AN EVALUATION OF AERIAL PHOTOGRAPHY AS A SOURCE OF ENVIRONMENTAL INFORMATION

Jean Mary McLellan

Submitted for the degree of M.Phil.

October 1975.

SUMMARY

The research examines the utility of aerial photographs in the mapping of urban land use, at scales of 1:2,500, 1:5,000, and 1:10,000, and production of a regional scale (1:100,000) map. Previous work on land use survey in Britain and America is described, and is followed by an outline of air surveys of land use.

The development of notations for use in this research is then explained, and is followed by descriptions of the features used when interpreting a photograph, and the appearance of major types of land use. The study area is located, and the methods used in the production of the maps outlined. The problems of accuracy - its definition, the factors affecting it and its assessment - are then considered, and the production of maps showing the location and types of discrepancy described.

Finally, some comments are made about the approach used in this research. It is suggested that a more useful way to tackle land use mapping would be to combine photo interpretation and field checking, as the division of these had given rise to many difficulties when mapping errors of discrepancies. It is emphasized that the information to be gained from air photos must be related to the problems under study, and that only in this situation will they prove to be a significantly useful source of information.

CONTENTS

BIBLIOGRAPHY

Appendix I

Yorkshire and Humberside Standing Conference of Local Planning Authorities.

Draft Project Report. Fourth Revision, 16th September, 1971.

Appendix II

Local Plan Notation (prepared by Leeds City Planning Department).

Appendix III

Regional Notation (prepared by West Riding County Planning Department).

Appendix IV

The Project Notation.

ILLUSTRATIONS

ACKNOWLEDGEMENTS.

The author would like to acknowledge the assistance of Dr W G Collins and of the staff of the Leeds City and the West Riding County Planning Departments.

CHAPTER 1

THE CONTEXT OF THE RESEARCH

This study of the utility of aerial photographs in the mapping of land use arises from the decision by the Yorkshire and Humberside Standing Conference of Local Planning Authorities to investigate air photos as a source of land use information (Appendix I). Land use data have been regarded as an essential prerequisite for the planning process for some years. In 1951 in an Information Report, the American Society of Planning Officials (1951) wrote:-

> "Not until the land-use pattern as it exists at present has been carefully recorded in map form, can the essential processes of evolving a comprehensive land-use plan for the community and developing a zoning ordinance which is clearly related to the comprehensive plan for land use be carried on."

The term "land use" has not been defined by many authors since they thought its meaning to be obvious from the content of their papers. Moreover its definition can cause many difficulties because of the use of the term in so many fields of study.

> ". . . an agronomist would regard a piece of land occupied by a warehouse and an office as falling into a class which included virtually all other buildings and which might be described as 'built-up area' or 'developed land'. An economist would associate the land and buildings with other land and buildings, possibly of a very different character, which happened to serve the same industry. . . A planner might classify them separately as 'warehouse' and 'office' and group each with similar buildings serving different industries." (Kaye 1970)

Thus the problem is whether it is possible to construct a definition of land use which will have some common ground with the various meanings of the term. Stamp (1966) defines land use as:-

"Literally the use which is made by man of the surface of the land, but in sparsely populated areas including the natural or semi-natural vegetation."

This definition has been criticised because it permits the inclusion of vegetation terminology, but it is simple and easy to use. The term "land use" implies that some conscious decision about the purpose of a plot of land has been made. It is usually considered to be made up of two individual concepts: firstly the status of the land - whether it is built or unbuilt, and secondly the activity - for example, manufacturing industry or dairy farming. But while this definition may be logical, its utility is very limited. Held, Stoddard and Clawson (1960) emphasize this point about a conscious decision to manage or to develop an area:-

"Ideally, use of land should be studied according to the nature and degree of consciousness of the decisions underlying its management. On this basis an unused forest, or one which grew up without decisions by anyone, would not be forestry, or at least would not be conscious forestry."

In the face of these difficulties, and the lack of any definition of "land use" by the Standing Conference of Local Planning Authorities, it was decided to adopt an informal, working definition that land use resulted from man's activity, which might or might not be reflected in the land cover.

For planning purposes information about the types of land use and their distribution may be acquired from various sources:-

i. Ground survey
ii. Air survey
iii. Previous surveys carried out by the planning department
iv. Official records such as valuation and rating records
v. Development permissions
vi. Development plans

White (1970) in a report on the patterns of information used in planning gives fourteen sources of "operational information", ranking them in order of importance. Although White notes that the results are not conclusive, they do indicate that aerial photographs, although a possible source of primary information are not widely used (they rank twelfth out of the fourteen items). White suggests two reasons for this:-

1. The capital cost of air cover.
2. The lack of personnel with the necessary training in air photo interpretation techniques.

The major uses of air photos by those who claimed to have considerable experience in their use, were the revision and updating of Ordnance Survey Plans, land use surveys and landscape evaluation exercises. White discovered, however, that many planners saw further scope for air survey in the first two major uses mentioned above. This, with the lack of published material in this country, suggests that many planners are unaware of the scope of air photos as an information source and store. This research attempts to assess how far air photos are of use in mapping land use information.

The Yorkshire and Humberside Standing Conference of Local Planning Authorities produced a document, which is reproduced in full in Appendix I, setting out the objectives of the study. These may be seen as five inter-related items:-

1. Isolating those items of land use which may be identified from air photos.
2. Developing methodologies for land use mapping at local and at regional scales.
3. Developing a notation for land use mapping at local and regional scales.
4. Evaluating which scales of photography (from 1:3,000, 1:5,000 and 1:10,000 scales) is most valuable in local and regional land use mapping.
5. Evaluating changes in land use at a regional scale between 1966/67 and 1971.

This document also suggested the approach to be used in the research, although expressed in general terms, proved to be quite restrictive, and introduced several problems and sources of error. The document stresses that the only source of land use information is to be the aerial photographs, thus no reference could be made to Ordnance Survey maps. Field surveys were to be carried out by planning officers and not by the research worker. Further difficulties arose because of the lack of a classification or notation system for the local scale mapping. The requirement was for the mapping of the "smallest identifiable land use unit", but the notation developed for mapping this was not comparable to that used in the field surveys. This is discussed in greater detail in Chapter 4. Moreover it was in some cases impossible to map the "smallest identifiable land use unit" in the interests of clarity, so that some potentially useful information has not been recorded in the map form.

This study begins with a brief survey of previous work in the recording and mapping of land use and continues with the methodology used here. The final part contains some comments about the accuracy of land use mapping from aerial photographs, and suggested methodologies for local and regional mapping of land use. The study area is shown in Map 1, and is described fully in Chapter 3.

References:

AMERICAN SOCIETY OF PLANNING OFFICIALS (1951)
Urban Mapping, Aerial Photography and Duplicating: Some Basic Elements
Advisory Service Report No. 29

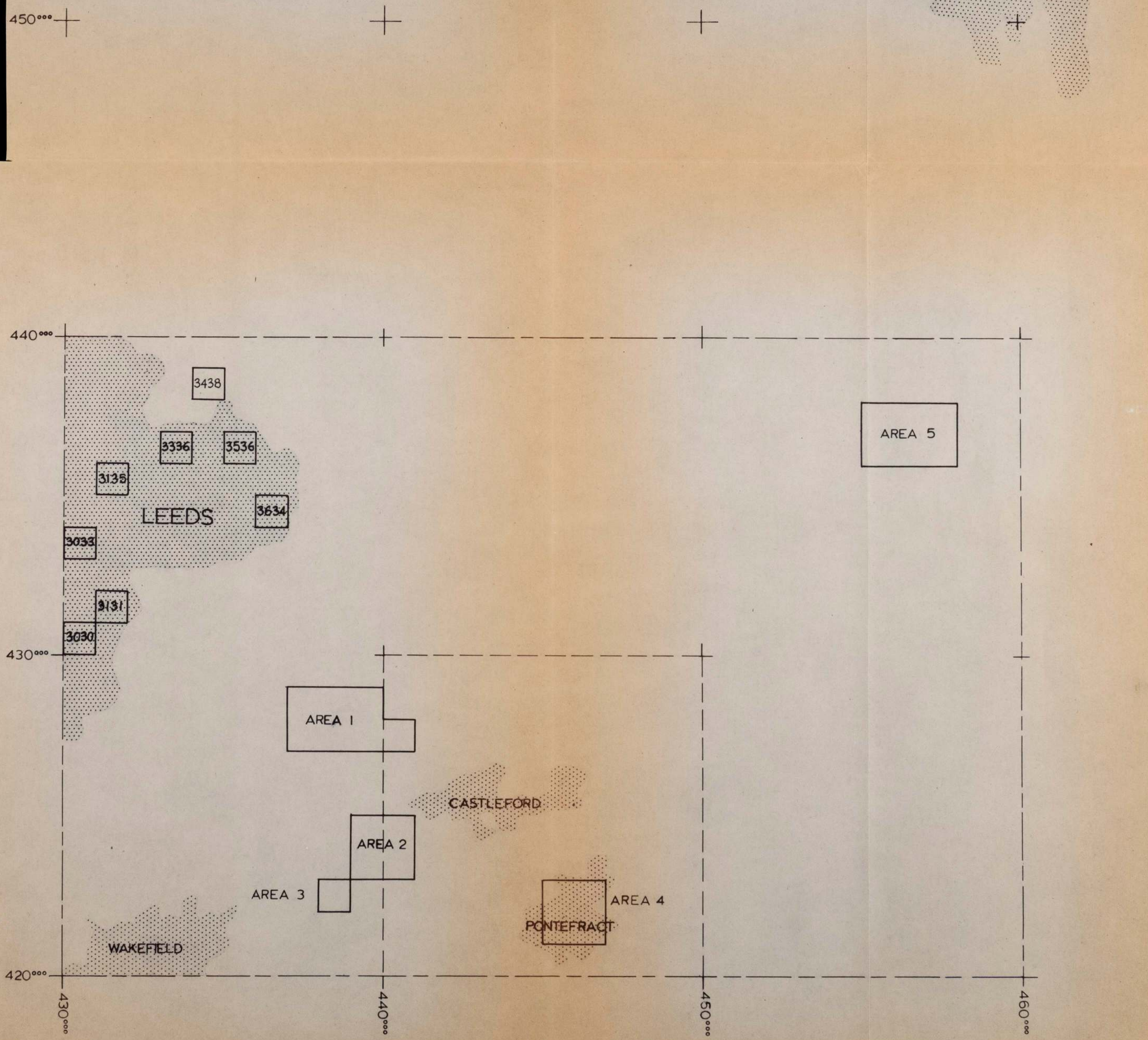
HELD, B., STODDARD, C. H. and CLAWSON, M. (1960)
Land for the Future
John Hopkins Press

KAYE, G. M. (1970)
G.L.C. Department of Planning and Transportation Intelligence Unit.
Research Memorandum 251
National Land Use Classification - An Approach

STAMP, L. D.(ED.) (1966)
A Glossary of Geographical Terms
2nd Edition, Longmans, London

WHITE, B.(1970)
Planners and Information
A Report of an Investigation into Information Provision in Town and County Planning, The Library Association, London

Map. 1. THE STUDY AREA
SCALE 1: 100.000



CHAPTER 2

LAND USE SURVEY AND THE COLLECTION OF URBAN LAND USE INFORMATION

The Domesday Survey was the first agricultural census in a Western European country since the fall of the Roman Empire. It provides a very valuable source of information about land use for those areas for which it survives, but it was not until 1866 that the collection of agricultural information on an annual basis was introduced, and these data form the foundation for much statistical information about land use, although they were designed for the purpose of estimating agricultural yields. These agricultural statistics also formed the basis for the urban land use statistics, that is the total amount of urban land and any changes in its extent.

Estimates for the total urban area were usually arrived at by a residual method, that is by subtracting the total agricultural acreage from the land area of the country. The figures obtained by this method were open to wide margins of error. Best (1958(a)) attempted to overcome these inaccuracies by a reassessment of the statistics, and by the use of the information contained in the "changes of occupancy" section of the agricultural returns. Here a farmer is required to record acreages taken into or removed from his holding. If a considerable acreage is involved an investigation is made into the previous, or present uses of land. However Best suggests that a more useful source of urban land use information might be the Development Plans prepared under the 1947 Town and Country Planning Act, and this idea is discussed below.

The first systematic land use survey in Britain was carried out in the 1930's under the direction of Sir Dudley Stamp. This was a time of rapid change in land use; agriculture was in recession, and land cheap. There was a great deal of building, the cities' slums began to be demolished, and the urban area expanded rapidly. Best (1970) suggests

that at this time urban expansion was taking more than 60,000 acres per year from agriculture, a larger amount than that at present being taken into the urban area. Stamp (1948) describes the method and the outcome of the survey which was essentially broadly based. The seven major categories were rurally orientated and did not permit the recording of any information about the types of urban land use and their distribution. However a measurement of the total amount of urban land (the category was entitled "land agriculturally unproductive") was made, and its distribution mapped. This was an extremely useful contribution at a time when the only source of information was the agricultural statistics, although the figures of 2,748,000 acres of urban land differed widely from the estimate by the Ministry of Agriculture and Fisheries in 1937 and quoted in the Scott Report*.

A second land use survey was begun under the direction of Miss A Coleman in 1960. This survey was undertaken to look at the developments in land use since the 1930's, and although there was a conscious aim to provide some means of comparing the first and second Land Use Surveys, two major alterations were made. The first was in the scale of mapping. Although the fieldwork was to be carried using 1:10,560 scale maps as before, the information was to be presented in the form of 1:25,000 scale maps, instead of the 1:63,360 scale maps of the first Land Use Survey. The sceond alteration was the increasing of the number of categories in the land use classification used in mapping. This resulted directly from the increase in scale, since more categories could be shown at 1:25,000 scale than at 1:63,360 scale with no loss of clarity. The first level of the classification was therefore expanded to thirteen groups instead of the seven in the first Land Use Survey. This extension was important, since, while the simple spatial relationships of land use had been revealed by the first Land Use Survey, land use information was now required in much

* Ministry of Works and Planning 1942

finer detail "to permit the tracing of more accurate and sensitive correlations" (Coleman and Maggs 1961). Several types of urban land could now be mapped:

Settlement - residential and commercial
Industry - manufacturing, extractive, tips and public utilities
Transport
Derelict Land
Open space

These five categories are equivalent to Stamp's category of "land agriculturally unproductive". Miss Coleman makes the point that some observations on the distribution of urban land uses can be made from the 1:25,000 scale maps:

> "The map of Sunderland emphasizes the riverside location of industry and a vast spread of post-war housing which, in fact, exceeds that of Newcastle-upon-Tyne. Great Yarmouth too, on a lesser scale shows an esturine concentration of factories, while Birmingham's central industrial sector is so prolific with tiny jewellers that there is insufficient space on the map to show each separately." (Coleman 1961)

Despite this, the survey was still essentially rurally orientated, and the discussion in Miss Coleman's paper is directed principally towards changes in the patterns of agriculture between the 1930's and the 1960's.

The first work directed at the urban area - its extent and diversity - was carried out by Best (1957; 1958(b)) who based his studies on the Development Plans compiled by local planning authorities. These Plans were prepared because of the requirements laid down in the Town and Country Planning Act of 1947. Local planning authorities were required to give a comprehensive statement of existing acreages under the various land uses in County Boroughs, Large Burghs and other areas for which Town Maps were produced. The Development Plans were compiled at varying speeds, so that any figures of the acreages under the various uses

are not strictly referable to any one year. Moreover, some of the larger settlements were either not covered by a Town Map so that details of urban land uses were not required by law, or else the Development Plans had not been submitted, so that information on even the larger urban areas was incomplete, for the period when Best carried out his study. Neither do these Plans provide any information about the extent and types of land use in the smaller settlements and rural districts.

Best's approach was to calculate a density figure in terms of urban acres per 1,000 population. This method of calculating the urban area meant that each person was being allocated an area of land, but since densities of development vary widely between large and small settlements, Best thought it desirable to divide urban land into several categories according to status. This classification was limited to those categories for which both acreage and population statistics could be obtained. The lack of any statistical information about the smaller settlements and isolated dwellings, required that a special survey should be carried out, and this was made in nine counties - five from the Highland Zone (the area north of a line from the Severn to the Wash) and four from the Lowland Zone, to ensure an adequate distribution of settlements. By applying the density allocations to the rest of Britain a figure for the total urban acreage of 4,071, 000 acres was obtained for 1950. This agrees with the first Land Use Survey figure of 2,748,000 acres when allowance is made for the growth of the urban area, rather than the estimate of 4,162,000 acres by the Ministry of Agriculture and Fisheries in 1937.

Best also used this method to estimate the acreages under four main urban land uses:

housing

industry

open space

education

He found that these four categories do in fact occupy the major part of all urban land, and, in total, account for nearly three quarters of the urban area. Housing in all sizes of urban settlement, exceeds forty per cent of the total area, and in settlements of 10,000 population or less it occupies a much greater proportion. At the extreme, isolated dwellings represent almost one hundred per cent utilisation of land, by housing and associated buildings. Open space occupies a considerable percentage of urban land - about twenty per cent, but industry (predominantly manufacturing) usually occupies no more than six per cent of a town's area. Of the residual land uses, some may take up large acreages in themselves, for example railways occupy 5.8 per cent of the total urban area.

Clawson (1966) outlines in much broader terms what she regards as an ideal land information system. This is of much wider application than land use, but the criteria which she lists for consideration are important when studying land use only. Clawson's paper continues with a comparison of two American land use studies: the first organised by the Urban Renewal Administration and Bureau of Public Roads (URA-BPR), and the second by the independent organisation Resources for the Future (RFF). The URA-BPR study was based upon the identification of small, accurately located parcels of land, while the RFF work was more widely based and considered at some length concepts other than land use. Clawson recommends that a permanent official committee on land use statistics should be set up to co-ordinate research and to establish consistent and rigorous criteria for the recording of information about the land in America. In the British context the establishment of rigorous "rules" by which information about land is recorded would remove many of the inconsistencies apparent in the recording and classification of information.

Aerial Photography and Land Use Information

In the work outlined above, aerial photographs were not considered as a source of land use information. However in America they have been used quite widely for some years in planning, and also in the mapping of land use. In 1943 Russel, Foster and MacMurry published a paper outlining in general terms some of the uses of aerial photographs and air photo keys, for use in the North-eastern United States when identifying and mapping features such as topography, soils, vegetation, agriculture and urban areas. Of more direct interest are the Information Report produced by the American Society of Planning Officials (1951) and the Agriculture Handbook produced by the United States Department of Agriculture (Davis 1966). Both describe in general terms the uses to which air photos may be put, but the former concentrates on the construction of a base map and the mapping of land use, while the latter defines terminology, outlines briefly the types of film, print and photograph available, and describes how photographs may be interpreted, besides discussing the part air photo interpretation may play in studies such as traffic and parking, recreation and air and water pollution.

Witenstein (1954) reports on a comparison of conventional urban evaluation methods (based on ground survey and accumulated statistical information) and aerial photographs as a source of urban data, to see how far air photos could be useful in the urban planning field. He writes:

> "Not only does it |aerial photography| enable rapid and economical mapping, but it provides a cross-section of the living urban organism in such a manner that its functional parts and structural features may be readily discussed and analysed."

Witenstein goes on to suggest that the social and economic features of urban society may be inferred from the structural features represented on an aerial photograph, and he considers the solving of planning problems in relation to land use in terms of three patterns:

i. of function (industrial, commercial, residential, i.e. type of use).

ii. of structure (i.e. category of commercial buildings or residences)

iii. density of roof cover (dense/moderate/sparsely built up).

These patterns may be identified from air photos, and Witenstein considers that they reflect the needs or capacity of industrial production, of transportation, or the ability of people to obtain various types of housing.

More localised studies have been carried out using air photos by Pownall (1950), Howlett (1963) and Avery (1965). Pownall describes work carried out in Madison, Wisconsin, in 1947 and 1948. The study began with the identification of "urban land use areas" - there were seven major functional areas in Madison: commercial, industrial, residential, transportation, institutions, recreation and vacant or idle land. These were identified with the aid of air photo keys developed by the author. This study, therefore, was not related to the identification of individual land use plots, but to the overall use of an area. The approach would be useful for studying air photo interpretation methods, and it provides information about the appearance (in America) of the major land uses, but the requirements in this country seem to be for individual plot recognition and not, except at small scales, for the "predominant land use" of an area.

Howlett and Avery describe studies using air photos to determine changes in land use. Howlett's work arose out of the Puget Sound Regional Transportation Study since trip generation is related to the distribution of urban land use types, and he found air photos, when used with other sources, to be of help in assessing the changing land use patterns. Avery describes the identification of land use changes in Clarke County, Georgia. He found that the figures obtained (a decrease in cultivated land, and large increases in urban land and pine forest) fitted in with the assumptions made in Clarke County, with its growth

as a major university and trade centre, and the growth of full-time employment for many part-time farmers after the war. This work, although not confined to the urban area, is very relevant to ideas in Great Britain about the extension of urban area and land use changes, for example the extension of the urban area in relation to population growth*, the type of land taken for urban expansion, and the outward movement of the degraded belt of land with the extension of the urban area.

Branch (1971) has published a book discussing and describing the role which aerial photography might play in city planning in America. He begins by describing his concept of "continuous master planning" - planning should include not only past commitments and requirements, but present needs and long-term strategies. Information should be fed into the planning system as it becomes available, and the master plan should be a continuously changing document, not one which emerges every ten (or twenty) years from a general survey of planning requirements and objectives. On to this Branch grafts his ideas about the use of aerial photography in the planning process. He describes the background to aerial photography and how to interpret a photograph, and discusses the use of air photos in relation to city planning. However the whole book revolves around Branch's theory of continuous city planning and unless this is accepted, there is little of direct relevance to indicate how aerial photography might be of help in planning in this country.

Few studies have been published in Britain referring to the use of air photos in planning and land use, and White's (1970) study of the sources of information in planning (described above - page 2) suggests that their use was not widespread. Joseph (1957) and Burry (1967) have published papers about the general applications of air survey methods in planning. Joseph sees the major advantage of the use of

*See Best and Champion (1970)

aerial photography as one of speed, and suggests that, using air photos a topographical map of a town or city may be available within three weeks of the flight, while ground survey methods might take six months to produce the same result. He also points out that air photos record the appearance of the ground in the time it takes to fly over an area, while a full scale land use survey using conventional methods may take months to complete. Joseph suggests that air photos have a part to play in publicity, since a photograph (particularly an oblique one) is more easily understood than a plan, and can help to focus attention on an object or highlight a problem area. However he does draw attention to some of the general problems of aerial photography: the difficulty of obtaining satisfactory photography because of weather conditions and the controls on flying height, and the problems produced by excessive amounts of shadow.

Burry's paper is more wide-ranging than Joseph's. He describes the principal methods of using air photos, how to obtain them and their use in planning practice. He gives three examples where aerial photographs can provide information which is not easily available from other sources:

i. Their use in the measurement of the extent of flood waters in the Severn valley in 1950.

ii. The intensity of use of a caravan site or car park at peak holiday periods.

iii. The use of aerial triangulation methods to provide a topographic map when conditions limit or prohibit ground survey techniques.

He goes on to discuss the limitations of air photos, the factors affecting their cost, and how the flight programme should be planned. His paper ends with a brief outline of the sort of studies which might use air photos as a data source. This is a useful paper since it gives a broad picture of air photos - their applications and how to obtain them, and would be of value to beginners in this field of photo interpretation.

Thomas's (1964)* work is more direct relevance to land use mapping. He describes his study of the Green Belt around London, and his use of aerial photography as a source of information about land use, identifying and mapping eleven major categories. This work is particularly useful, since it shows air survey methods being used in the examination of a problem and not in the rather theoretical light of Joseph's paper which was discussed above.

Childs' (1966; 1967) work, like Branch's in America, focuses on a new planning process. He describes a new methodology for decision-making in planning, and suggests the role which aerial photography could play. The new methodology resulted from the need to integrate the existing methods, and practices pursued separately when reviewing Development Plans. He suggests that regular air surveys flown at a variety of scales would be of considerable help in organising and recording information. Childs also recommends the use of orthophotos† in conjunction with Ordnance Survey plans, which he feels could be of help. He points out that the costing of photo interpretation for urban studies has not been widely studied, and suggests that his work in Elstree, Borehamwood and Watford could be of help in finding out whether field survey time and costs can be reduced by the use of aerial photography. Childs advocated the use of air survey methods in planning in the context of his new methodology only and since it would be feasible (and valuable) to incorporate such an information source without completely altering planning methods, it is difficult to take his air survey techniques out of context and apply them to the planning process.

Collins and El-Beik (1970) describe some earlier work in Leeds, investigating air photos as a source of information about land use. This early work used 1:10,000 scale "split vertical"†† aerial photographs.

* See also Thomas (1968) "London's Green Belt" for a full exposition of his work.

† Aerial photographs corrected mechanically to produce a photograph with the properties of a map.

†† Photographs taken using two cameras placed side by side, both camera axes being displaced slightly from vertical.

A very different technique to that used in this study was applied, since by a combination of air photo interpretation and field survey an air photo key and a classification were developed for those items which could be identified from the aerial photography. An attempt was then made to assess the accuracy of the air photo interpretation on the basis of the number of items correctly identified, but this needs very careful scrutiny, and in Chapter 4 the problems arising from any attempt to measure accuracy are discussed. However the study is useful as an initial project on the mapping of land use from air photos.

A study in Glasgow by Lo (1971) outlines the attempts to use automatic recognition techniques in land use surveys. The starting point for the research was the hypothesis that "the two groups of images separated by a line or plane are significantly different", and the author began with the indirect evidence of man's use as indicated by the arthitectural styles in the centre of Glasgow, and shows that the characteristics recorded by a photo interpreter can be grouped automatically into six periods. This, although interesting and useful, does not help with the abstraction of the information from the photographs - still essentially a manual process. Until this has been mechanised, problems will always occur - when a large number of photographs have to be scanned by several people*.

In contrast to the local studies mentioned above is the regional survey in the Crati Valley in Calabria, Italy, outlined by Huson (1970). He gives an account of the criteria he used to distinguish twelve land use categories, and discusses the utility of the air photo approach in terms of the land use map produced. He points out that while a map not contain all relevant information about land use, it may be of great practical value, since the socio-economic units mapped may provide a basis for various planning purposes.

* A study has been carried out under the auspices of the D.o.E. into automatic data extraction techniques for land use. Collins - personal communications.

The literature mentioned above illustrates the many different approaches available when using air photos in planning land use surveys. Although there has been a considerable amount of work in America using air survey methods, the lack of published material in Britain suggests that knowledge of the applications of aerial photography in the planning field is limited.

References:

AMERICAN SOCIETY OF PLANNING OFFICIALS (1951)
Urban Mapping, Aerial Photography and Duplicating: Some Basic Elements
Planning Advisory Service Report No. 29

AVERY, T. E.(1965)
Photogrammetric Engineering 31 pp. 620-624
Measuring Land Use Changes on USDA Photographs

BEST, R. H.(1957)
Town Planning Review 28 pp. 191-208
The Urban Area of Great Britain - An Estimate of the Extent of Urban Land in 1950

BEST, R. H.(1958(a))
Town and Country Planning 26 pp. 426-431
The Loss of Farmland to Other Uses in England and Wales

BEST, R. H.(1958(b))
Journal of the Town Planning Institute 44(7) pp. 160-164
The Composition of the Urban Area in England and Wales

BEST, R. H.(1970)
New Society 15 pp. 556-558
Laying the Land Use Myths

BEST, R. H., and CHAMPION, A. G(1970
Transactions of the Institute of British Geographers No. 49 pp. 15-32
Regional Conversions of Agricultural Land to Urban Use in England and Wales 1945-1967

BRANCH, M. C.(1971)
City Planning and Aerial Information
Harvard U.P., Cambridge, Mass.

BURRY, M. G.(1967)
Town Planning Review 38 pp. 135-150
Air Survey Methods: Their Application to Physical Planning

CHILDS, D. R.(1966)
Journal of the Town Planning Institute 52(9) pp. 367-380
Our Changing World: An Introduction to a Combined Exercise in Planning

CHILDS, D. R.(1967)
Journal of the Town Planning Institute 53(9) pp. 416-418
Planning Information for Planners

CLAWSON, M.(1966)
Journal of the American Statistical Association 61 pp. 647-657
Recent Efforts to Improve Land Use Information

COLEMAN, A.(1961)
Geographical Journal 127 pp. 168-186
The Second Land Use Survey: Progress and Prospects

COLEMAN, A. and MAGGS, K. R. A.(1961)
Land Use Survey Handbook
2nd Edition

COLLINS, W. G. and EL-BEIK, A. H. A.(1970)
Photogrammetria 27 pp. 71-92
The Acquisition of Urban Land Use Information from Aerial Photographs of the City of Leeds (G.B.)

DAVIS, J. M.(1966)
Uses of Aerial Photos for Rural and Urban Planning
Department of Agriculture Handbook No 315, Washington D.C.

HOWLETT, B. E.(1963)
Highway Research Record No 19 pp. 1-16
Determining Urban Growth and Changes from Aerial Photograph Comparison

HUSON, J. J.(1970)
International Institute for Aerial Survey and Earth Sciences Series B No. 57
Land Utilisation in the Crati Valley (Calabria, Italy). A Study on the Applicability of Medium Scale Air Photos

JOSEPH, S. G.(1957)
Official Architecture and Planning 20(4) pp. 180-184
Aerial Survey and the Planning Officer

LO, C. P.(1971)
Photogrammetria 27(4) pp. 135-157
A Typological Classification of Buildings in the City Centre of Glasgow from Aerial Photographs

MINISTRY OF WORKS AND PLANNING (1942)
Report of the Committee on Land Utilisation in Rural Areas
Command 6378. H.M.S.O.

POWNALL, L. L.(1950)
Photogrammetric Engineering 16 pp. 414-426
Aerial Photographic Interpretation of Urban Land Use in Madison, Wisconsin

RUSSELL, J. A., FOSTER, F. W. and McMURRY, K. C.(1943)
Michigan Academy of Science, Arts and Letters 21 pp. 315-341
Some Applications of Aerial Photographs to Geographic Inventory

STAMP, L. D.(1948)
The Land of Britain - Its Use and Misuse
Longmans, Green and Co. Ltd., London

THOMAS, D.(1964)
Journal of the Town Planning Institute 50(10) pp. 434-439
The Components of London's Green Belt

THOMAS, D.(1968)
London's Green Belt
Faber

WHITE, B.(1970)
Plannery and Information
A Report of an Investigation into Information Provision in Town and Country Planning

The Library Association, London

WITENSTEIN, M. M.(1954)
Photogrammetric Engineering 20 pp. 419-427
Photo-Sociometrics - The Application of Aerial Photography to Urban Administrative and Planning Problems

CHAPTER 3

THE INTERPRETATION AND MAPPING OF LAND USE FROM AERIAL PHOTOGRAPHY

The Development of the Project Notation

No photo interpretation could be attempted until the problem of the notation to be used had been considered. As mentioned previously one of the objectives of the research was the development of a notation system for land use mapping. It was decided not to embark on the production of a land use classification because of the difficulty of constructing one which was theoretically sound. McDonald (1971) discusses in great detail the construction of such a classification, and stresses the importance of obeying the rules of logic in constructing such a system, since violation of these requirements results in classifications which far from classifying the subject under study, only lead to confusion. Armand (1965) writes:

> "Classifications can be built on various principles: morphologic, genetic, temporal, spatial, quantitative, etc. But all must follow certain general and unalterable laws of logic."

These "laws of logic" are discussed at some length by both McDonald and Armand and will not be listed here. The mapping of land use without a purpose in mind formed another reason for not constructing a classification. Land use mapping is not an end in itself, but is carried out with some purpose or problem in mind. Therefore it would be inappropriate to construct a land use classification without knowing the reasons for collecting the information. It would be better to map the land uses visible on the photographs and to list these without further grouping, since the information would then be available at the lowest possible level, and could be grouped in any desired manner.

The problem of the notation to be used was tackled initially by the listing and numbering of items as they were identified from the aerial photographs. When the mapping of the 1971 land use situation had been completed, this list was reorganised on a more coherent basis to provide some logical grouping of items, that is, to bring together types of housing, industry, open space, etc. instead of each occurring separately throughout the list. For example allotments were No. 11, while parks were No. 17 and playing fields No. 53. This grouping of like items also facilitated the use of the Local Plan Notation provided by the Leeds City Planning Department*.

The regrouping of the listed items was based upon the first order of the classification set out by the West Riding Coding Manual, which formed the basis of the Local Plan Notation. Every item was listed under one of the ten headings given below:

A. Open country; Agricultural; Forestry

B. Extractive industries; Tipping, disposal of waste; Spoiled, degraded and unutilised land and buildings

C. Manufacturing industries

D. Commerce

E. Residential

F. Civic, cultural and special community uses

G. Educational establishments

H. Open space

I. Transportation; Utilities; Communications; Defence establishments

J. Buildings under construction

each of these categories being allotted the upper case letter listed beside it. The individual items were then allotted a lower case letter to identify them within their major grouping. So a land use item usually has two letter code, for example Ha represents allotments, the upper letter identifying its general grouping, and the lower case one the

* This is reproduced in full in Appendix II. It is based upon the very comprehensive land use classification devised by the West Riding County Planning Department.

specific item. Not all land use units have been given a two letter code however. Those which can be identified as far as the general category have been given the appropriate letter, for example a plot may be identified by the letter 'C' indicating that that plot has been identified as a manufacturing industry, but that no decision could be made as to the type of produce produced. Roads are the only land use item which is not coded.

It must be emphasized again that this is not a hierarchically constructed classification. The grouping of the items into ten "classes" was to facilitate the conversion of the Project Notation into the Local Plan Notation, and so speed up the production of maps using the latter notation. A numbering system could have been used instead of upper and lower case letters, but this would have been more difficult to read where numerous small land use plots occur together. An examination of the groups will show that they are not hierarchically organised. For example the general category of manufacturing industries (C) includes not only specific types such as brick works and wire works, but also "umbrella groups" such as heavy industry. The incorporation of these items into a classification would introduce problems of mapping, since a two letter notation would not distinguish the various levels within the classification, and as some of the plots are very small (see Plan SE 3033) a long code could not be inserted.

The Development of a Regional Project Notation

Although the development of a notation system for regional land use mapping is one of the objectives listed above (page 3), a regional notation was prepared by the West Riding Planning Department. It is reproduced in full in Appendix III. The Notation has four first level categories:

Natural and semi-natural
Agricultural
Extractive
Built or Developed

Each of these is subdivided into second and third order categories. It was felt that this detailed type of classification would be too complex for use at any level below the first at 1:100,000 scale, but that more than four units could be clearly mapped. However the notation needed testing before any decision could be made about its utility.

Accordingly an experimental area was chosen covering one 6" map (SE 53 NE), using 1:10,560 scale photography for ease of handling. The photographs were scanned and the land use mapped in rough draft as a scale of 1:10,560 using the Regional Notation (Appendix III). This was then reduced "by eye" to produce a 1:25,000 scale map which was redrawn on plastic drawing film. This map was reduced photographically to 1:50,000 scale and 1:100,000 scale. The resulting maps illustrated that quite apart from any deficiencies in the Regional Notation, special care was needed in their drafting since some of the coding was completely illegible. The 1:25,000 scale map was therefore redrawn with larger lettering (Map 2), and reduced to 1:50,000 and 1:100,000 scales (Maps 3 and 4). The coding is now legible. However this does not clarify the land use, as the confusion of lines and codes does not make detail apparent. This results from the attempt to map land uses of small areal extent at too small a scale - a function of the number and type of second order classes in the "Built or Developed" category.

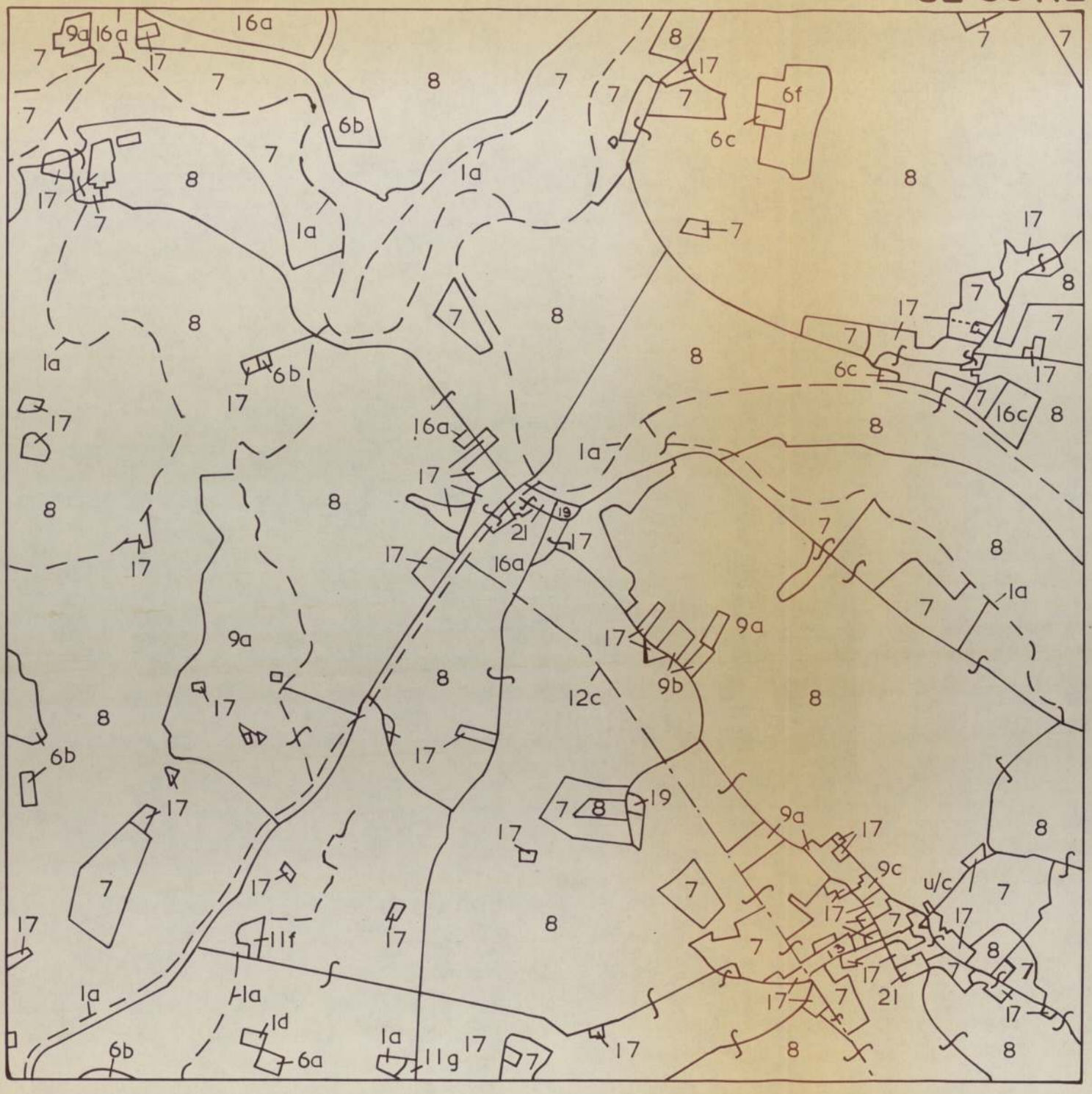
In an attempt to overcome this problem Map 5 was produced. This map is like Map 3 except for the grouping together of all the "Build or Developed" classes which have been shaded, the remainder of the coding being as before. Map 5 is much clearer, but the built up areas are emphasized at the expense of other land use types.

After examining and discussing these maps, a Regional Project Notation was developed, based upon the Regional Notation and the classification devised for the second Land Utilisation Survey of Great Britain*. This

* See Coleman, A. and Maggs, K. R. A. (1961)

AIR PHOTO INTERPRETATION PROJECT
LAND USE REGIONAL NOTATION

SE 53 NE



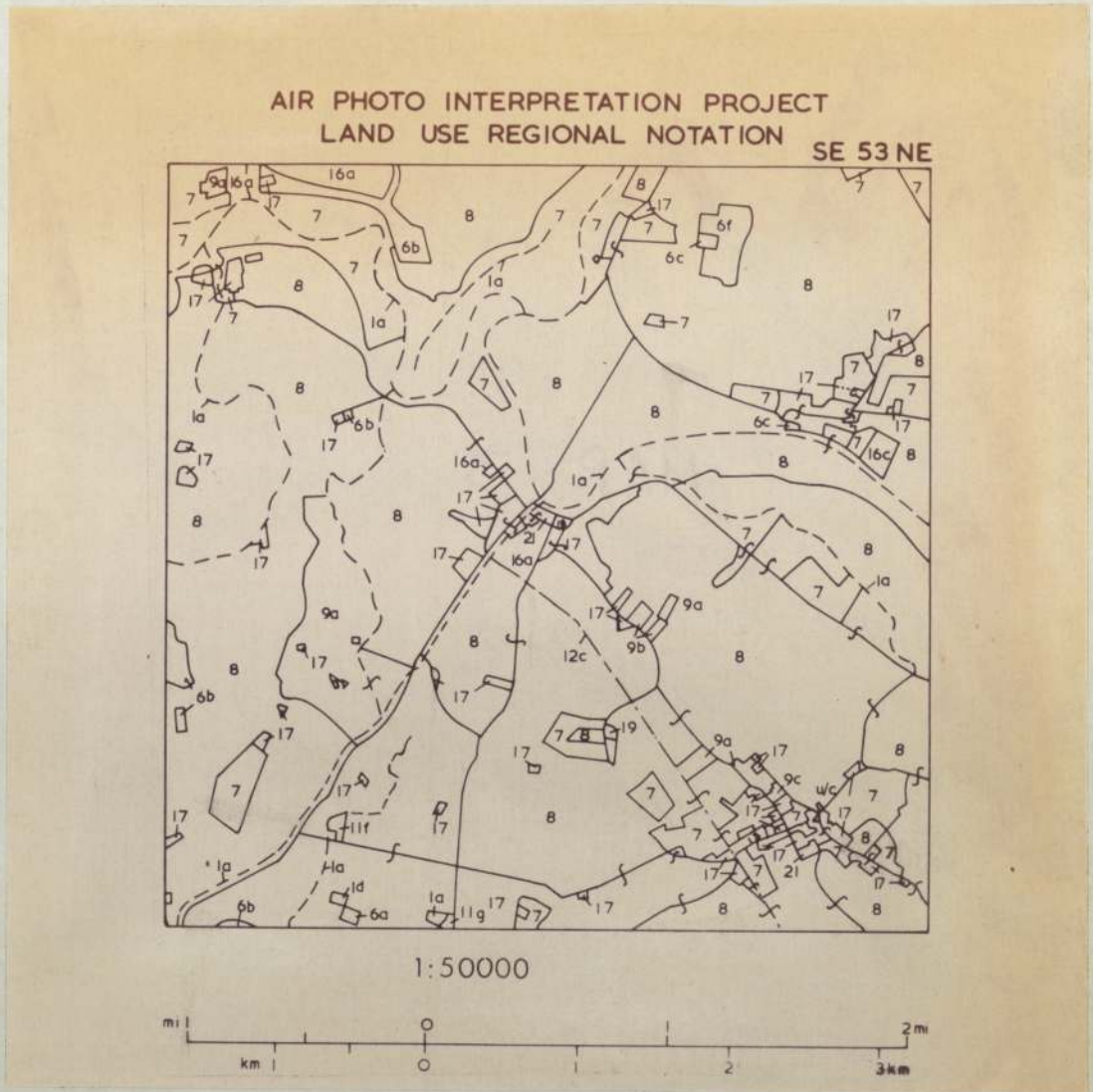
SCALE 1 : 25 000

mi 1 0 1 2 mi

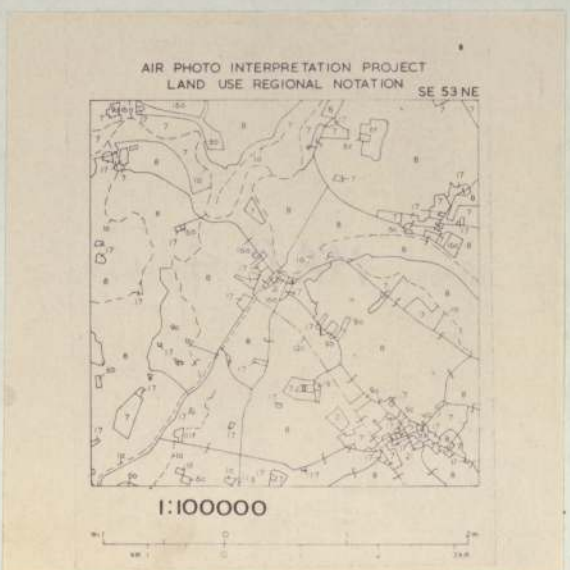
km 1 0 1 2 3 km

Information derived from 1 : 10.000 photos

Map. 2. EXPERIMENTAL AREA REGIONAL NOTATION



MAP 3: Experimental Area. Regional Notation Scale 1:50,000

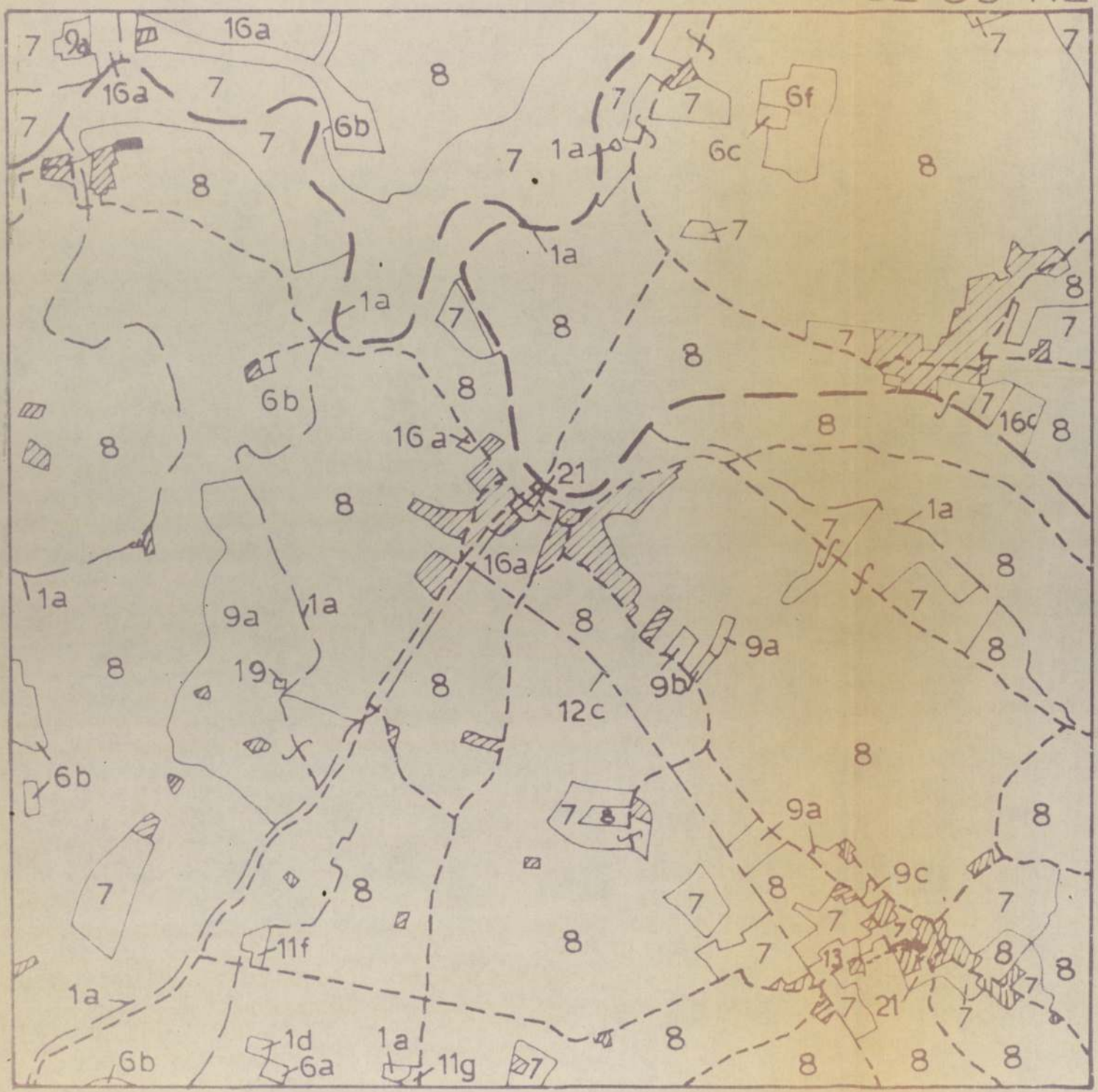


MAP 4: Experimental Area. Regional Notation Scale 1:100,000

AIR PHOTO INTERPRETATION PROJECT

LAND USE REGIONAL NOTATION

SE 53 NE



Map.5. EXPERIMENTAL AREA WITH ADAPTED REGIONAL NOTATION

SCALE 1:25000

Regional Project Notation has eight divisions:

1. Built Environment
2. Extractive Industries/Tipping/Dereliction
3. Transportation
4. Recreational Open Space
5. Agricultural Land (including horticulture and orchards)
6. Woodland
7. Heath/Moorland/Scrub
8. Water/Marsh

This list cannot be described as a classification in the strict sense of the word, since it is not logically sound. Eight items were felt to be the maximum number which could be shown with clarity on a 1:100,000 scale map without the introduction of colour. Some stylisation was found to be necessary when the maps were produced, to make roads, railways and waterways visible as units in themselves rather than appearing to be boundary lines.

General Features Used in Interpreting the Photographic Image

Having described how the notations used in mapping the land use were developed, the methods used in interpreting the photographs and map production can now be outlined. Discussion is limited to vertical* black and white aerial photography with reference to land use only, since the interpretation of other types of imagery for purposes such as soild and vegetation mapping, topographical and geological studies is covered elsewhere†.

There are eight features of the photographic image used in photo interpretation:

* Vertical air photos are taken with the axis of the camera at no more than 2^0 from the vertical.

† See "American Society of Photography (1960), (1968)"

size	shadow
shape	site
tone	situation
texture	pattern

Size and shape are perhaps the most easily understood features of a photographic image. Size is important in both relative and absolute terms. A comparison of two images will prevent the identification of a bush as a tree, while a rough measurement would stop a small hut being identified as a house. Shape involves not only the plan of an item, but also its three dimensional appearance. However shape and size are rarely conclusive evidence of a particular land use, they are used together to exclude certain land uses from the list of possibilities when making an identification.

Tone refers to the degree of greyness of an image, and the variations in tone prevent the photograph appearing flat and without relief. The texture is the variation of tone within an object, and indicates whether it has a smooth, highly reflective surface, or whether the surface is rough and lacks uniformity thus giving a textured or dappled appearance. For example roads usually seen a uniform shade of light grey - an indication of smoothness, while the top of a domestic rubbish tip will have a very varied surface appearance. The causes of textual differences vary with the scale of photography. For example at medium and large scales, the leaves on a tree may provide the tonal variations, but at small scales these are caused by the individual trees themselves.

Shadows are familiar phenomena, and can provide valuable help when identifying objects, particularly those which have a small plan area and lack tonal contrast. A good example would be the pylons and buckets of an aerial ropeway from a colliery to a tip heap. These can rarely be identified directly, and their shadows may be the only means of recognition.

Site, situation and pattern are not functions of the photographic image, but relate the image to its wider context. Site is the point where the image is located and its immediate vicinity, for example a house and its garden, whereas situation is the setting in a wider area, for example the positioning of the house with regard to the city centre. Pattern is the spatial arrangement of the image, and is made up by the repetition of tonal differences. Taking the example of the house again, the single unit of the house and garden may form part of the pattern of a block of semi-detached houses.

This separation of the features used in photo interpretation is, in a sense, misleading, since in practice they are considered together. There is a great deal of "automation" in the recognition of these general features, and considerable difficulty may be experienced in describing the part each plays in identification, since the importance of each varies with the image which is under study. How the general features are used in the identification of land use is described below.

The Form/Function Relationship and its Part in Air Photo Interpretation

The identification of land use from the aerial photograph requires some distinctive visual factor to be associated with the land use, and to be identifiable on the aerial photograph. This visual factor usually consists of several items which together indicate the type of land use; no one item generally being sufficient in itself for identification. The clues used in recognising land use vary considerably, but they are based upon the general factors discussed above which are brought together into some distinctive relationship. For example, the recognition of a colliery depends upon the association of winding gear, the washing and coal loading plant, extensive railway sidings and the ventilation system. Some land uses are almost impossible to identify because their external form gives no clue to their function. Examples of this are the many commercial land uses such as post offices, banks and many shops and

offices, and community uses such as libraries, doctors' and dentists' surgeries, and museums and art galleries. Identification in such cases may be based upon intuition, which in its turn comes from the photo interpreter's experience and knowledge of the structure and layout of urban areas.

The process of identification is based upon the form/function relationship, but the photo interpreter does not consciously ask himself about the visual clues to a land use until he has made some judgement about it. He scans an area and makes a tentative decision about its use, and then scans the area again to see whether its visual appearance fits in with his knowledge of that land use. This will either confirm the first judgement or result in a new decision being made.

From this brief description of the process of photo interpretation it is clear that it is a complex one, and one which is heavily dependent on the experience of the photo interpreter. The qualities which make a good photo interpreter are outlined in Chapter 4.

The Recognition of Individual Land Uses

Having described the general features used to interpret the photographic image and the importance of the form/function relationship, the appearance of the major categories of urban land use on the aerial photograph can now be outlined. The descriptions which follow are by no means exhaustive, but they do give an indication of some of the methods by which land uses are identified. As mentioned above it is often very difficult to separate the visual clues which lead to the recognition of a land use, and to describe the part each plays.

Housing, a very familiar land use, is on the whole easily recognised. On photo 1 both terraced (1) and semi-detached (2) houses can be seen, with an oblique view of the frontages. This illustrates the roof and chimney patterns, with the surrounding plot and road layout. "Back-to-back" terraced housing is more difficult to distinguish, as it has a very

similar appearance to conventional terraced housing. However it has chimneys on either side of the roof ridge, and little or no garden. The terraces are usually cramped together in straight rows. "Back-to-back" housing can be seen on photo 2 (1).

Commercial premises of all sorts are much more difficult to identify than residential property, because as outlined above, the form usually gives no indication of the building's function. Small "corner" shops in a largely residential area can frequently be identified by the paved area which may replace the garden, by a sunblind, or if an oblique view is obtainable on the edge of the photograph, by the name board and advertisements in the window. Such a shop can be seen on photo 2 at (2). In the more modern housing developments shops usually have a slightly different appearance from the surrounding houses and they may have a delivery bay at the back of the premises. Often the building line is set back a little. A row of shops, some with their sunblinds pulled out, is visible on photo 2 at (3). From this description of the points used when identifying shops it is clear that while a building may be recognised as a shop no attempt can be made to identify the products dealt with in the building. Offices are extremely difficult to identify, except those office blocks which are purpose built. In residential areas their appearance is very similar to the surrounding houses, since they are usually no more than a converted house. However the paved area with car parked upon it in place of a garden may prove helpful in recognising such a conversion. In central urban areas distinguishing between offices and shops is largely a matter of guesswork and intuition. As with shops it is usually impossible to say what business is carried on in the building. Public houses, particularly those outside the central urban area, can usually be identified. They often have a corner site, and the building may be larger than the surrounding houses, with perhaps an extension and several outbuildings. Car parking is often available around the building or on the next door plot, and sometimes the sign may be visible. Other commercial land uses

such as dairies, builders and coal merchants, bakeries and timber merchants may occasionally be recognised. From the aerial photograph the interpreter may be able to see the milk floats and small tankers at a dairy, and outside storage of material at a timber, coal or builders merchant, or the chimney, the associated production building and the delivery vans at a bakery.

Industrial and warehousing uses also pose problems of identification, although except for the very small "back-street" workshops it is usually possible to pick them out. The difficulties come when distinguishing between industrial premises and warehousing or identifying the industrial processes involved. Modern warehousing and industrial premises are often very similar, with a rectangular plan shape, a low pitched roof and a location on an industrial estate or commercial area. However they differ in several aspects also. Warehousing usually lacks the numerous windows of an industrial building, and its chimneys. Loading bays, or perhaps lorries backed up under a canopy, may be visible. Warehouses often take up a large part of the plot, where car parking facilities are limited because of the small number of people employed. Older warehousing also resembles industrial premises of the period, and there are fewer features to distinguish between them. Again loading facilities may be visible - large doors into the building or perhaps a loading bay, but the shape of warehouses and industrial buildings tend to be similar, although of course chimneys will be lacking from the former. On photo 2 three warehouses may be seen in an industrial area at (4), (5) and (6). At (4) the warehouse is for a motor repair depot. The form of the buildings suggests that no manufacturing process is carried out, while the large doors and canopy visible on one side of the buildings indicates some sort of storage function, and the number of vehicles suggests a connection with the motor trade. At (5) and (6) are two other warehouses, neither providing much clue to their use except their shape, but this can be contrasted with the printing works at (7). This is clearly industrial,

although there is no indication of the processes involved. Heavy manufacturing industries can usually be recognised by the layout of the plot, with railway lines disappearing into buildings, perhaps overhead cranes, and piles of raw materials or half finished products lying outside. At (8) on photo 2 an old, well established scrap-yard can be seen, and adjacent to it at (9) a heavy metal-working industry with piles of metal and scrap around the sites.

In contrast to the problems of identifying warehouses and manufacturing industries, extractive industries and the various forms of dereliction are usually easy to pick out - the problems arise not so much from identification, but rather with the definition of the term "derelict". The features used to identify a colliery have been listed above. On photo 1 at (3) an active brick works can be seen. Under a stereoscope the steep sides of the brick clay pit, the kilns, the chimney and the stacks of bricks are visible. At (10) on photo 2 is an old waste heap from a colliery, the dark partially vegetated surface indicating that it has been inactive for some time. Near it at (11) is a former railway line. The track has been removed, but the distinctive shape of the embankment remains. At (4) on photo 1 is an area of tipping, but there is no indication of the source of the material. Degraded or neglected land which may be included as derelict poses problems of definition as mentioned earlier, since its inclusion will rest upon its visual characteristics. Areas of this type of land may be seen at (5) on photo 1 and at (2) on photo 2.

Recreational areas and open space can be clearly identified from the air photos, although again there may be problems of definition and nomenclature. Clearly delineated areas such as parks and playing fields present few problems, and the markings on the ground permit the identification of the sports played in such areas. It is those parts of housing or industrial estates which are left vacant which

present the problems, since they have no apparent use. In this research the problem has been overcome by designating areas such as these as "open ground apparently unused", rather than using the term "amenity space" which suggests that such areas are planned and managed.

This brief outline of the appearance of the general land use categories on aerial photographs illustrates the diversity of the visual clues used in recognition, and also the need for some knowledge on the observer's part of the visual appearance of land use. Having described how land uses may be recognised, this report of the research continues with a discussion of the study area, and the methods used to produce the land use maps.

The Study Area (Map 1)

The pilot study area covers 600 sq. km. between Leeds and Selby, and comprises six 2½" scale maps: SE32, SE33, SE42, SE43 SE52 and SE53. Originally the research was planned to include the whole of this area, but when consideration was given to the number of maps and photographs involved*, this idea was abandoned. Instead study areas were chosen from within the pilot study area, covered by the three scales of photography, and 2 sq. km. in York were added to provide a central urban association of land uses covered by 1:10,000 scale aerial photography. These study areas were chosen by the Leeds and the West Riding Planning Departments to cover a wide variety of land uses at the three scales of air cover. Map 1 shows the pilot study area and the areas selected for air photo interpretation.

The regional land use survey was also originally intended to cover the whole of the pilot study area, but again when the volume of material to be scanned was considered this survey was reduced to the selected parts of the study area shown in Map 1. However when this part

* There are approximately 800 1:3,000 scale air photos alone, and these cover only about 70 sq. km.

of the research came to be tackled, the mapping of areas of between 1 and 7 sq. km. at 1:100,000 scale was not very meaningful, and the suggestion that one entire 1:25,000 scale map would be more appropriate was accepted by the SCOLPA Committee. Accordingly Ordnance Survey sheet SE42 was selected. This area had two advantages; firstly it had a wide variety of land uses within it, and secondly it was covered by two scales of photography (the 1966/67 photography being at 1:10,500 scale, and that for 1971 at 1:5,000 scale) permitting a comparison of the two to be made.

The photography for the selected parts of the pilot study area was scanned using a Wild ST4 mirror stereoscope, and the information obtained from the air photos was recorded on trace overlays. The conversion of this information into land use maps at local and regional scales is described below.

The Production of Land Use Maps at Local Scales

There was some variation in the techniques used to record the information from the trace overlays in map form. This has resulted in slight discrepancies in the plan positions of various items, and this could be corrected in any future work by standardising the methods for the transference of data.

Initially the rough drafts of the maps were produced by laying a piece of tracing paper over the Ordnance Survey Plan and drawing out the required detail. A master copy was then drawn from this rough draft on plastic drawing film. This method resulted in boundary differences between the master and the Ordnance Survey Plan because of the distortion of the tracing paper. Unfortunately this problem was not realised until all the maps for the 1971 land use situation had been completed (some twenty-two maps), and it was felt that the research would be unduly delayed if these maps were redrawn. While it was realised that these discrepancies would result in errors in any areal

measurements, no such measurements were planned, and the street patterns were recognisable. To try and overcome this problem of distortion, the 1966/67 land use detail was mapped in rough draft on dyeline copies of the Ordnance Survey Plans. These are also distorted but the distortion is only in the direction in which the transparency goes round the rollers in the dyeline process, and is not usually of the same order as that on the tracing paper copies, so the plan position of an item should be nearer its true position. Unfortunately this technique could not be used for the 1:5,000 scale mapping in Areas 1 to 4 because no dyeline prints could be produced which showed all the topographical detail, and which were light enough for the ink to be visible. Consequently the original method of using tracing paper was again used for the 1966/67 land use maps of Areas 1 to 4.

The Production of Land Use Maps at a Regional Scale

Having scanned the photography covering SE42 for both 1966/67 and 1971, rough drafts of each map were produced, using the Regional Project Notation, at a scale of 1:25,000 omitting the intermediate 1:10,500 scale used in the experiment. This was found to be practicable with the much smaller number of units to be mapped, and it was felt that any inaccuracies at this stage (unless wildly wrong) would be reduced to negligible proportions when the maps were reduced to 1:100,000 scale. Moreover no measurements were to be made from these maps. The resulting maps provide some visual picture of land use at the two periods.

The question of the scale of photography needs some comment here. As mentioned above SE42 was chosen because of the difference in scale between the 1966/67 air cover (1:10,500 scale) and that for 1971 (1:5,000 scale). The broad notation system used meant that no difficulties were experienced in the identification of land uses using

the small scale of photography which had two advantages:

1. The small scale meant that there were fewer photographs to handle, and their scanning was completed more quickly.

2. Direct comparisons with the map was easier, and judging which items were too small to warrant inclusion was simpler.

Land Use Changes at a Regional Scale Between 1966/67 and 1971

A comparison was made of the two regional land use maps at a scale of 1:25,000 (that is with no reduction), and changes in land use recorded. Two problems were immediately apparent. Firstly, there was some difficulty in deciding what were changes in land use, and what were not, since land use information from the trace overlays was recorded in map form simply by drawing in detail freehand. This was resolved by making further reference to the photographs. Secondly, any changes in land use would have to be visible when the map was reduced to 1:100,000 scale.

References:

AMERICAN SOCIETY OF PHOTOGRAMMETRY (1960)
Manual of Photographic Interpretation
2nd Edition, Washington

AMERICAN SOCIETY OF PHOTOGRAMMETRY (1968)
Manual of Colour Photography
Washington

ARMAND, D. L.(1965)
Soviet Geography 6(9) pp. 20-38
The Logic of Geographic Classifications and Regionalisation Systems

COLEMAN, A. and MAGGS, K. R. A.(1961)
Land Use Survey Handbook
2nd Edition

McDONALD, P. I.(1971)
Urban Land Use and the Record of the Aerial Photograph
Unpublished Ph.D. Thesis. University of Leeds

CHAPTER 4

THE ACCURACY OF INFORMATION DERIVED FROM AERIAL PHOTOGRAPHS

Factors Affecting Accuracy

The accuracy of the land use information obtained from the photographs is dependent on five major factors:

1. The Skill of the Interpreter

   This is perhaps the most important of the factors affecting accuracy. It is very difficult to define what makes a good photo interpreter, but he must be observant, and be able to relate his experience of land use at ground level to the aerial view on a photograph.

2. The relationship Between Form and Function

   This has been discussed earlier but needs to be touched upon here, since the accuracy of the identification of land use is related to the type which one is trying to identify. As mentioned previously some land uses are extremely difficult to recognise, and if these form the major part of the area under study then the number of correct identifications will be small. If however, an easily recognisable land use such as residential development is being mapped, accuracy will be high.

3. The Type of Environment

   As mentioned in section (2) the form/function relationship plays an important part in the recognition of land use types. If the centre of a town or city is being studied, and land uses mapped, there is a concentration of those uses whose exterior form gives little or no indication of their use, so the number of units correctly identified drops. This problem

is made worse in a long-established city such as Leeds, because many buildings have altered their original function but not their form.

4. The Type of Classification

The detail to which the classification goes is important when considering the accuracy of photo interpretation. Any classification which is logically sound and which distinguishes several types of land use will be difficult to apply to the results of an air survey, since not all items will be identified to the same level; for example residential areas may be subdivided into house type, while an industrial plot may be recognised only as a manufacturing industry. If all that is required is a very general picture of land use this can be achieved from aerial photographs (for example the mapping of built and unbuilt land). But if the requirement is for twenty different types of industry, then air photos cannot be regarded as a reliable source of information. The problems associated with inadequate definitions of units also need mention here, and care must be taken to have clear working definitions of the items in the classification to prevent the photo interpreters identifying items in different ways, and so classifying similar items differently.

5. The Scale and Quality of the Aerial Photography

Increasing the scale of the photography is of considerable help in photo interpretation, but this is only so up to certain limits, since above that the amount of extra information obtained from the air cover is minimal and does not warrant the increases money and time spent on acquiring it. However large scale photography does have the advantage that it is easier to map information from it on to trace overlays. The prints need to have good tonal contrasts and definition, and as little deep shadow as possible.

The Definition of the Term "Error and the Source of Discrepancy

The use of the term "accuracy" implies that errors can be identified and measured on land use maps derived from air photo interpretation. However it is difficult to apply the term "error" as defined ("differences between a quantity obtained by observation and the true value"*) in the context of this research, since not all discrepancies between the ground truth and air survey are errors in identification. Moreover both the results from the air photo interpretation and from the ground survey are the outcome of observations.

The most important type of discrepancy is the incorrect identification of land use at the first stage of grouping, for example the identification of an industrial building as residential. These are described as errors, and have been identified and mapped. It was felt that errors of identification within a major land use type - for example the identification of a semi-detached house as detached - were of insufficient importance to warrant a separate map and so these were included on the maps showing both errors and discrepancies. The selection of those discrepancies which were errors in identification was carried out by a subjective comparison of the item recorded from the air photo and that on the field sheet. The two terms are used in an attempt to distinguish those land uses which have not been correctly identified from those which have, but because of differences in classification or alterations in land use, do not appear with the same land use code on both the field sheets and the maps derived from air photo interpretation. These sources of discrepancy are discussed below, but it should be mentioned here that this subjective method of identifying errors when used by another researcher would not give the same results.

* Chambers 20th Century Dictionary

TABLE I

CONVERSION OF PROJECT TO LOCAL PLAN NOTATION

Description of Item	Project Notation	Local Plan Notation
(i). Farm building (including house)	Ab	01/H1/ST
(ii). Area where trees felled	Ai	03/D5
(iii). Colliery sludge pit	Bg	W1/MW2
(iv). Waste ground associated with colliery	Bi	D5/MW2
(v). Scrap-yard	Dc	14/D5
(vi). Open ground apparently unused	Hm	D5
(vii). Water storage for colliery	Im	U3/ST/MW2
(viii). Power plant associated with manufacturing industry	Ik	U/1

An important source of discrepancy was the incompatability of the Project and Local Plan Notations. When the Project Notation (Appendix IV) was converted into the Local Plan Notation (Appendix II) several items did not correspond directly, or were coded differently. Examples of the former are given in Table I. There was considerable difficulty in coding item (vi) in Table I - "Open ground apparently unused" - when converting the Project Notation to the Local Plan Notation. It was finally coded with derelict land since this is the only term which contains some concept of non-utilisation. However it is not derelict in the general sense of the word, which is of land laid waste. The other items listed in Table I were coded to give some idea of their function; thus a colliery sludge pit is coded W1 for mining waste and MW2 to indicate that is results from deep mining. Similarly item (viii) is coded U to indicate utility, and 1 to connect it with an industrial establishment.

A further source of discrepancy is the disagreement between the ground truth and the photo interpretation resulting from the difference in time between the ground and air surveys. Examples of this type of discrepancy are given in Table II. However there are several examples of what may only be called a difference of opinion between the photo interpreter and the ground surveyor. These have been carefully checked and the only interpretation which can be made is that there is a certain degree of error in the field study, not only in terms which might be missed, but in one case a long-established scrap-yard with several associated heavy metal works nearby is mapped as a brick, pottery and glass industry. Examples of this type of discrepancy are given in Table III.

TABLE II

DISCREPANCIES RESULTING FROM TIME DIFFERENCES BETWEEN AIR AND GROUND SURVEY

Item Identified by the Air Photo Interpreter	Item Identified by the Ground Surveyor	Grid Reference
Open ground apparently unused (D5)	Domestic residential (H1)	430750 430170
Active waste tipping (W2)	Other derelict land (D5)	435960 436880
Active waste tipping (W2)	Other derelict land (D5)	435400 435600
Active waste tipping (W2)	Other derelict land (D5)	435600 436750

TABLE III

DISCREPANCIES RESULTING FROM ERROR IN GROUND SURVEYS

Item Identified by the Air Photo Interpreter	Item Identified by the Ground Surveyor	Grid Reference
Open country - Agriculture (O1)	Open country - Forestry and Woodland (O3)	436970 434440
Open space - Allotments (OS11)	Open country - Horticulture (O2)	436330 434420
Scrap-yard (14/D5)	Manufacturing industries - Glass, Pottery, Bricks, etc. (114)	430200 436800
Disused colliery spoil heap (D1)	Other derelict land (D5)	430700 430050

Measurement of Error

The measurement of the amount of error in photo interpretation is difficult. The problems arise from two major sources:

1. The difficulty of deciding what does constitute an error, and the subjective nature of that decision. The types of discrepancy have been outlined above, but the decision as to whether a discrepancy does in fact constitute an error in identification must lie with the photo interpreter, unless an examination of each discrepancy is made with another observer - for example the ground surveyor - who has an intimate knowledge of the notation being used. This was impracticable here, and so the decision was left entirely with the research worker.
2. How is the error to be measured? Error can be measured either in areal or in unit terms, but either method may give an anomalous answer. To illustrate this point let us consider a hypothetical study area of 100 acres containing 100 land use units of differing sizes. Of this 100 acres 60 acres have been

correctly identified so we have an error of 40 per cent. But if the number of units correctly identified is only 20 out of 100, then our error increases to 80 per cent.

Neither of these figures is incorrect, but neither gives any information about the type of errors most frequently occur. Collins and El-Beik (1971) when assessing accuracy, used the method of comparing the units identified on the photographs with those identified from a field survey, and Table IV shows the results of this comparison. One of the difficulties of this method of "measuring" accuracy is the problem of those units which have been missed out of the photo interpretation or have been incorrectly identified. Column 5 in Table IV attempts to overcome this problem by giving the percentage of units over or underestimated, but this does not show what types of mistake are being made - for example the consistent identification of blocks of flats as office premises - nor where the errors occur.

TABLE IV (Source Collins and El-Beik (1970)

ASSESSMENT OF ACCURACY

Type of Urban Land Use	A*	F	C	C(%)	(A-F)/F x 100(%)
Commercial	48	39	33	84.5	+23.0
Industrial	173	184	159	86.5	- 6.0
Residential	222	235	216	92.0	- 5.0
Bodies of water	3	3	3	100.0	0
Transportation	11	9	9	100.0	+22.0
Public Building	152	159	145	91.0	- 4.4
Open improved land	70	70	69	99.0	0
Open unimproved land	23	24	23	96.0	- 4.0
Complex urban land use	20	33	12	36.4	-39.4
Total Number of Areas	722	756	669	88.5	- 5.2

* Explanation of vertical column headings: A = number of units recorded from aerial photographs; F = number of units recorded from field investigation; C = number of units correctly identified; C(%) = percentage of correctly identified units; (A-F)/F x 100(%) = percentage over or underestimated derived from the aerial photographs.

On consideration of these problems, it was decided that a direct measurement of error was of little practical value, and that errors and discrepancies could best be shown in map form. This would give an idea of where most discrepancies occur, and the area involved without the problems of measuring or counting individual plots.

Compilation of the Error and Discrepancy Maps

The discussion of the methods by which the error and discrepancy maps were compiled will be dealt with in several stages, since a number of problems occurred in the production of the maps for Areas 4 (Pontefract), 5 (Cawood) and 6 (York), which did not occur in the Leeds areas.

In Leeds the ground truth for the eight square kilometres is at the same scale (1:2500) as the maps produced from the air photo interpretation. This made comparison easy, since one map could be laid over the other. All areas which did not correspond were outlined on tracing paper, and the two notations listed in different colours beside the area. Minor boundary differences resulting from the method of map production discussed earlier were not included. This produced maps of great complexity with no distinction between the sources of discrepancy, and also introduced the problem of reproducing maps containing more than one colour. Since the problem of correct identification was felt to be of paramount importance, two contrasting areas were chosen in which to distinguish the errors in identification from all other discrepancies. The two areas chosen were SE3033 (the centre of Leeds) and SE3536 (Seacroft, a surburban centre). For each of these, two maps were produced: one showing errors in identification only, and the other all forms of discrepancy.

In considering Areas 1 to 4 to decide which to begin with, Area 4 (Pontefract) was selected since it had the greatest diversity of land uses. The first problem was the difference in scale between the ground truth (at a scale of 1:2500) and the maps produced from air photo

interpretation (at a scale of 1:5000). Some difficulty was met with therefore in accurately transferring discrepancies from one sheet to another. The second problem was the notation system used on the ground truth. This was a numbering system, and was not directly comparable with the maps produced using aerial photographs. Each plot was allocated a number, and reference then had to be made to a manual which contained a description of the plot. Each description therefore had to be compared with the Project Notation used in the mapping. This, while relatively easy in the majority of cases, prolonged the task considerably, and some of the descriptions did not give exact information as to the land use. Examples of this are given below:

TABLE V

NOTATION SYSTEM OF THE WEST RIDING GROUND SURVEY

O. S. Sheet No.	Plot No.	Description of Use
SE 4622	23	Outbuildings and Yard
SE 4522	197	Shed

As for the Leeds areas two maps were produced for Area 4: one showing errors in identification and one all discrepancies. But the time taken to complete these maps and the difficulties experienced let to the decision not to produce such maps for Areas 1 to 3, particularly since it was felt that they would merely reinforce the opinions about errors in identification brought out by an examination of SE 3033, SE 3536 and Area 4, without adding anything new.

Area 5 (Cawood) was the next to be tackled, and again the problem of numbered plots described in an accompanying manual was encountered. But the major problem here was one of scale. The air photo interpretation and mapping had been carried out at a scale of 1:10,560, while the ground truth was at a scale of 1:2500. This caused considerable difficulty in

the centre of Cawood, where very small land use units had been identified, and eventually the attempt to make a fair comparison of the air and ground surveys was abandoned. The remainder of Area 5 was compared with the ground truth, and a single map prepared showing all forms of discrepancy.

In Area 6 (York) the problem of scale was again encountered. As in Area 5 the ground survey was compiled at a scale of 1:2500, while the air photo interpretation and mapping was at 1:10,000 scale. The difficulty of notation was not present, since the Local Plan Notation had been used in the field survey. However, the problem of scale was even more acute than in Area 5, since Area 6 covers the central portion of York, where land use units are very small and mixed. Eventually this was overcome by outlining those areas where large numbers of discrepancies occurred, with no attempt to distinguish the reasons for the discrepancies. This map was produced at 1:10,000 scale, since the particular reason for including Area 6 in the study was to examine the effectiveness of mapping a central urban area from aerial photographs alone at a scale of 1:10,000.

An Examination of the Error and Discrepancy Maps

On examining the error maps of Area 4 (Pontefract), SE 3033 (Central Leeds) and SE 3636 (Seacroft), it is clear that it is in the central areas of towns and cities that air photo interpretation of land use is most difficult and inaccurate. It was mentioned earlier that the identification of land use is dependent on the form/function relationship, and that many commercial uses exhibit no such relationship. Since many of these are concentrated in the central urban areas, the number of errors there will be high. This is the most important reason for the number of errors in central Leeds and Pontefract. A second reason for the number of errors in identification in these central areas is the small nature of the land use plots. This means that any visual clues will be difficult to interpret, and their significance overlooked, because of the close mixture of land uses.

Looking at the error and discrepancy maps for SE 3033, SE 3536 and Area 4, we see that the amount of error both in terms of units and of area decreases as we move away from the central region. This is because we are moving away from those land uses which have little or no relationship between form and function, to those which have, and it is here that types of discrepancy, other than errors in identification, become more frequent. In these outer areas, it would seem that the most important source of discrepancy is the use of different notations for the ground truth and for the air photo interpretation.

Lastly, the discrepancy maps for Area 5 (Cawood) and Area 6 (York) must be discussed. The production of only one map for Area 5 was felt to be adequate since the number of discrepancies and their sources was limited. This reflects the fact that the centre of the village was not examined. In Area 6 the number of errors in identification is large, but as described above, the only practicable method was to mark off blocks where any type of discrepancy occurred, thus including errors in identification. These blocks therefore contain discrepancies from all sources, but also some land uses correctly identified. No attempt to delineate between these was made because of the small scale, and it was felt to be putting the maps on an invidious footing to simply enlarge them to the scale of the ground truth. This illustrates the limitations both of 1:10,000 scale photography and of mapping at that scale for urban land use, and also demonstrates the need for ground truth to be at the same scale and to use the same notation as the photo interpretation.

The Definition of Accuracy and its Application in the Context of this Research

This discussion of the sources and distribution of discrepancies leads on to the wider question of accuracy. How far is the survey as a whole correct or exact?* Accuracy is generally accepted as the result of

* Chambers 20th Century Dictionary: definition of accuracy - "correctness; exactness"

testing a piece of work against a standard. In this research the accepted standard is the ground truth compiled by the Leeds and the West Riding Planning Departments, but what is being tested against it is not the photograph, but one person's perception of the photograph. This means that any test of accuracy is not applicable to all photo interpretation exercises except in very general terms because of the subjective nature of air photo interpretation.

Accuracy (in the sense of fewer errors in identification) would certainly be improved by local knowledge of the area under study, and by some specific knowledge of the land uses occuring there. The use of Ordnance Survey Plans would also help with identification (a source of information specifically excluded in this study), as many buildings are named on the 1:2500 scale maps. Examples from Area 3 (Normanton) are:

Public Baths	438600422800
Clothing Factory	438325422540
U.D. Council Offices	438620422855

From the aerial photograph it might be possible to make some decision as to whether the building's function is likely to have changed. Local knowledge and the use of Ordnance Survey Plans have been mentioned here, since it would be unlikely that some of the inaccuracies which have occurred in this research would be made by a planning officer who would have, not only these available to him but also the other sources of information mentioned previously.

Summary

Despite the problems of defining an error, and the inadvisability of thinking of accuracy in quantitative terms, it would seem that the greater proportion of urban land uses in terms of the total urban area might be identified from aerial photographs. Residential development (thought to be more than 40 per cent of the total area in cities)* is

* Best (1958)

relatively easy to identify, as is open space, although here there is the problem of "amenity space" which cannot be readily defined from the aerial photograph. Industrial premises and warehousing cannot be immediately recognised, if in small units, in areas of great land use complexity, but on a larger scale will usually be picked out. However there may be a problem in distinguishing one from the other. Educational buildings can usually be identified, although there may be difficulty with some of the more specialised forms of educational structure, such as government training establishments (see photo 2).

The major problems in the identification of land uses from aerial photographs occur with the business premises and the special community uses. Banks, post offices, and offices of all kinds are almost impossible to recognise, while public houses and shops can, in some circumstances, be identified with a reasonable degree of certainity. Libraries, halls, social clubs, doctors' and dentists' surgeries are rarely identifiable directly from the aerial photograph, because they have few if any "clues" to their function in their external appearance. Thus land use mapping from aerial photographs will be most difficult and inaccurate where these commercial and community uses predominate - in the central urban areas.

References:

BEST, R. H.(1958)
Journal of the Town Planning Institute 44(7) pp. 160-164
The Composition of the Urban Area in England and Wales

CHAMBERS 20th CENTURY DICTIONARY
W. and R. Chambers, (1972)

COLLINS, W. G. and EL-BEIK, A. H. A.(1970)
Photogrammetria 27 pp. 71-92
The Acquisition of Urban Land Use Information from Aerial Photographs in the City of Leeds (G.B.)

CHAPTER 5

COMMENTS AND CONCLUSIONS

Aerial photographs can be used in two principal ways: to map features identified on the photograph, and to help in the analysis of a specific problem. Witenstein (1955) suggests three uses for air surveys in urban areas:

i. In mapping physical features, that is topography, communications and land use, etc.

ii. In analysis of these physical features, to establish the patterns of population density, community services, and movement of people.

iii. In planning the future layout of the area under consideration.

The first of these involves interpretation of the images on the photograph, while (ii) and (iii) use the interpretation for the purpose of further analysis.

Some of the problems experienced in this research arose because this basic distinction in the two ways of using air photos was not realised at the beginning, when the objectives were set out. Mapping land use (however it is defined) is recording what can be identified, but the decision as to which land uses should be grouped together - the drawing up of a classification - required that the requirements of some specific planning problem should be considered. This was outside the scope of the research, and so the notation systems described in Chapter 3 were devised. Doubts were expressed as to whether the research would prove useful when examining specific problems, when a planning officer would require information on the location of one particular land use (or perhaps more than one) in his area of study. If he required to know the distribution of children's playgrounds for example he could turn to the list of items identified and he would find that this had been recorded, so he would be able to assume that he could turn to his air photos and take the information from them. However, if

the planning officer wished to examine the distribution of trees in the urban setting, or perhaps the number of houses with garages and their location he would not know from the list of land use items identified here whether he could do so. Indeed he might assume that he could not do so as the "smallest identifiable land use unit" should have been mapped. However, as was mentioned at the end of Chapter 1, when mapping all land uses it proved impossible to record everything that could be identified because of the impossibility of representing very small units on the map.

This does not mean that the research has been useless, indeed to a beginner in air photo interpretation it will provide an indication of the types of land use which can be identified with relative ease, those which cannot, and the way in which specific items have been identified. This will be of help in extending his mental "air photo key", that is, the sorts of visual clues he will need to look for when he comes upon a land use with which he is unfamiliar. However, it suggests also that rather than asking "what can I identify from aerial photographs?", a planner should be saying "I need to know the location and type of, for example, playing fields to help me with the allocation of open space. Is this information which I can get from air photos?". This approach requires that some preparatory work is done to sort out how the particular problem developed, and the influences working upon it, before deciding what information is required, rather than recording everything that might prove useful. When looked at in these terms the air photo is placed in perspective - as a possible source of information.

The problems of classification and the use of air surveys need to be considered from another viewpoint. Webster and Beckett (1970) write:

> "Firstly, the information on terrain that is available or is likely to be required and gathered and that must be indexed in terms of terrain classes is of many kinds and relates to a

wide range of possible uses of the terrain . . . . The classification would need to be a general purpose one. Classes would, therefore, have to be defined on the properties of the terrain that affected or controlled the greatest number of uses, provided that such properties were either themselves easily observed or closely associated with other easily observed attributes."

This raises two important points:

i. Whether a "general purpose" classification can be constructed.

ii. Whether a classification developed on the basis of air photo interpretation (whether general purpose or not) will have relevance when viewed in terms of the problem on the ground.

Kaye (1970) implies that because the term "land use" can be defined so widely, no "general purpose" classification involving all its component parts is possible. Both Armand (1965) and McDonald (1971) stress the importance of following certain "laws of logic" when constructing a classification, and these require that there must be an end in view for the classification to be valid. When using a classification based upon air surveys the researcher needs to assure himself that what he is mapping is of relevance to the problem in hand. Goodier and Grimes (1970) when discussing the mapping of vegetation from air photos in North Wales suggested that:

". . . the development of a classification approach appropriate to the needs of photo-ecology will take account of the close association of plant ecology and geomorphology in the central roles of environmental ecology, while at the same time producing categories which can easily be cross-referenced with a more standard phytosociological approach."

However, the possibility seems a long way off that a similar classification will be developed for urban land uses - one which will take into account the many different requirements of planning and also the limitations of aerial survey.

Another source of difficulty was the division between field checking and air photo interpretation, and the differing notations and scales used. The production of a notation system for air photo interpretation was one of the stated objectives of the project, but when the comparison between the project notation and the notations used in the ground truth came to be made, it was clear that they were not directly comparable. The discrepancies arising from this have been discussed in Chapter 4, where the difficulties encountered, because of differences in scale, were also described. These bring to the fore the problems which crop up when fieldwork and air photo interpretation are kept completely separate, and suggest that in any future studies a combination of field and laboratory work is essential to cut down the number of errors, and the amount of fieldwork necessary for checking accuracy. A suggested method for using air surveys in future work on land use might then be:

First stage - the planning officer, having decided exactly what he wants to record from the photographs, familiarises himself with the item(s) which he wishes to identify.

Second stage - he then maps the occurrence of the items over his whole study area.

Third stage - he field checks a sample of his study area to identify omissions and errors in identification.

Fourth stage - he re-maps his study area taking account of the errors and omissions in his sample area.

When mapping land use in Leeds, the West Riding and York three different scales of photography were used. The construction of the land use maps from these photographs is described in Chapter 3 and the compilation of the error and discrepancy maps in Chapter 4. When outlining the factors which influence accuracy, it was pointed out that increasing the scale of photography may be of assistance in the identification of land use and also the speed of identification. Larger scale photography

is of help when delineating the individual land use units. However, both these factors need to be weighed against the increased amount of money and time spent on acquiring the photographs. From the error and discrepancy maps it would seem that there is little extra information taken from the 1:3000 scale photos when compared with that from the 1:5000 scale photos. There is a more marked difference between 1:5000 and 1:10,000 scales. This seems to lie not only in the actual identification of items, but also in the speed of identification, and the ease with which information can be taken from the photograph. This suggests that in urban areas where land uses are very mixed and of small areal extent, 1:10,000 scale photography is not entirely adequate, and 1:5000 and 1:3000 scales would be more valuable. The use of 1:3000 over 1:5000 scale air cover is more difficult to justify except in terms of the requirements of engineering and building needs. Indeed, a smaller scale between 1:5000 and 1:10,000 might be equally useful for land use mapping (perhaps 1:7,5000 scale) but this is outside the scope of this research.

So far the discussion in this chapter, which has been of a general nature, can be related to both local scale (1:2500 to 1:10,000) and to regional scale (1:1000,000) mapping. However, with reference to the latter, another point needs to be made - the purpose for such a map must be considered. A map at 1:100,000 scale can do little more than show generalised relationships between fairly large scale items; it cannot show developments within a town for example, on a street by street basis. As a "data store" its applications are limited. If one accepts that the 1:100,000 scale map will give a generalised picture of the relationship of several large scale features, then the method used in this study will, on the whole, be a useful one. Thus the eight items (see Chapter 3) which were identified on Sheet SE42 were sufficiently easy to pick out so that no field checking was done, and the only ground truth against which it was tested was that provided by the West Riding Planning Department for

parts of Areas 1 (Mickletown) and 4 (Pontefract), which covered only 3 sq. km. One further comment should be made about the 1:100,000 scale map SE42. Although care was taken when drawing up, and the number of units mapped was only eight (some of these stylised), the map still lacks clarity, and would probable be better in a coloured form.

The SCOLPA document setting out the terms of reference for this research (see Appendix I) suggests that a possible future use for air survey would be recording and mapping of land use changes. This needs very careful examination, since in Leeds and York the change of use of a building was in many cases very difficult to identify. Collins and El-Beik (1970) quote the examples of two churches in Leeds, one of which had become a computer centre for the University, and the other a furniture factory. The former they failed to identify, at the latter they noted the storage of wood outside, and so were able to infer the change of use. Changing land uses are most common in those parts of the cities where land uses are most difficult to identify - the other, more cramped parts. Here industrial uses change - to storage, offices, shops, and small businesses come and go, uses which are often difficult to identify anyway as they lack distinctive form/function relationships, and there is frequent multiple use of buildings. From the error maps it would seem that the use of air photos in these old central areas of towns and cities is limited, because of the difficulty of identifying land use except in very general terms, and it would suggest that air survey methods can best be employed in suburban areas, and to direct attention to those areas requiring extensive fieldwork.

From the preceding remarks it might seem that air photos have a negligible part to play as a source of information in planning. However, they do provide a large amount of information once the techniques of air photo interpretation have been mastered. When measured against Ordnance Survey Plans they can be prepared quickly, and can be considered

as a form of "data storage" which is readily accessible to sudden demands for information. Their capital cost needs to be assessed against the number of times and purposes for which they are used, and perhaps no real decision can be made as to the benefits and savings that aerial photographs permit until they have been in constant use for a variety of planning problems for some years.

References:

ARMAND, D. L.(1965)
Soviet Geography 6(9) pp. 20-38
The Logic Geographic Classifications and Regionalisation Systems

COLLINS, W. G. and EL-BEIK, A. H. A.(1970)
Photogrammetria 27 pp. 71-92
The Acquisition of Urban Land Use Information from Aerial Photographs in the City of Leeds (G.B.)

GOODIER, R. and GRIMES, B. H.(1970)
Photogrammetric Record 26(36) pp. 553-566
The Interpretation and Mapping of Vegetation and Other Ground Surface Features from Air Photographs of Mountainous Areas in North Wales.

KAYE, G. M.(1970)
G.L.C. Department of Planning and Transportation Intelligence Unit Research Memorandum 251
National Land Use Classification - An Approach

McDONALD, P.I.(1971)
Urban Land Use and the Record of the Aerial Photograph
Unpublished Ph.D. Thesis, University of Leeds

WEBSTER, R. and BECKETT, P. H. T.(1970)
Photogrammetria 26(2/3) pp. 51-75
Terrain Classification and Evaluation Using Air Photography: A Review of Recent Work at Oxford

WITENSTEIN, M. M.(1955)
Photogrammetric Engineering 21 pp. 566-572
Uses and Limitations of Aerial Photography in Urban Analysis and Planning

BIBLIOGRAPHY

AMERICAN SOCIETY OF PHOTOGRAMMETRY (1960)
Manual of Photographic Interpretation
2nd Edition, Washington

AMERICAN SOCIETY OF PHOTOGRAMMETRY (1968)
Manual of Colour Photography
Washington

AMERICAN SOCIETY OF PLANNING OFFICIALS (1951)
Urban Mapping, Aerial Photography and Duplicating: Some Basic Elements
Planning Advisory Service Report No.29

ARMAND, D. L.(1965)
Soviet Geography 6(9) pp. 20-38
The Logic of Geographic Classifications and Regionalisation Systems

AVERY, T. E.(1965)
Photogrammetric Engineering 31 pp. 620-624

BEST, R. H.(1957)
Town Planning Review 28 pp. 191-208
The Urban Area of Great Britain - An Estimate of the Extent of Urban Land in 1950

BEST, R. H.(1958)
Town and Country Planning 26 pp. 426-431
The Loss of Farmland to Other Uses in England and Wales

BEST, R. H.(1958)
Journal of the Town Planning Institute 44(7) pp. 160-164
The Composition of the Urban Areas in England and Wales

BEST, R. H.(1970)
New Society 15 pp. 556-558
Laying the Land Use Myths

BEST, R. H. and CHAMPION, A. G.(1970)
Transactions of the Institute of British Geographers No.49 pp. 15-32
Regional Conversions of Agricultural Land to Urban Use in England and Wales 1945-1967

BRANCH, M. C.(1971)
City Planning and Aerial Information
Harvard U.P., Cambridge, Mass.

BURRY, M. G.(1967)
Town Planning Review 38 pp. 135-150
Air Survey Methods: Their Application to Physical Planning

CHAMBERS 20th CENTURARY DICTIONARY
W. and R. Chambers, 1972

CHILDS, D. R.(1966)
Journal of the Town Planning Institute 52(9) pp. 367-380
Our Changing World: An Introduction to a Combined Exercise in Planning

CHILDS, D. R.(1967)
Journal of the Town Planning Institute 53(9) pp. 416-418
Planning Information for Planners

CLAWSON, M.(1966)
Journal of the American Statistical Association 61 pp. 647-657
Recent Efforts to Improve Land Use Information

COLEMAN, A.(1961)
Geographical Journal 127 pp. 168-186
The Second Land Use Survey: Progress and Prospects

COLEMAN, A. and MAGGS, K. R. A.(1961)
Land Use Survey Handbook
2nd Edition

COLLINS, W. G. and EL-BEIK, A. H. A(1970)
Photogrammetria 27 pp. 71-92
The Acquisition of Urban Land Use Information from Aerial Photographs of the City of Leeds (G.B.)

DAVIS, J. M.(1966)
Uses of Aerial Photos for Rural and Urban Planning
Department of Agriculture Handbook No.315, Washington D.C.

GOODIER, R. and GRIMES, B. H.(1970)
Photogrammetric Record 26(36) pp. 553-566
The Interpretation and Mapping of Vegetation and other Ground Surface Features from Air Photographs of Mountainous Areas in North Wales

HELD, B., STODDARD, C. H. and CLAWSON, M.(1960)
Land for the Future
John Hopkins Press

HOWLETT, B. E.(1963)
Highway Research Record No.19 pp. 1-16
Determining Urban Growth and Changes from Aerial Photograph Comparison

HUSON, J. J.(1970)
International Institute for Aerial Survey and Earth Sciences Series B No.57
Land Utilisation in the Crati Valley (Calabria, Italy). A Study on the Applicability of Medium Scale Air Photos

JOSEPH, S. G.(1957)
Official Architecture and Planning 20(4) pp. 180-184
Aerial Survey and the Planning Officer

KAYE, G. M.(1970)
G.L.C. Department of Planning and Transportation Intelligence Unit
Research Memorandum 251: National Land Use Classification - An Approach

LO, C. P.(1971)
Photogrammetria 27(4) pp. 135-157
A Typologival Classification of Buildings in the City centre of Glasgow from Aerial Photographs

McDONALD, P. I.(1971)
Urban Land Use and the Record of the Aerial Photograph
Unpublished Ph.D. Thesis, University of Leeds

MINISTRY OF WORKS AND PLANNING (1942)
Report of the Committee of Land Uitlisation in Rural Areas
Comment 6378 H.M.S.O.

POWNALL, L. L.(1950)
Photogrammetric Engineering 16 pp. 414-426
Aerial Photographic Interpretation of Urban Land Uses in Madison, Wisconsin

RUSSELL, J. A., FOSTER, F. W. and McMURRAY, K. C.(1943)
Papers of the Michigan Academy of Science, Arts and Letters 21 pp. 315-341
Some Applications of Aerial Photographs to Geographic Inventory

STAMP, L. D.(1948)
The Land of Britain - Its Use and Misuse
Longmans, Green and Co. Ltd., London

STAMP, L. D.(ED)(1966)
A Glossary of Geographical Terms
2nd Edition, Longmans, London

THOMAS, D.(1964)
Journal of the Town Planning Institute 50(10) pp. 434-439
The Components of London's Green Belt

THOMAS, D.(1968)
London's Green Belt
Faber

WEBSTER, R. and BECKETT, P. H. T.(1970)
Photogrammetria 26(2/3) pp. 51-75
Terrain Classification and Evaluation Using Air Photography: A Review of Recent Work at Oxford

WHITE, B.(1970)
Planners and Information
A Report on an Investigation into Information Provision in Town and Country Planning
The Library Association, London

WITENSTEIN, M. M.(1954)
Photogrammetric Engineering 20 pp. 419-427
Photo-sociometrics - The Application of Aerial Photography to Urban Administrative and Planning Problems

WITENSTEIN, M. M.(1955)
Photogrammetric Engineering 21 pp. 566-572
Uses and Limitations of Aerial Photography in Urban Analysis and Planning

APPENDIX I

Yorkshire and Humberside Standing Conference of

Local Planning Authorities

D R A F T P R O J E C T R E P O R T

Pilot Project for the Identification of Land Use (Status and Activity) from Aerial Photographs.

Preamble

In order that the wealth of information obtainable from the aerial photography available to the planning authorities may be fully exploited, it is proposed that the Pilot Project specified in the following pages should be undertaken. This will provide the authorities with a tested methodology for the interpretation of land use (status and activity) for the wider area for which aerial photography is, and may in future, be available.

This experimental project will draw on the aerial photography of Dr. Collins and other University researchers, and the practical planning expertise of the participating authorities planning staff.

The area chosen for the pilot study is probably unique in the range of land use (status and activity) types and scales of photography available, and should provide a particularly valuable contribution to the methodology available to the planning authorities in fulfilling their functions.

However, the limitations of aerial survey must be recognised, and it is acknowledged that the project will not show all the information required by planners, but it will enable concentration of manpower resources in the field to limited areas, e.g. areas of mixed use and rapid change.

Steering Committee

Chairman: R.R. Rhodes

Dr. W.G. Collins

J. Casson

F.W. Forster

G.G. Newman

K. Walker

N.C. Wood

Contents

1. Objectives

The principal objective of the Pilot Project: to develop and test a methodology for the identification of land use (status and activity) from aerial photographs for planning at regional and local scales; to enable the specification of a methodology and notation for (a) the production of a regional scale land use (status and activity) map at 1/100,000 scale, (b) the production of land use (status and activity) maps at a local plan scale of 1/5,000.

A further objective will be to record changes in land use (status and activity) at regional level in the pilot area, using 1966 and 1971 air cover to test the effectiveness of the methodology as a means of identifying changes in land use/activity.

2. Subsequent Utilisation

The Pilot Project will concentrate on land use (status and activity); the results of the study can then be applied to a variety of planning tasks e.g.:-

(i) the production of land use (status and activity) maps at regional scale (1/100,000) and local scale (1/5,000) for general application over a wider area; these maps would provide the essential maps for assessing changes.

(ii) the identification of changes in land use (status and activity) between 1966 and 1971 at regional and local levels over a wider area.

(iii) the drawing of preliminary conclusions regarding data storage requirements for maintaining and monitoring land use records from interpretation of aerial photographs and interfacing with other records e.g. Census data.

3. Area of Pilot Project

An area between Leeds and Selby covered by six 100 kilometre squares on $2\frac{1}{2}$" scale O.S. maps SE 32, 33, 42, 43, 52, 53; this provides a wide range of land use (status and activity) types and scales of aerial photographs.

4. Classification

Extraction of information to be for smallest identifiable units of land use/activity for each appropriate scale of photography available.

Dr. Collins to ensure that account is taken of customer requirements as indicated on copies of the "West Riding Land Use/Activity Coding Manual" (February 1971), viz., an annotated version provided by Mr. Forster, a note by Mr. Casson (July 1971) for broad regional purposes; a note by Mr. Wood (21st July 1971) for Urban Structure and Local Plans.

5. Output

An Interim Report - produced six months after commencement should provide tentative information on unit costs of interpretation, as a guide to urban, sub-urban and country land use, enabling a parallel regional study to be initiated as a separate exercise.

The Final Report on the Pilot Project should comment on data obtained, the form in which recorded, accuracy levels and the techniques employed. It would include:-

(i) an operational manual, including keys, comprised of annotated stereoscopic aerial photographs to show examples of each land use (status and activity)

(ii) Maps showing the boundaries of the smallest identifiable land use (status and activity) units, a land use (status and activity) code, areas (in hectares) and an indicator of confidence levels - one set of land use maps covering selected parts* of the pilot area, comprising maps at scales of 1/2,500,1/5,000 and 1/10,560, showing 1971 detail, and one set of 1/10,560 scale maps, covering the selected areas showing 1966 detail.

(iii) as Appendices - Appendix 1, maps for the selected parts of the pilot area to a scale of 1/100,000 showing land use in accordance with a regional notation, one map showing the 1966 situation and one showing 1971 detail; Appendix 2, maps for the selected parts of the pilot area to a scale of 1/5,000 showing land use in accordance with a local plan type notation showing 1971 detail.

Other forms of output

Magnetic tape output should be investigated as this may facilitate computer analysis and classification manipulation (this form of analysis is expected to be available from parallel research work in the University and would not, therefore, influence the cost of the project).

6. Materials Required

Photographs and maps for the selected parts of the six 100 kilometre

*e.g. 5-8 1/2,500 maps for 1/3,000 air cover, 4-6 1/5,000 cover, and two 6 inch O.S. sheets for 1/10,500 cover.

square area at the three relevant scales, i.e. 1/3,000, 1/5,000 and 1/10,560, provision as follows:-

1971 Photographs (at all three scales) - special set for the selected parts of the project area

1971 maps - 1/10,560 scale maps for the selected parts of the West Riding area to be provided by the West Riding, 1/2,500 scale maps of the selected parts of the Leeds part of the area to be provided by Leeds

1966 photographs (1/10,560 scale) to be loaned by the West Riding

1966 maps 1/10,560 scale maps to be provided by Leeds and the West Riding for their respective parts of the project area

7. Ground Checks

Field or other accuracy checks of known land use/situation as at time of aerial photography, to be carried out by Leeds and the West Riding for sample areas of urban development, dereliction and country areas, for units identifiable at a map scale consistent with the scales of the 1971 photography.

8. Means

The Pilot Project to be a research commissioned from and directed by Dr. Collins, Department of Civil Engineering, University of Aston, Birmingham.

9. Timing

The period of the project to be from 1st October, 1971 to 31st September, 1972, including the completion of Appendices 1 and 2.

10. Other Resources

The provision and cost of offices, facilities and equipment, e.g. digitiser, sketchmaster, stereo-viewers, computer facilities, and the expertise of other University researchers would be provided by the University of Aston.

APPENDIX II

LOCAL PLAN - LEEDS CITY

H: RESIDENTIAL	Code
Domestic Residential	H1
Hotels, Hostels, etc.	H2
Holiday Camps	H3
Caravan Sites	H4
Other Residential Establishments	H5

HW: HEALTH & WELFARE	
Hospitals	HW1
Clinics	HW2
Others	HW3

E: EDUCATION (NON-RESIDENTIAL)	
Schools	E1
Further Education	E2

OS: OPEN SPACE	
Golf Course	OS1
Race Course	OS2
Racing Track	OS3
Games Areas	OS4
Other Sports	OS5
Parks	OS6
Children's Play Areas	OS7
Amenity Spaces	OS8
Open Air Swimming Baths	OS9
Boating Pools	OS10
Allotments	OS11
Other Recreational Spaces	OS12
Cemeteries	OS13

A: PLACES OF ASSEMBLY	Code
Public Halls	A1
Community Centres	A2
Cinemas & Theatres	A3
Clubs	A4
Sports Stadium	A5
Indoor Sports Facilities	A6
Religious Assembly	A7
Libraries, Museums, Art Galleries	A8
Others	A9

P: OTHER PUBLIC SERVICES & SPECIAL ESTABLISHMENTS	
Police Stations	P1
Fire Stations	P2
Law Courts	P3
Others	P4

R: ROAD TRANSPORT	
Roads	R1
Bus or Coach Station	R2
Bus Depots & Taxi Garages	R3
Haulage Depots	R4
Car Park	R5

O: OPEN COUNTRY	
Agriculture	01
Horticulture	02
Forestry and Woodland	03

MW: EXTRACTIVE INDUSTRY	Code
Surface Working	MW1
Mining	MW2
I: MANUFACTURING INDUSTRIES	
Food, Drink, Tobacco	I1
Coal & Petroleum Products	I2
Chemicals & Allied Industries	I3
Metal Manufacture	I4
Mechanical Engineering	I5
Instrument Engineering	I6
Electrical Engineering	I7
Shipbuilding, Marine Engineering	I8
Vehicles	I9
Other Metal Goods	I10
Textiles	I11
Leather Goods & Fur	I12
Clothing & Footwear	I13
Bricks, Pottery, Glass, Cement, etc.	I14
Timber, Furniture, etc.	I15
Paper, Printing, Publishing	I16
Other Manufacturing	I17
U: UTILITIES	
Electricity	U1
Gas	U2
Water	U3
Sewage Disposal	U4
Refuse Disposal	U5
Telephone & Telegraph	U6
Radio & T.V.	U7

W: ACTIVE WASTE TIPPING	Code
Mining & Quarrying Waste	W1
Other Industrial & Non-Domestic Waste	W2
Domestic Waste	W3
D: DERELICTION	
Disused Colliery Spoil Heaps	D1
Other Disused Spoil Heaps	D2
Disused Tipping in Excavation	D3
Abandoned Quarries & Mineral Workings	D4
Other Derelict Land	D5
Derelict Buildings & Installations	D6
S: SALES & SERVICES	
Retail Shops	S1
Wholesale Establishments	S2
Service Establishments	S3
ST: STORAGE/WAREHOUSING	ST
B: OFFICES	B
T: OTHER TRANSPORT FACILITIES	
Rail Transport	T1
Air Transport	T2
Water Transport	T3

APPENDIX III

REGIONAL - WEST RIDING

Draft coding headings for 1/100,000 Regional Land use survey backed by 1/25,000 data map storage and interpreted from 1/10,000 and 1/5,000 aerial photographs.

Dates of Survey 1971 and possibly 1966 (to measure subsequent changes).

A. Natural and Semi-Natural (Status predominant)		Code
1. Water (excl. canals)	(a) Natural freshwater	A1a
	(b) Sea (incl. tidal estuaries)	A1b
	(c) Impounded and artificial bodies of water, e.g. reservoirs	A1c
	(d) Marsh, bog and semi-wetlands (fresh)	A1d
	(e) Saltmarsh, and salturf	A1e
	(f) Esturial mud	A1f
2. Sand Dune	(a) Unvegetated	A2a
	(b) Vegetated (possibly separate marran pioneers)	A2b
3. Rock Outcrop	(a) Limestone	A3a
	(b) Sandstone (sedimentary) and Shales	A3b
	(c) Igneous	A3c
4. Soil exposure	Natural surface eroded by water, wind, pollution or intensive use. (OVERPRINT)	A4
5. Moorland	(a) Heath	A5a
	(b) Acid (Peat Moss)	A5b
	(c) Calcareous	A5c
	(d) Calluna/Erica (Heather/Ling, etc.)	A5d
6. Woodland - Areas over 1000m^2	(a) Natural, scrub, thicket, etc.	A6a
	(b) Mixed	A6b
	(c) Hardwood	A6c
	(d) Softwood	A6d
	(e) Felled	A6e
	(f) New Plantation - canopy not closed (OVERPRINT If identifiable)	A6f

B. Agricultural (Status and activity)

Pasture - not ploughed 1970/71 and under grass, clover or other fodder crop standing more than one season — B7

7. Farmland - ploughed 1970/71 and under crops other than grass — B8

8. Horticulture		
	(a) market gardening and nursery	B9a
	(b) orchard - trees and shrubs	B9b
	(c) glass	B9c

9. Intensive - independent housing units and buildings

Buildings associated with 7, 8 and 9 should fall within the main use of the unit (including living accommodation)

C. Extractive (Activity and status)		Code
10. Dereliction and Extractive Industry - Spoiled and Degraded Land.		
Heaps	(a) Active	C11a
	(b) Disused	C11b
Holes	(c) Active	C11c
	(d) Disused	C11d
	(e) Tipping and Backfilling	C11e
Ground Level	(f) Vegetated	C11f
	(g) Unvegetated	C11g

10. requires consideration of separate county survey level and detail of district level as well as compatibility with Bush method.

D. Built or Developed (by construction works) - (Activity predominant/uses)

11. Transportation/Communication		
	(a) Roads	D12a
	(b) Car Parks	D12b
	(c) Railways	D12c
	(d) Airfields	D12d
	(e) Harbours and Landings	D12e
	(f) Canals	D12f
	(g) Surface Aquaducts	D12g
	(h) Power Lines (Electric)	D12h
	(i) Radio, Radar, Telephone, etc.	D12i
12. Power/Energy - (Power Stations, Gas, Oil, etc., Collieries)		D13
13. Water Works-(including pumping stations - excluding open reservoirs)		D14
14. Sewage Works - (including pumping stations and tanks for sewerage)		D15
15. Recreation	(a) Parkland/open spaces apparently open to public	D16a
	(b) Golf Courses	D16b
	(c) Games areas (pitches, running tracks, stadia, etc.)	D16c
	(d) Racecourses	D16d
	(e) Caravan Sites	D16e
	(f) Camping Sites	D16f
	(g) Other, e.g. shooting ranges	D16g
16. Residential		D17
17. Education		D18
18. Storage/Warehousing		D19
Manufacturing		D20
Business - Shops		D21
Offices with public access		
19. Administration		D22
20. Mixed - where no use predominates in concentrated urban areas		D23

APPENDIX IV

PROJECT ASTON

ITEM	PROJECT NOTATION	LOCAL PLAN NOTATION EQUIVALENT
Agricultural land	Aa	01
Farm buildings (incl. house)	Ab	01/H1/ST
Factory farm buildings	Ac	01/ST
Horticulture/nursery gardens	Ad	02
Tree-covered areas	Ae	03
Marsh	Af	D5/T3
Rivers/streams/lakes	Ag	T3
Formerly covered by trees	Ai	03/D5
Glasshouses	Aj	
Orchards	Ak	
Ruined buildings	Ba	D6
Colliery buildings	Bb	MW2
Colliery tip heap	Bc	W1/D1
Sand and gravel workings	Bd	MW2
Cleared land	Be	D5
Derelict railway (track removed),	Bf	T1/D5
Colliery sludge pit	Bg	W1/MW2
Landscaped tip heaps	Bh	D1
Waste ground associated with colliery	Bi	D5/MW2
Waste ground associated with sand & gravel	Bj	D5/MW2
Disused sewage works	Bk	U4/D5
Tipping (material unspecified)	Bl	W2
Sewage sludge pit	Bm	U4
Tipping to reclaim opencast working	Bn	W2/MW1
Opencast working	Bp	MW1
Ground associated with opencast working	Bq	MW1/D5

ITEM	PROJECT NOTATION	LOCAL PLAN NOTATION EQUIVALENT
Brick clay pit	Br	MW1
Wire works	Cb	I10
Metal works	Cc	I4
Light manufacturing	Cd	I
Heavy manufacturing	Ce	I
Works for coal loading	Cf	I2
Scrap metal works	Cg	I10
Chemical works	Ch	I3
Wood processing	Ci	I15
Brewery	Cj	I1
Brick works	Ck	I14
Malthouse	Cl	I1
Shops	Da	S1
Warehousing/storage	Db	ST
Scrapyard	Dc	I4/D5
Garage	Dd	S3
Offices	De	B
Coal dump	Df	ST/I2
Wood storage	Dg	ST/I15
Petroleum storage depot	Dh	ST/I2
Pub	Di	S3
Greenhouse/garden shed shop	DI	S1
Car dump	Dn	I4/D5
Haulage firm	Dp	R4
Builder's yard	Dq	S2
Metal storage	Dr	ST/14
Market (covered)	Ds	S1
Market (open)	Dt	S1

ITEM	PROJECT NOTATION	LOCAL PLAN NOTATION EQUIVALENT
Detached housing	Ea	H1
Semi-detached housing	Eb	H1
Terraced housing	Ec	H1
Back to back housing	Ed	H1
Blocks of flats	Ee	H1
Halls of residence	Ef	E2/H5
Church	Fa	A7
Hospital	Fb	HW1
Club (sports)	Fc	A4/A6
Cinema, Theatre	Fd	A3
Hotel	Fe	H2
Club	Ff	A4
Rugby stadium	Fi	A5
Football stadium	Fj	A5
Library	Fk	A8
Cultural ruins	Fl	A9
Old people's home	Fm	H5
Schools	Ga	E1
Nursery Schools	Gb	E1
Allotments	Ha	OS11
Bowling green	Hb	OS4
Cricket ground	Hc	OS4
Playing field (multiple use)	Hd	OS4
Tennis court	He	OS5
Rubgy ground	Hf	OS4
Football ground	Hg	OS4
Playground	Hh	OS7
Park	Hi	OS6
Greyhound track	Hj	OS5
Golf course	Hk	OS1

ITEM	PROJECT NOTATION	LOCAL PLAN NOTATION EQUIVALENT
Cemeteries	Hl	OS13
Open ground - apparently unused	Hm	D5
Yards	Hn	Hl/ST
Hockey pitch	Hp	OS4
Car park	Ia	R5
Railway	Ib	Tl
Railway station (passenger)	Ic	Tl
Goods station	Id	Tl
Canal	Ie	T3
Gas works	If	U2
Sewage works	Ig	U4
Verge/roundabout/cutting along road	Ih	Rl
Railway cutting/embankment	Ii	Tl
Locks	Ij	T3
Power plant associated with manufacturing industry	Ik	U/I
Telephone exchange	Il	U6
Water storage for colliery	Im	U3/ST/MW2
Paved "square"	In	OS8
Bus depot	Ip	R3
Disused railway (track remaining)	Iq	Tl/D5
Bus/coach station	Ir	R2
Generating station	Is	Ul
Wharf	It	T3
Reservoir	Iu	U3/ST
Building plots - residential	Ja	U/C Hl
Building plots - non-residential	Jb	U/C
Land associated with building plots	Jc	D5/U/C