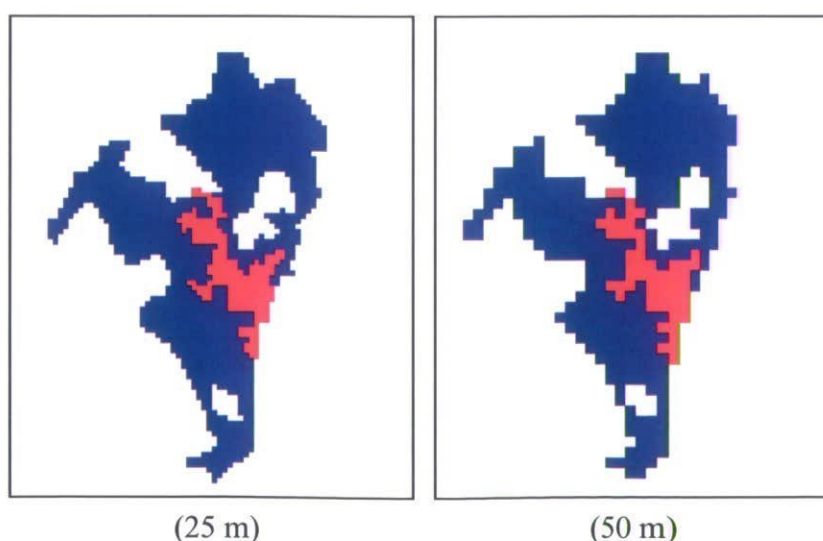
The choice of an appropriate LCM2000 output for the derivation of new index values of urban extent was relatively straightforward. Neither the Broad Habitat nor Target classes discriminate between urban and suburban areas and the 72 class Variants are

thought to be inconsistently mapped. However, urban and suburban land cover types are represented in the 26 class LCM2000 Subclasses dataset, appear to be synonymous with the types of development described by the urban and suburban classes used to derive URBEXT<sub>1990</sub>, and are clearly the most appropriate output for use in updating the index.

The target format for the use of LCM2000 data, in the generation of an updated FEH urban extent index, is a regular 50 m grid of values. This format and resolution is consistent with the digital terrain model used to generate the catchment boundaries employed in the derivation of FEH catchment descriptor values.

Review of LCM2000 outputs determined that no additional benefits would accrue from using data from the vector database as a basis for producing 50 m gridded data. Raster data at 1 km resolution providing dominant land cover class were insufficiently detailed but at a resolution of 25 m were appropriate for use as an input to producing the target grid of 50 m values. Data at 25 m resolution were available as Erdas Imagine image files.

The GIS software package ArcInfo was used to convert the 25 m raster data provided as image files to Arc format using the 'imagegrid' command. The generalisation of the 25 m dataset to 50 m resolution using Arc routines was achieved using a two-stage procedure. The dominant land cover class was determined for each 50 m cell using the 'blockmajority' command. Where no dominant class existed, a nearest-neighbour ('nearest') assignment was used to determine the land cover class given to that cell. Figure 2.1 illustrates the effect of the generalisation procedure on 25 m data assigned to LCM2000 Subclasses Suburban and Urban for the town of Whitehead in County Antrim. It is apparent that although a little of the fine detail is lost, the 50 m data accurately mirror the land cover patterns evident in the 25 m data.



**Figure 2.1** Effect of generalising 25 m Suburban (blue) and Urban (red) land cover data to a 50 m resolution – Whitehead, County Antrim.

## 2.3 Subclasses

Subclasses were defined, where possible, to describe the complete range of Broad Habitats identified by the UK Biodiversity Group, but also aimed to give cover classes sought by other users. Table 2.1 (Section 2.2) indicates the relation between Broad Habitats and LCM2000 Subclasses and Table 2.2 (below) that between Subclasses and Variants.

**Table 2.2 LCM2000 Subclasses and their relation to the Target classes and Broad Habitats (from Fuller *et al.*, 2002a)**

LCM Subclasses		
Sea / Estuary		
Water (inland)		
Littoral rock		
Littoral sediment		
Saltmarsh		
Supra-littoral rock		
Supra-littoral sediment		
Bogs (deep peat)		
Dense dwarf	Open dwarf	
shrub heath	shrub heath	
Montane habitats		
Broad-leaved / mixed woodland		
Coniferous woodland		
Arable cereals		
Arable horticulture		
Non-rotational horticulture		
Improved grassland		
Setaside grass		
Neutral grass		
Calcareous grass		
Acid grass		
Bracken		
Fen, marsh, swamp		
Suburban/rural developed		
Continuous Urban		
Inland Bare Ground		
26 target/subclasses		

Variants		
sea		
water (inland)		
rock, rock with algae		
mud, sand, sand/mud with algae		
saltmarsh, saltmarsh (grazed)		
rock		
shingle, shingle (vegetated), dune, dune shrubs		
bog: shrub, grass/shrub, undifferentiated (all on deep peat)		
dense ericaceous, gorse		open ericaceous
montane		
deciduous, mixed, open birch, scrub		
conifers, felled, new plantation		
barley, maize, oats, wheat, cereal (spring), cereal (winter),		
arable bare ground, carrots, field beans, horticulture, linseed, potatoes,		
peas, oilseed rape, sugar beet, mustard, non-cereal (spring), unknown		
orchard, arable grass (ley), setaside (bare), setaside (undifferentiated)		
intensive, grass (hay/ silage cut), grazing marsh		
grass setaside		
rough grass (unmanaged), grass (neutral / unimproved)		
calcareous (managed), calcareous (rough)		
acid, acid (rough), acid with Juncus, acid with Nardus/Festuca/Molinia		
bracken		
swamp, fen/marsh, fen willow		
suburban/rural developed		
urban residential/commercial, urban industrial		
despoiled, semi-natural		
72 target/subclasses/variants		

LCM2000 subclasses 'Suburban/rural developed' and 'Continuous urban' appear to be consistent with the Suburban and Urban classes defined by the LCMGB and which were used as a basis for deriving catchment values of URBEXT<sub>1990</sub> for the FEH. It is also apparent from the LCM2000 Variants used to define the Suburban and Urban Subclasses (Table 2.2) that they both include, and discriminate between, the types of urban and suburban development identified by the equivalent classes defined by the LCMGB. In summary, both LCM2000 and LCMGB Suburban classes recognise development that comprises a mixture of built-up and vegetated surfaces and both Urban classes delineate areas of continuous development with little if any vegetation. It is evident that the LCM2000 Subclasses Suburban and Urban are likely to be the most appropriate classes on which to base an index of urban extent. Additionally, their use should provide consistency with the types of development recognised by, and discriminated between, the LCMGB classes used to define URBEXT<sub>1990</sub>.

Fuller *et al.* (2002a) report how, in rural areas, the LCM2000 Subclass 'Inland Bare Ground' maps exposed rock surfaces such as limestone pavements and quarries. They also note that in an urban context this includes gravel car parks, railway sidings and derelict industrial land. Consequently, the mapping of Inland Bare Ground in built-up areas should also be evaluated, along with the Urban and Suburban Subclasses described above.

### **3. EVALUATION OF THE MAPPING OF BUILT-UP AREAS**

#### **3.1 Introduction**

The derivation of the FEH catchment descriptor URBEXT<sub>1990</sub> was based on the delineation of urban and suburban areas provided by the Land Cover Map of Great Britain. Urban and suburban mapping taken from the LCMGB was seen to exaggerate the extent of built-up areas and was only used to compute descriptor values after a rectification procedure had been applied. The mapping of built-up areas by LCM2000, and in particular the provision of data for LCM2000 Subclasses Urban, Suburban and Inland Bare Ground (Section 2.3), provides an opportunity for the indexing of urban extent to be brought up to date. It is important, however, that before this can be considered a thorough evaluation of the mapping takes place. [It should be noted that although LCM2000 provides land cover mapping for Great Britain (GB) and Northern Ireland (NI), and references to GB will be made where appropriate, the evaluation reported here refers to NI. Review of data for GB has recently been carried out (Bayliss & Davies, 2003) under a project funded by Defra and the Environment Agency].

#### **3.2 Evaluation tools**

##### **3.2.1 GIS and mapping software**

The GIS packages used for the evaluation were ArcView (3.1) and ArcInfo (8.0.1) within a Unix environment (due to the large UK-wide datasets used in the analysis the superior processing power of Unix workstations were utilised rather than PC-based applications). Both packages were used for analysis, however only ArcView was employed for viewing and presenting the spatial data.

The in-house mapping software dg8 (Flavin, 1994) provides a series of commands that can be customised to suit user requirements by changing parameter values. It has the advantage that it has been specifically designed to display the spatial datasets held at CEH Wallingford. It is not a GIS but datasets can be combined and the results subsequently mapped.

##### **3.2.2 Topographic maps at 1:50 000 scale**

The 1:50 000 Discoverer Series (B and C Editions), published by the Ordnance Survey of Northern Ireland (OSNI) between 2001/03, provide an accurate depiction of urban extent at that time and have the advantage of being almost coincident with the satellite imagery used to produce LCM2000, which was taken principally between 1998 and 2000. They can be compared on a large light table with LCM2000 urban and suburban mapping displayed at 1:50 000 scale.

There is also a need to review the mapping of built-up areas by LCM2000 for those areas in the Republic which drain into Northern Ireland. Similarly, the 1:50 000 Discovery Series (1<sup>st</sup> and 2<sup>nd</sup> Editions), published by the Ordnance Survey of Ireland



(OSI), are also broadly coincident with the satellite imagery and represent a useful evaluation tool.

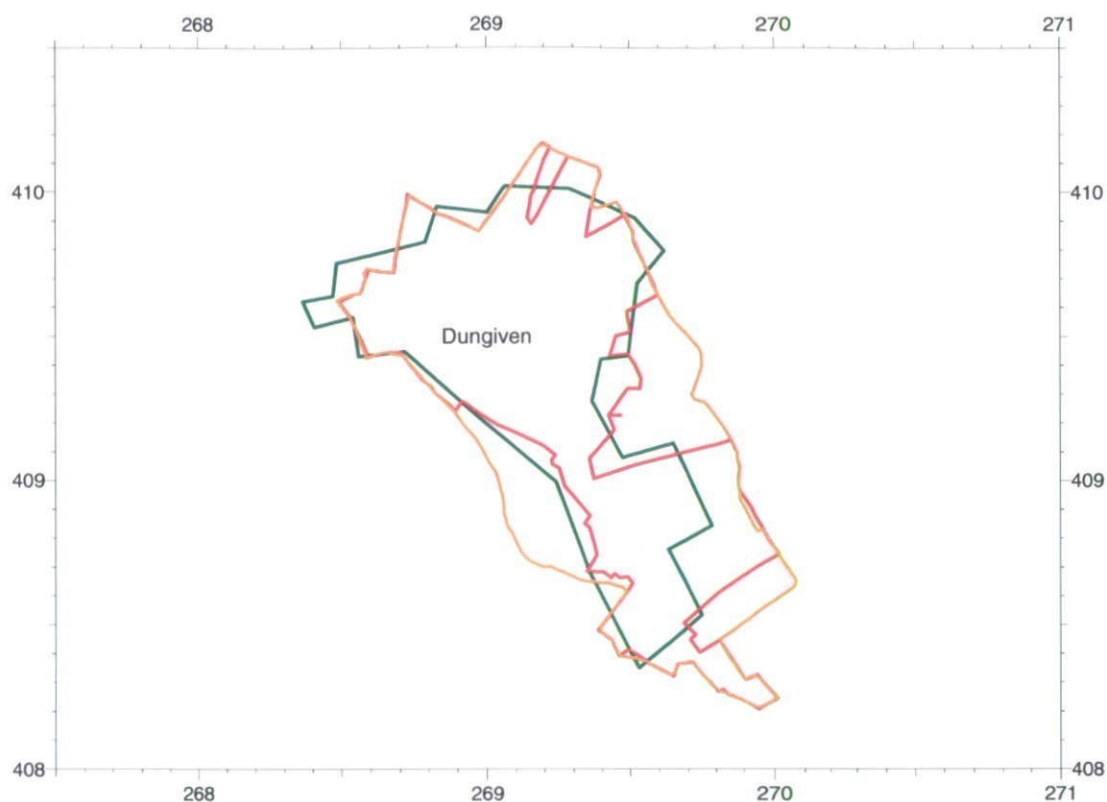
### **3.2.3 Digital settlement outlines**

The derivation of URBEXT<sub>1990</sub> for GB was based on digital urban and suburban mapping taken from LCMGB. The classification exaggerated the extent of built-up areas and consequently a rectification procedure was applied. This procedure involved the use of OS settlement outlines, as a mask. LCMGB urban and suburban data that fell outside these settlement outlines (and their 250 m extensions) were considered to be spurious and consequently rejected (Bayliss & Scarrott, 1999). Overall, the application of this procedure was judged to be successful in producing an enhanced dataset and consequently the use of digital settlement outlines in the validation of built-up areas defined by the new classification, LCM2000, was desirable, if an appropriate dataset could be identified. Three such datasets were available to the study and before being used in an evaluation or refinement process, the settlement data themselves were reviewed for accuracy and consistency. A brief description of the datasets, and comments on their suitability for use in this role, are given below.

**OSNI 1:210 000 Settlement data** – The dataset is licensed from OSNI and comprises outlines for larger settlements, in vector format, and point data, for a number of villages. The data are intended for use at a scale of 1:210 000 and the outlines appear spatially inaccurate when viewed at more detailed scales. The representation of a large number of settlements as points rather than vector outlines also presents difficulties in utilising the data to validate land cover parcels. Additionally, a comparison of the settlement data with Ordnance Survey (OS) maps published at 1:50 000 scale, found that a number of settlements of significant size had been omitted from the dataset.

**Urban Footprints** – As part of the Regional Development Strategy, the Department of Agriculture and Rural Development (DARD) Planning Service was required to capture digital outlines for all settlements in Northern Ireland with a population in excess of 5000. Some planning authority regions also included built-up areas below this threshold, as part of a housing monitor exercise, but since this was not undertaken throughout Northern Ireland there were likely to be spatial inconsistencies in the dataset. Settlement polygons were supplied to CEH Wallingford for consideration as a validation tool. Comparison with OS maps confirmed the inconsistency in capturing settlement outlines but did indicate that, where a settlement outline had been digitised, its outline closely followed that shown on 1:50 000 scale mapping.

**Development Limits** – These limits are designated by the DARD Planning Service for settlements of all sizes in Northern Ireland through the area plan process. They have been captured digitally as settlement polygons and made available to CEH Wallingford for use in this study. Comparison of Development Limits with Urban Footprints indicated that, for many settlements, outlines were generally coincident but that in some parts of the settlement the former, unsurprisingly given the nature of their use, extended beyond the 'footprint' (Figure 3.1 provides an example). Reference to OS 1:50 000 maps identified a greater consistency in the size of settlements included in the Development Limits dataset compared to that captured as Urban Footprints.



**Figure 3.1 Comparison of OSNI Settlement Outlines (green), DARD Urban Footprints (red) and DARD Development Limits (orange)**

The review of the three datasets concluded that the outlines licensed from OSNI were not sufficiently accurate for use in the validation and possible refinement of raster data at 50 m resolution. It found that the Urban Footprints accurately defined built-up areas but the dataset was spatially inconsistent (i.e. it included smaller settlements in some areas but not in others). However, assessment of settlement outlines defining Development Limits established that this dataset was both accurate and broadly consistent, and, with some enhancements, could form the basis of a useful validation tool.

Comparison with OS 1:50 000 mapping revealed that, although the size of settlements incorporated into the Development Limits dataset was broadly consistent across Northern Ireland, there were some areas where noticeably smaller settlements were included. The decision was made to remove these smaller settlements from the dataset to improve spatial consistency, but the editing needed to be carried out in an objective way. The depiction of settlements shown on OS 1:50 000 mapping was used as a guide. Those settlements shown as clusters of individual dwellings by OS (rather than the grey polygon used to denote the larger settlements) were judged to be 'small', and removed when present in the Development Limits dataset.

The comparison also showed that some significant settlements had been omitted from the Development Limits dataset. Where an omission was identified, and an Urban Footprint was available for that settlement, it was brought into the dataset. If neither a

Development Limit nor an Urban Footprint were available, an outline was digitised using OS 1:50 000 mapping. The datasets prepared by the DARD Planning Service relate only to Northern Ireland, so in order to assess land cover mapping where catchments extended across the border into the Republic, settlement outlines in those areas were digitised from 1:50 000 mapping published by the Ordnance Survey of Ireland.

With a set of vector settlement outlines now in place, the polygons were converted to 50 m raster data using ArcInfo in order that they were consistent with the project's holdings of LCM2000 Subclass data. Following this procedure, a final enhancement of the gridded settlement data was carried out. Settlement outlines digitised manually, where omissions in the Planning Service datasets were evident, encompassed the entire built-up area. However, a comparison of Development Limits, the selected Urban Footprints, LCM2000 Urban and Suburban data, and OS 1:50 000 mapping, showed that although the digital Planning Service outlines generally followed the outer edge of the built-up area precisely, in some areas there was some small spatial inaccuracy (partly as a result of the conversion from vector to raster data). To ensure that all settlement outlines included the full extent of built-up areas, all gridded settlement outlines based on the Planning Service datasets were extended by 50 m. [For brevity, the gridded settlement polygons based on the enhanced Development Limits dataset will, in general, be referred to as 'Development Limits' in subsequent sections in this report].

### **3.3 Summary of findings**

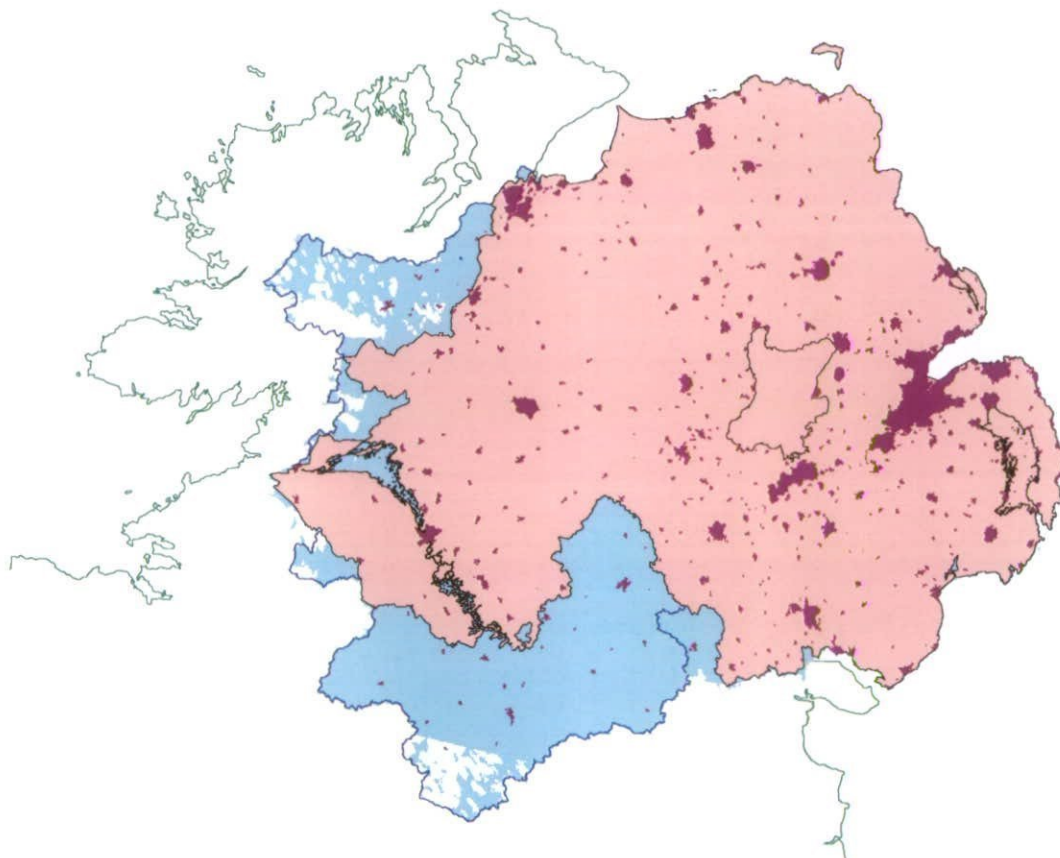
#### **3.3.1 LCM2000 in the Republic of Ireland**

Land Cover Map 2000 provides complete coverage for Northern Ireland but data are not necessarily available for more than a short distance beyond the border. In Northern Ireland there are a number of rivers that begin in the Republic of Ireland but subsequently flow across the border (e.g. the River Erne). In order that catchment values of urban extent can be computed accurately for those locations in Northern Ireland where the headwaters for the river of interest are in the Republic, it is necessary that land cover data are available for the whole catchment. It was important, therefore, to establish the extent of LCM2000 data available for Ireland.

Figure 3.2 shows the extent of LCM2000 mapping in Ireland, where coverage in Northern Ireland is shown with pink shading, and coverage for those parts of the Republic of Ireland that drain across the border, shown in blue. It is evident that LCM2000 is not available for all the areas of the Republic that drain into Northern Ireland (i.e. those areas with no LCM2000 data appear white).

Those 'no data areas' are located in very rural regions and the number of settlements is extremely small. Using ArcInfo, Development Limits were combined with LCM2000 coverage. This established that there were only four settlements (or part settlements) in these no data areas and that the total area within these four outlines represented a meagre 2 km<sup>2</sup> (0.3% of the total area within Development Limits). Indeed, the absence

of land cover data would only be important if the settlement was likely to be influential on the value of urban extent for the catchment of interest.



**Figure 3.2 LCM2000 coverage in Ireland (pink shading indicates coverage for Northern Ireland, blue for those areas of the Republic of Ireland that drain into Northern Ireland and maroon indicates gridded Development Limits)**

In Ireland, FEH procedures are recommended for use (consequently urban extent is required) at sites within Northern Ireland, but not in the Republic. Three of these settlements (Castlefinn, Stranorlar and Ballybofey) lie on the River Finn, and at the point where the river enters Northern Ireland, near Strabane, the catchment area is nearly 500 km<sup>2</sup>. Consequently the potential influence of these settlements on this catchment, and subsequent catchments downstream, is minuscule. The fourth settlement identified was Arvagh in County Cavan, in the headwaters of the River Erne. Similarly, at the point where the river crosses the border (where it flows into Upper Lough Erne) the catchment area is around 1500 km<sup>2</sup>, and again the effect of 'missing' land cover data from this point downstream is diminutive. It was concluded, therefore, that although LCM2000 coverage does not extend to all parts of the Republic that drain into Northern Ireland, this does represent a problem for the use of the data required here.



### 3.3.2 LCM2000 Subclasses found within settlements

It is expected that the types of development typically found within built-up areas be principally assigned to the LCM2000 Subclasses 'Suburban/rural developed', 'Continuous Urban' and 'Inland Bare Ground' (Section 2.3). To test this assumption, Development Limits (Subsection 3.2.3), were superimposed on mapping of all Subclasses, for the whole of Northern Ireland (NI), using ArcView. Table 3.1 presents the results from this comparison.

**Table 3.1 Principal LCM2000 Subclasses found within Development Limits – Northern Ireland**

LCM2000 Subclass	Percentage of total area within Development Limits covered by Subclass	Percentage of total Subclass area within Development Limits	Percentage of total NI Land Cover
Suburban / rural developed	38	68	2.4
Improved grassland	26	2	50.7
Continuous urban	6	74	0.4
Neutral grass	8	4	9.7
Arable horticulture	7	5	5.5
Inland Bare ground	3	33	0.4
Acid grassland	2	1	7.3
Broadleaved / mixed woodland	2	6	1.9
Dense dwarf shrub heath	2	4	2.5
Calcareous grass	2	3	2.6

It is evident that 38% of the area defined to be within Development Limits equates to LCM2000 Suburban land cover and 6% to Urban land cover (Table 3.1). Inland Bare Ground (gravel car parks etc.) represents only 3% of the area within settlements defined by these settlement outlines. However, this is not surprising since this Subclass only represents 0.4% of the total land cover mapped for Northern Ireland.

The total area within Development Limits assigned to non-urban classes totals 56% and dominating this group is 'Improved grassland'. This is the largest single land cover Subclass in NI and is well classified by LCM2000 (Fuller *et al.*, 2002a). In an urban context, parks and playing fields are examples of land use likely to be assigned to this class. Consequently, the total area defined as Improved Grassland within Development Limits (26%) does not seem unreasonable. Similarly, the presence of some woodland within developed areas does not look out of place. The occurrence of Neutral, Acid and Calcareous grasses within Development Limits is, in many cases, likely to be the result of the misclassification of Improved grassland, since distinguishing between these Subclasses using the LCM2000 methodology is difficult (Fuller *et al.*, 2002a ).

Perhaps more noteworthy is that it is apparent from the summary provided in Table 3.1 that 7% of settlement areas are assigned to the Subclass 'Arable horticulture' by LCM2000. Intuitively one would expect much of this 7% was the result of misclassification. Fuller *et al.*, (2002a) identified that "confusion between arable and built up land is a small but nonetheless significant problem: it relates mostly to erroneous classification of satellite images, where part-grown or ripening crops have spectral signatures readily confused with those of partly vegetated suburban areas".

This initial evaluation of LCM2000 Subclasses found within settlement outlines has been useful in confirming that built-up areas are principally assigned by LCM2000 to the land cover classes Suburban and Urban. The comparison has also established that some areas within settlements have been classed as Inland Bare ground, which is consistent with the description of the class given by Fuller *et al.* (2002a) (summarised here in Section 2.3). It also highlighted the possible misclassification of some areas within settlements as the Subclass Arable horticulture. Further evaluation of the land cover assigned by LCM2000 to the Subclasses Suburban, Urban and Inland Bare Ground was required, and it was also now clear that these investigations should include the mapping of the Subclass Arable horticulture.

### 3.3.3 Suburban

The delineation of suburban land cover by LCM2000 was mapped, using 50 m raster data, for a number of sample areas of Northern Ireland using the in-house software dg8. Suburban areas were shown along with the Development Limits described in Subsection 3.2.3. These settlement outlines were used, along with the OSNI Discoverer and OSI Discovery 1:50 000 Series, to evaluate the accuracy of LCM2000 in defining suburban areas.

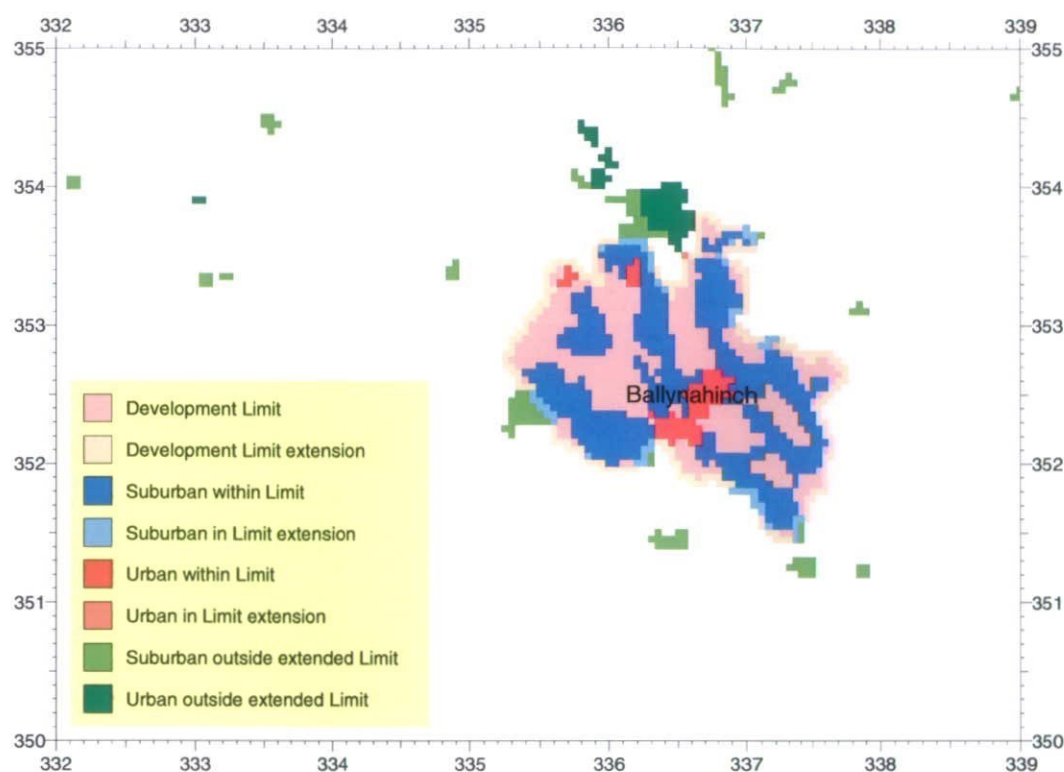
It was evident that, reassuringly, the majority of areas defined as Suburban by LCM2000 lay within Development Limits (Table 3.1 shows that across NI 68% of Suburban areas were within these outlines). Use of 1:50 000 mapping confirmed that within settlements the typical type of land cover assigned to the suburban class was a mixture of the urban and vegetated areas often found in residential areas dominated by detached and semi-detached housing.

It was also apparent that, in the majority of cases, extending Development Limits by 50 m (Subsection 3.2.3) was necessary to encompass the entire area of the settlement. Figure 3.3 illustrates that the use of a 50 m extension to the Development Limits includes Suburban land cover on the outskirts of Ballynahinch in County Down, which would otherwise fall outside the settlement polygon. [Suburban land cover depicted in blue lies within the original settlement outline and that in light blue in the 50 m buffer].

Although land cover defined to be Suburban by LCM2000 largely fell within settlement outlines, it was also evident that some suburban areas (32% across NI) were defined outside these polygons (depicted in light green in Figure 3.3). In part this was due to very small hamlets and rural dwellings, such as farmhouses, not forming part of the Development Limits dataset. However, there also appeared to be a problem of non-urban land cover mistakenly being classified as Suburban.

Land cover that includes areas of bare earth and rock was, on occasions, mistakenly assigned to the subclass Suburban since the spectral reflectance from these cover types is similar. In NI, areas misclassified as Suburban by LCM2000 were frequently shown, by reference to OS 1:50 000 mapping, to be quarries and pits. Figure 3.3 provides examples of such misclassification around Ballynahinch. Immediately to the north of the town are two quarries - parts of which have been erroneously classified as Suburban land cover. The figure also shows Suburban land cover beyond the Development Limit,

but immediately adjacent to the eastern edge of the settlement. Again, reference to OS mapping indicates that the land cover has mistakenly be classified as Suburban.



**Figure 3.3 LCM2000 Suburban and Urban land cover and gridded settlement outline based on Development Limit (with 50 m extension) - Ballynahinch.**

In conclusion, the review of the mapping of Suburban areas by LCM2000 found that the assignment of land cover to the class within Development Limits was largely correct. In rural areas (outside these settlement outlines) the occurrence of Suburban land cover indicated the presence of small villages and hamlets not included in the Development Limits dataset. Perhaps more significantly, it also included the misclassification of areas of bare earth or rock (most commonly pits and quarries) resulting in some exaggeration of the extent of Suburban areas depicted by LCM2000.

### 3.3.4 Urban

In common with the evaluation of the mapping of Suburban land cover by LCM2000, described above, dg8 maps were produced for sample areas showing LCM2000 Urban land cover along with Development Limits. Similarly, OS 1: 50 000 mapping was used to assess the accuracy of LCM2000 in delineating Urban land cover.

Review of the mapping for sample areas provided by dg8, indicated that typical land cover assigned to the Urban class within Development Limits, was town centre developments, industrial estates and large buildings such as hospitals. This is consistent

with the description of the class by Fuller *et al.* (2002a) as continuous urban development with practically no vegetation.

It was also apparent from the evaluation of sample plots that Urban land cover was recorded by LCM2000 in rural areas. This is confirmed by the summary presented in Table 3.1 which shows that 74% of Urban land cover delineated by LCM2000 across NI lay within Development Limits (it follows, therefore, that 26% was found to fall outside these areas). Intuitively, one would expect less than 26% of Urban land cover to occur outside built-up areas. Assessment, using 1:50 000 mapping indicated that pits, quarries and mountain ridges were commonly misclassified as Urban land cover. An illustration of this type of misclassification is provided by Figure 3.3. The quarries to the north of Ballynahinch have, for the most part, been misclassified as Urban land cover, although there is also misclassification of these areas of exposed rock as Suburban land cover (described in Subsection 3.3.3).

In the analysis of satellite imagery, confusion between bare earth, typical of an annual cropping cycle, and developed areas, is combated by the use of seasonal images as an aid to discrimination. Despite their use in the production of LCM2000, Bayliss and Davies (2003) found that in GB, much of land cover misclassified as Urban was bare earth or part-grown crops. This type of misclassification is not a factor in the use of LCM2000 in NI however, since agricultural land cover is dominated by grassland, rather than the arable cereals that feature so strongly in GB.

In summary, the evaluation of the mapping of Urban land Cover by LCM2000 indicated that within settlements this was predominantly successful. However, outside the principal settlements the assignment of land cover to the Subclass Urban was frequently the result of misclassification.

#### **3.3.4 Inland Bare Ground**

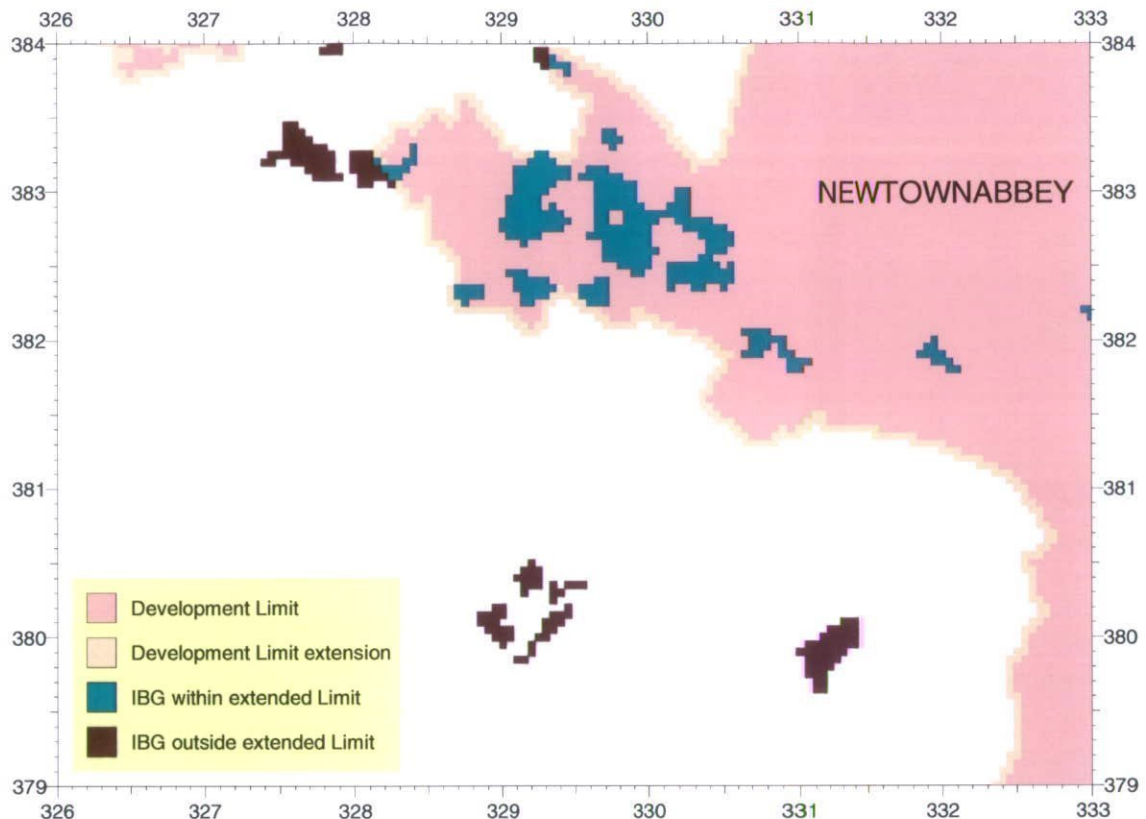
Maps illustrating the delineation of Inland Bare Ground by LCM2000 were produced using dg8 for sample areas across NI. Again Development Limits were also plotted to evaluate the success in defining such areas. Review of these mapped areas was carried out in conjunction with the use of OS 1:50 000 maps.

It was evident that in many places, the land cover assigned to the Subclass Inland Bare Ground was consistent with the description of the class provided by Fuller *et al.* (2002a). They reported that in rural areas Inland Bare Ground includes exposed rock surfaces such as limestone pavements and quarries but in an urban context this comprises gravel car parks, railway sidings and derelict industrial land. However, the evaluation carried out here also revealed that, within settlements, there appeared to be some land cover classified as Inland Bare Ground that would more appropriately reside in the Subclass Suburban or, more frequently, in the Subclass Urban.

Reference to OS 1: 50 000 maps identified many instances where factories, schools, hospitals, airport buildings and town centres had been misclassified as Inland Bare Ground. Some industrial estates were also incorrectly mapped by LCM2000, and Figure 3.4 provides an example. Within the Development Limit for Newtownabbey, on the northern outskirts of Belfast, parts of the industrial estate in the west of the town



have been misclassified as Inland Bare Ground (shown in blue). The figure also shows areas of Inland Bare Ground beyond the settlement outline (shown in brown) which OS mapping indicates are quarries – justifying their inclusion in the Subclass.



**Figure 3.4 LCM2000 Subclass Inland Bare Ground (IBG) – Newtownabbey**

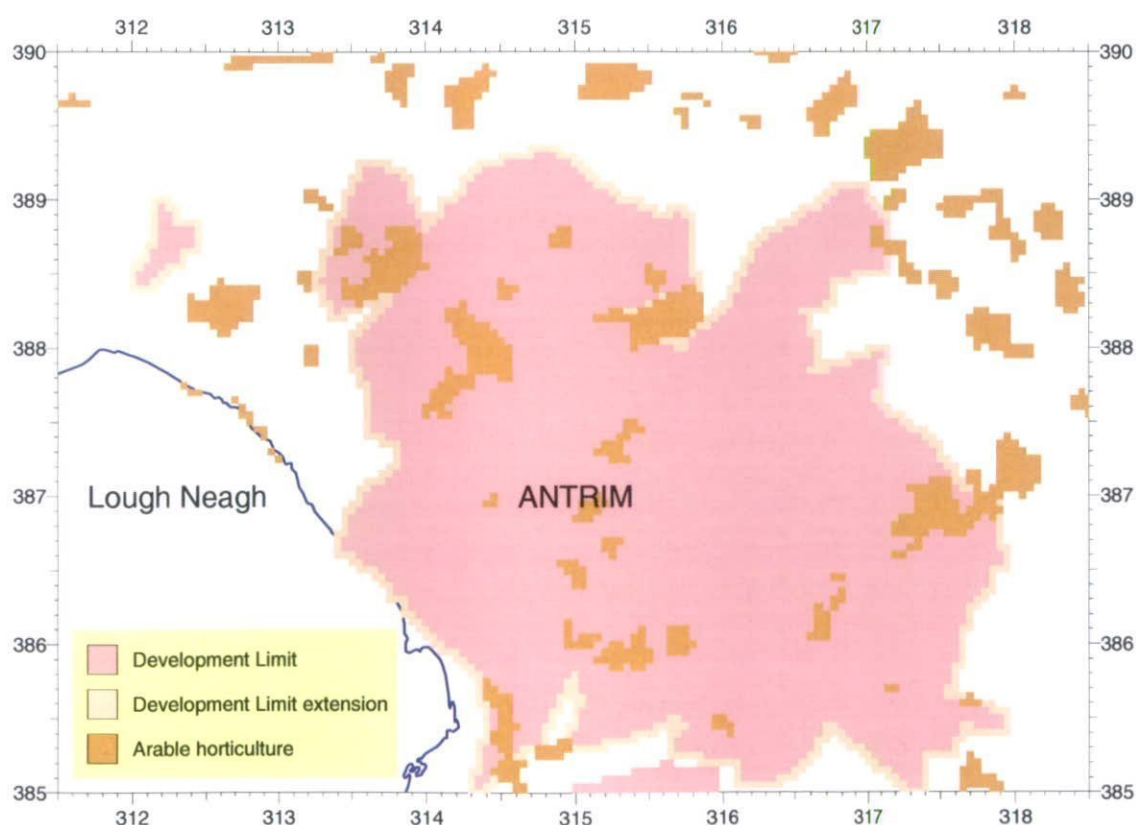
The evaluation showed that, in an urban context (i.e. within Development Limits), land cover assigned to the LCM2000 Subclass Inland Bare Ground was, in some instances, consistent with the description of the class in these areas, but more commonly represented misclassified Urban and Suburban development. Consequently, it was concluded that within settlement outlines, with respect to both the correct and incorrect classification that occurred, Inland Bare Ground represented a land cover type that could be grouped together with the Subclasses Urban and Suburban. However, areas defined as Inland Bare ground outside Development Limits would not be included since, in the rural context, the class typically represented quarries or areas of exposed rock.

### 3.3.5 Arable horticulture

The LCM2000 Subclass Arable horticulture includes, as the name suggests, land cover types associated with arable farming (except cereals which have their own Subclass) and land given over to horticulture – arable bare ground, potatoes and linseed for example (a full list of LCM2000 variants for this Subclass is given in Table 2.2). An initial comparison of areas classified as Arable horticulture with Development Limits (Subsection 3.3.1) had revealed that 7% of built-up areas in NI had been attributed to

this Subclass by LCM2000 (Table 3.1). Consequently it was important to assess the reliability of the delineation of Arable horticulture land, where it occurred within these settlement outlines. The mapping of land cover assigned to the LCM2000 Subclass Arable horticulture was carried out using the in-house software dg8 for eight sample areas (each of 40 km x 30 km) across Northern Ireland.

Reference to equivalent OS 1:50 000 map sheets indicated that, in nearly all cases, land cover assigned to the Arable horticulture Subclass had been incorrectly classified where occurring within Development Limits. The evaluation suggested that this misclassification was not the result of confusion with a single land cover type but that a range of types were being incorrectly assigned to the class. Most commonly however, OS mapping indicated that the vast majority of these areas should have been mapped as grassland, suburban or urban areas. The delineation of Arable horticulture land cover by LCM2000 within the Development Limit for Antrim provides an example (Figure 3.5). Many of these areas within the settlement outline appear, when compared with OS mapping, to be grassed areas misclassified as Arable horticulture land cover. To a lesser extent, there is also evidence that some suburban and urban areas have been incorrectly assigned to the Arable horticulture subclass.



**Figure 3.5 LCM2000 Subclass Arable horticulture - Antrim**

In conclusion, the evaluation of the mapping of the Subclass Arable horticulture by LCM2000 showed that where these areas occurred within settlement outlines they were usually the result of misclassification. Some of these misclassified areas within Development Limits were found to be suburban or urban developments. In five of the

eight (63%) sample areas the degree of misclassification of these two land cover types as Arable horticulture was small. In the remaining sample areas it was judged that, if possible, there would be some benefit in attempting to reclassify Arable horticulture land cover where it had been incorrectly delineated within settlements.

## **4. REFINEMENT OF LAND COVER MAP 2000 DATA**

### **4.1 Objectives**

A principal aim of the Land Cover Map 2000 project was to provide a census of land cover in the UK at the turn of the millennium and in particular the mapping of Broad Habitats. Although LCM2000 included the Broad Habitat 'Built-up areas, gardens', and the Subclasses 'Suburban/rural developed' and 'Continuous urban', the work was not focused on mapping the urban environment.

The FEH catchment descriptor that defines urban extent (URBEXT) plays a key role in the Handbook procedures. It is important, therefore, that the land cover data used to derive index values are the best that can be made available within the constraints of budget and schedule. The evaluation described in Chapter 3 has necessarily concentrated on those LCM2000 classes seen to define built-up areas. It is also evident that any refinement procedures developed to improve the mapping of the urban environment have the advantage that they do not need to consider the wider effect these procedures might have on other 'non-urban' classes. Hence, it is possible to consider refinement methodologies that could not be used by the LCM2000 team tasked with mapping 20 Broad Habitats and 26 land cover Subclasses.

The evaluation of the mapping of built-up areas by LCM2000 identified a number of findings (summarised in Section 3.3) that need to be addressed to make best use of the data. The review found that the mapping of Subclasses Suburban and Urban within Development Limits was largely correct but in rural areas (outside these settlement outlines) there was evidence of misclassification resulting in the exaggeration of the extent of Suburban and Urban areas. It also found that land cover assigned to the Subclass Inland Bare Ground within Development Limits was similar to that classified as Suburban or Urban, but outside built-up areas, represented quarries or exposed rock. Finally, it noted that within settlements some Suburban and Urban areas had been misclassified as the Subclass Arable Horticulture.

Procedures were developed, where possible, to address these issues and refine the data provided by the LCM2000 classes described above. The objective of those methodologies was to produce an overall improvement in the land cover data likely to be used in the derivation of new values of urban extent. The refinement procedures were tailored to the relevant land cover Subclasses and are reported below.

### **4.2 Procedures**

#### **4.2.1 Suburban**

The evaluation of the mapping of Suburban areas by LCM2000 indicated that within Development Limits the classification was largely accurate. Beyond the settlement outlines it was found that quarries and pits were frequently misclassified as Suburban areas.



The refinement procedure saw the use of the gridded extended Development Limits as a mask to test each 50 m square classified by LCM2000 as Suburban land cover. If the grid square fell within the extended polygon it was accepted, but if it lay outside the mask it was rejected. Figure 3.3 provides examples of rejected Suburban data (shown in light green) around Ballynahinch.

#### **4.2.2 Urban**

In common with the evaluation of Suburban areas, the review of the delineation of Urban areas by LCM2000 revealed that Urban areas were generally mapped accurately within those extended outlines. However, outside these areas, Urban land cover was found to be frequently the result of misclassification of mountain ridges, pits and quarries.

Again the refinement procedure saw the use of extended Development Limits as a mask where Urban data within were accepted, and outside were rejected. Figure 3.3 gives an example of rejected Urban data (shown in dark green) to the north of Ballynahinch.

#### **4.2.3 Inland Bare Ground**

The evaluation of the mapping of Inland Bare Ground by LCM2000 concluded that, in rural areas, the land cover assigned to this class was, in general, consistent with the description of the Subclass (i.e. exposed rock surfaces, such as those found in quarries). However, the evaluation also revealed that, within Development Limits, there was evidence that suburban and urban land cover had been misclassified as Inland Bare Ground.

In the case of Inland Bare Ground, Development Limits were used to delineate between those areas assigned to the class in an urban environment from those mapped in a rural context. Rather than representing a refinement of the data as such, for example by rejecting misclassified areas, the outlines were used to determine which of those areas mapped as Inland Bare Ground should be included as part of a composite index describing urban extent. Consequently, those areas within extended Development Limits would be included, and those outside would not.

#### **4.2.4 Arable horticulture**

Appraisal of the land cover classes found within Development Limits revealed that, across Northern Ireland, the LCM2000 Subclass Arable horticulture made up 7% of such areas. Further investigation indicated that typically these areas of Arable horticulture land cover were the results of the misclassification of grassed areas, but that in some cases, were misclassified suburban or urban developments. The evaluation concluded that there would be some benefit in attempting to correct these misclassified developments if a satisfactory scheme could be found.

Any reclassification scheme developed for this purpose needs to be applied automatically if changes are to be made in a consistent and cost effective way. Bayliss and Davies (2003) reported that, in Great Britain, the mapping of Arable horticulture land cover within settlement outlines was largely spurious, and in some areas, would

result in the significant underestimation of the extent of built-up areas if not addressed. Consequently for GB, a methodology was established to identify Suburban areas misclassified as Arable horticulture land cover by LCM2000. The first stage of the procedure involved the use of settlement outlines to identify where LCM2000 had shown Arable horticulture land cover to be within built-up areas. In a second stage, it made use of data from the Land Cover Map of Great Britain (LCMGB) for 1990. If the Arable horticulture land cover parcel identified in stage one, was shown to be predominantly urbanised in 1990, it was reclassified as Suburban. This 'validation' by using data from the LCMGB was an important part of the procedures.

In Northern Ireland, Development Limits could be used to replicate the role of settlement outlines employed in the first stage of the reclassification scheme used in GB. However, not all land cover parcels defined within Development Limits to be Arable horticulture were misclassified suburban or urban developments – many were found to be grassed areas for example. Confidence in any reclassification requires verification that the change is appropriate. The LCMGB does not extend to Northern Ireland so cannot be used to fulfil this task and the low resolution of the CORINE data, used to provide an indication of urban extent for NI in the FEH, means they are not of sufficient quality. As a result there were no datasets 'to hand' that could be used to perform this task.

It was evident that within the schedule and funds available to the study that a reclassification scheme could not be identified for Northern Ireland. However, the extent of misclassification of suburban and urban development as Arable horticulture land cover by LCM2000 was judged, during the evaluation, to be far less significant than in Great Britain. Misclassification of this type was spatially clustered in GB, which without address, would result in significant underestimation in these areas when defining urban extent. This appeared not to be the case in NI, where misclassification occurred more evenly across the country and the potential impact on catchment values minor. Consequently, the absence of such a scheme would not have a significant effect on the quality of the final dataset.

### **4.3 Results**

Following the application of the procedures described above it was necessary to determine whether this has resulted in an overall improvement of the land cover data likely to be used to compute catchment values of urban extent. Sample areas were therefore appraised across NI using OS 1:50 000 mapping.

In the refinement of data classified by LCM2000 as Suburban and Urban land cover, extended Development Limits were used as a mask to reject areas mapped outside these limits. The appraisal concluded that the majority of Suburban and Urban data rejected had been incorrectly classified or, in the case of Suburban land cover, represented small hamlets that would have little effect on the flood regime. It also concluded that without the application of the refinement procedure, catchment values of urban extent would tend to be overestimated, particularly so in the case of Urban land cover.

The review also included assessing the effect of using extended Development Limits to discriminate between those areas of Inland Bare Ground that could be considered to be within the urban environment and those areas mapped in a rural context. Overall the procedure was considered to be successful. It appeared that those areas defined in this way to be urban Inland Bare Ground related to land cover that could be included when mapping urban extent (e.g. school buildings, factories and offices), and those areas defined to be rural Inland Bare ground to typically be quarries, naturally exposed rock faces and Lough shorelines, and therefore correctly excluded.

## **5. CONCLUSIONS AND RECOMMENDATIONS**

### **5.1 Conclusions**

It was important that a thorough evaluation of appropriate Subclasses from Land Cover Map 2000 be conducted before being considered for use in updating values of the Flood Estimation Handbook catchment descriptor that defines urban extent (i.e. URBEXT). The appraisal was primarily carried out using settlement polygons, based on those provided by the DARD Planning Service Development Limits, with reference to topographic mapping.

Evaluation of land cover assigned to the LCM2000 Subclasses 'Suburban/rural developed' and 'Continuous urban' indicated that within Development Limits the delineation of such areas was largely accurate. However, outside these settlements, areas shown by LCM2000 to be Suburban or Urban were often the result of misclassification. There was a requirement therefore, to reject those spurious data if the extent of catchment urbanisation was not to be exaggerated.

Appraisal of the mapping of Inland Bare Ground by LCM2000 revealed that in an urban context the Subclass represented land cover that could be grouped together with that depicted by the Subclasses Suburban and Urban. Outside settlements the land cover shown as Inland Bare Ground was commonly found to be quarries, or areas of naturally exposed rock, and not consistent with land cover associated with built-up areas. It was evident that, if land cover assigned to Inland Bare Ground was to be used to define urban extent, it would be necessary to exclude the class when mapped in a rural context.

Across Northern Ireland, on average 7% of the area within settlement outlines was shown to be mapped as the Subclass Arable horticulture. The evaluation revealed that this was frequently the result of misclassification of grassed areas, but in some instances, was the result of the misclassification of suburban and urban development. It was not possible identify an automatic reclassification scheme but this was not seen as a significant problem since the extent of this type of misclassification was relatively minor.

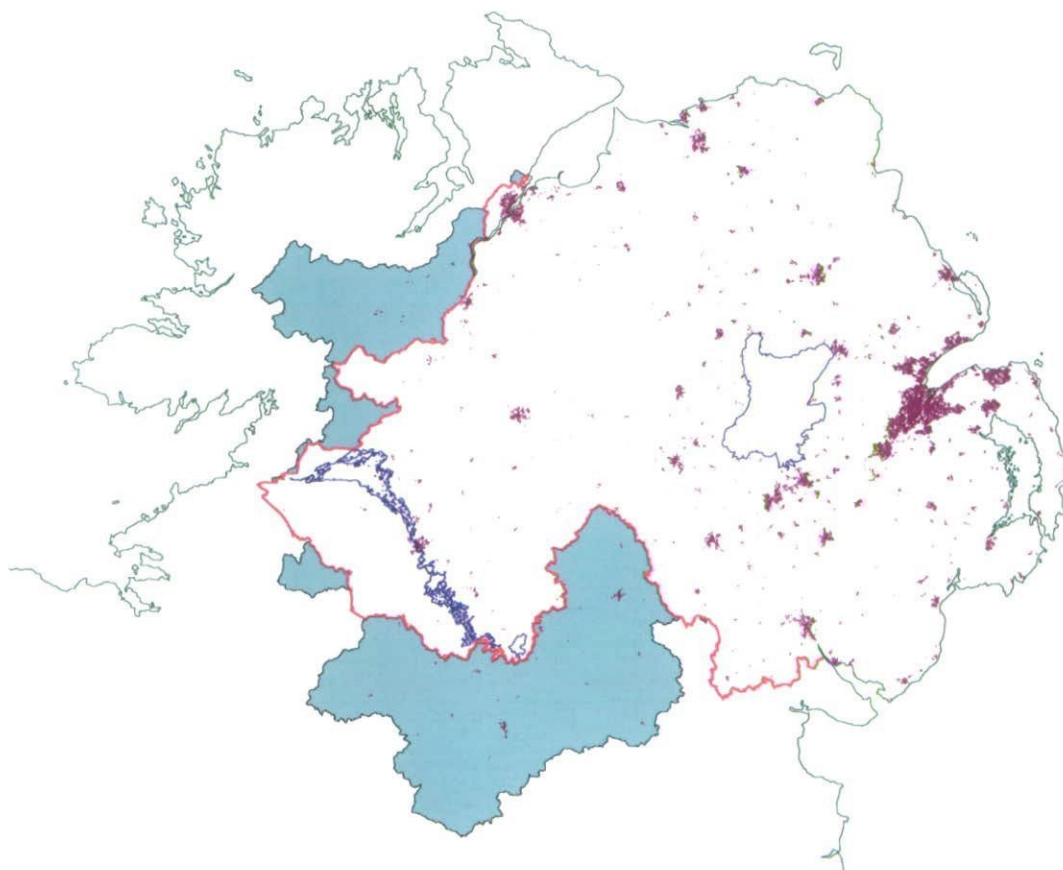
Table 5.1 illustrates the relative importance of the component classes when mapping built-up areas using the refined land cover data. Suburban areas dominate with 80% of the total built-up area across NI, defined using these data, assigned to this class. Town centres, industrial estates, and developments that include large buildings such as hospitals, are typically assigned to the Urban class and this makes up 13% of the refined data. Inland Bare Ground represents 7% of the refined land cover dataset and without its inclusion the extent of built-up areas mapped using these data, would be underestimated.



**Table 5.1      Component classes of refined land cover data – Northern Ireland**

Refined land cover class	Percentage of built-up areas defined using refined land cover data
Suburban	80
Urban	13
Inland Bare Ground	7

The mapping of built-up areas across Northern Ireland using the refined LCM2000 data provided an important check on the integrity of the data. Figure 5.1 showed that there appeared to be no spatial discontinuities in the data, reassuringly the overall settlement pattern was consistent with what one would expect, and the major conurbations are evident. In addition, the effect of refinement procedures was assessed at a more detailed scale for sample areas and they were judged to be successful (Section 4.3). In conclusion, the refinement procedures summarised above were considered to have produced an overall improvement in the mapping of built-up areas by LCM2000.

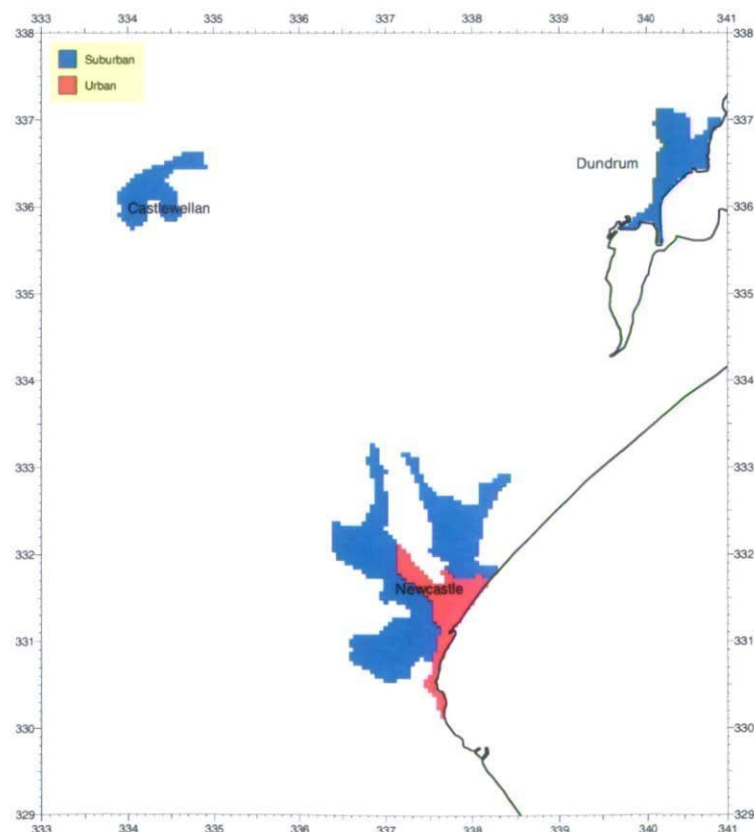


**Figure 5.1      Built-up areas mapped using refined LCM2000 data (light blue shading indicates those areas of the Republic of Ireland that drain into Northern Ireland)**

Catchment values of URBEXT<sub>1990</sub> were defined for Northern Ireland and made available to users through use of the FEH CD-ROM. These were computed using a two-stage process. Firstly, urban extent was defined using land cover mapping produced under the European Community CORINE programme. Secondly, an adjustment factor was applied so that the index values were broadly consistent with those derived for catchments in Great Britain, which were based on the land cover map of 1990. Since, the URBEXT<sub>1990</sub> values for Northern Ireland were derived in such a way, they are only seen as indicative.

The use of mapping based on data taken from LCM2000 would provide both an update to descriptor values calculated for NI and an opportunity to ensure consistency with those derived for catchments in GB. However, this is of little benefit if the delineation of built-up areas is less accurate overall. Comparisons of the CORINE mapping used to define URBEXT<sub>1990</sub> values with the refined LCM2000 data are therefore worthwhile.

Figures 5.2 and 5.3 provide contrasting examples for the area around Newcastle in County Down on the east coast. The former illustrates the mapping of Suburban and Urban areas based on equivalent classes from the CORINE land cover mapping that were used to define indicative values of URBEXT<sub>1990</sub> for Northern Ireland. Although the vector land cover polygons were converted to a 50 m raster dataset (the same resolution as the refined LCM2000 data) the generalised nature of the CORINE land cover polygons is still evident. The CORINE programme was focused on providing European-wide land cover mapping and, understandably, the resolution was relatively

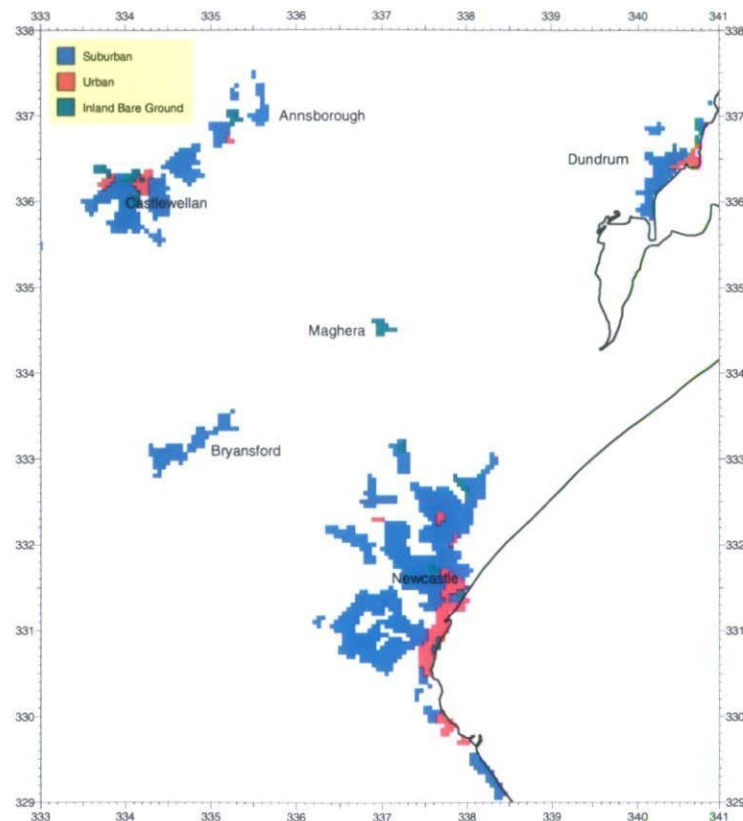


**Figure 5.2 Suburban and urban areas – based on equivalent classes from CORINE land cover mapping**



coarse (the minimum mappable unit was 0.25 km<sup>2</sup>). In the review of CORINE data for use in deriving URBEXT<sub>1990</sub>, Bayliss and Scarrott (1999) found that non-urban areas (parks, for example) were not preserved within the polygons depicting the larger conurbations and that many small settlements were not shown.

Figure 5.3 provides an example of the benefits of using the refined LCM2000 data in comparison to the use of CORINE data. The depiction of settlements is more detailed when based on LCM2000, and reference to OS 1:50 000 mapping, suggests more accurate. For example, Castlewellan (to the northwest of Newcastle) is poorly depicted by mapping based on the CORINE data (the southern half of the settlement is not shown) in contrast to the delineation of the town by the refined LCM2000 data, which is in greater accord with OS mapping.



**Figure 5.3 Suburban and urban areas – refined LCM2000 data**

In addition, the use of data taken from LCM2000 provides mapping of built-up areas that is more up-to-date than that based on CORINE data produced for NI using imagery taken between 1989 and 1990. Comparison of OS 1:50 000 mapping dated 1992 and, more recent mapping dated 2001 (the 'B Edition'), shows a new development in the south easterly part of Newcastle that is not evident on the earlier map and consequently is not shown as built-up by the CORINE mapping. This development is, however, shown as a Suburban area when using the refined LCM2000 data.

Comparison of Figures 5.2 and 5.3, confirms the many smaller settlements are not defined by the use of CORINE data and that the more detailed resolution provided by the refined LCM2000 is more likely identify these villages and hamlets and

consequently provide a more accurate definition of catchment urbanisation. Use of the refined LCM2000 data for the area around Newcastle (Figure 5.3) means that small settlements, such as Annsborough, Maghera and Bryansford, are shown as combinations of the land cover classes Suburban, Urban and Inland Bare Ground.

Further comparisons across NI confirmed that the use of refined LCM2000 data offered a number of advantages in defining catchment urban extent when compared to the CORINE land cover mapping used in the derivation of URBEXT<sub>1990</sub>, namely:

- The raw data are of greater resolution, resulting in a more detailed depiction of built-up areas and the mapping of many smaller settlements not defined by CORINE mapping.
- The data are consistent with those that will be used to derive new values of urban extent for catchments in Great Britain.
- The land cover mapping is based on imagery taken principally between 1998 and 2000 and is therefore more up-to-date.
- The improved delineation of built-up areas is likely to lead to automatically derived catchment values of urban extent that are of far greater accuracy than those derived from data based on CORINE mapping, which are only seen as indicative.

## **5.2 Recommendations**

The recommendations of the authors are that:

- Refined LCM2000 data described in this report are used to produce an update to the FEH catchment descriptor URBEXT to be known as URBEXT<sub>2000</sub>.

and in a second stage (subject to funding) that:

- URBEXT<sub>2000</sub> be a composite index based on catchment values of the refined land cover classes Suburban, Urban and Inland Bare Ground.
- Analyses are carried out to determine the most appropriate weightings of the individual components of the composite index URBEXT<sub>2000</sub>.
- Procedures used in the software that computes catchment values of URBEXT<sub>2000</sub> for NI are consistent with those that were used in GB to produce values of URBEXT<sub>1990</sub> and will be used to derive URBEXT<sub>2000</sub> values. [In NI, a two-stage procedure was used to produce approximations of URBEXT<sub>1990</sub>.]
- In addition to calculating URBEXT<sub>2000</sub> for all catchments defined on the FEH CD-ROM, values for the catchment descriptors URBLOC (describing the location of built-up areas within the catchment) and URBCONC (defining the concentration of catchment urbanisation) are also computed based on the refined

land cover classes taken from LCM2000. [In GB, URBLOC<sub>1990</sub> is a composite index with the influence of the location of suburban areas down weighted in its computation. In NI, the poor resolution of the CORINE data did not justify delineating between urban and suburban land cover in the calculation of URBLOC<sub>1990</sub>, consequently urban and suburban areas were given equal weight. URBCONC<sub>1990</sub> was not calculated for catchments in NI due to the generalised nature of the CORINE mapping. Use of refined LCM2000 data will allow URBLOC<sub>2000</sub> and URBCONC<sub>2000</sub> to be calculated in a consistent way throughout the UK.] They will be known as URBLOC<sub>2000</sub> and URBCONC<sub>2000</sub> respectively.

- Since the use of a parcel-based approach in LCM2000 is likely to give different values of catchment urban extent to that derived from the pixel-based LCMGB data, the FEH models that include URBEXT as an input parameter should be revisited. [The models were based on GB data but would now include NI catchments].
- Catchment values of URBEXT<sub>2000</sub> are disseminated to FEH users through the production and release of Version 2.0 of the FEH CD-ROM. Values for URBLOC<sub>2000</sub> and URBCONC<sub>2000</sub> will also be provided.
- Corrections to the Digital Terrain Model used to define catchment boundaries, based on feedback from FEH users, are embraced where possible when deriving values of URBEXT<sub>2000</sub> and that other descriptor values presented on the FEH CD-ROM are recalculated across NI using the improved catchment definition.
- Since there is a requirement to recalculate all descriptor values, and this is computationally intensive, the programming code is reviewed in the light of recent advances in processing power and updates to database software.
- New functionality be included as part of upgrade to the FEH CD-ROM.

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