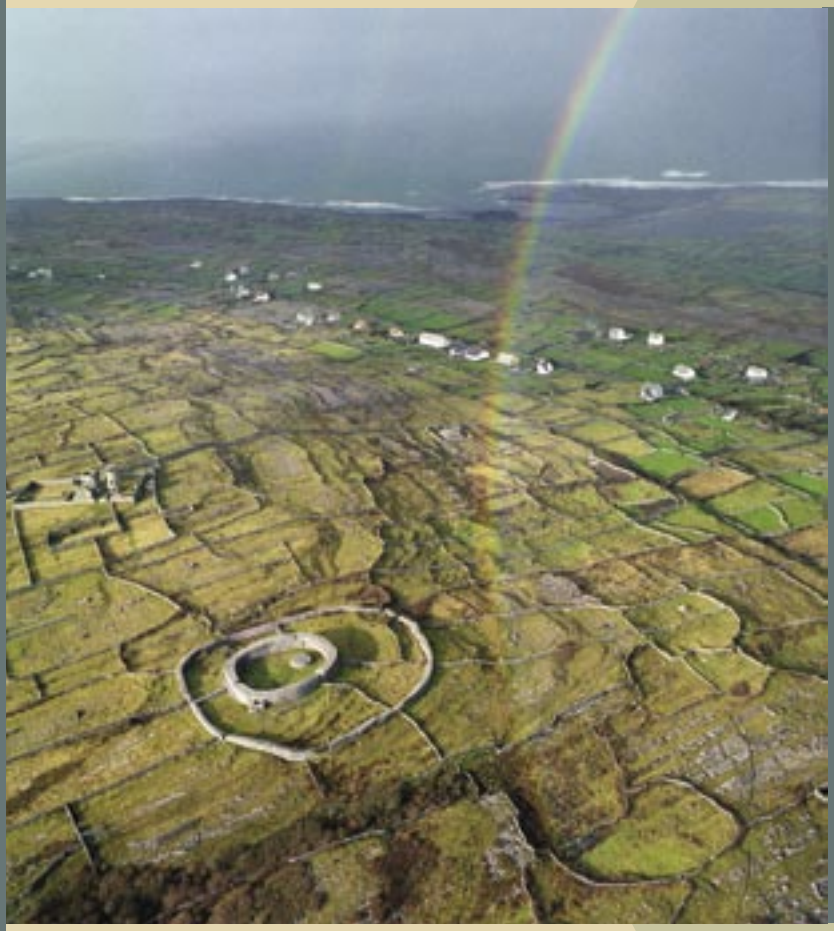


AIR AND EARTH

Aerial Archaeology in Ireland

A Review for the Heritage Council
By George Lambrick

An Chomhairle Oidhreachta
The Heritage Council

AIR AND EARTH

Aerial Archaeology in Ireland

A Review for the Heritage Council

George Lambrick

An Chomhairle Oidhreachta
The Heritage Council

Published by The Heritage Council

The Heritage Council of Ireland Series

ISBN 978-1-906304-03-4

Price €15.00

Designed and Produced by
B. Magee Design

Editorial Consultant: Roberta Reeners

Printed on Recycled paper containing a minimum of 75% de-inked post consumer waste.

CONTENTS

LIST OF FIGURES

Foreword

One of the initiatives identified by the Heritage Council's Strategic Plan 2007-2013 is that archaeological research issues and practice in the widest sense should be more overtly and consistently identified and from time to time reviewed. These research issues should also engage more with what both specialists and local communities find interesting about the past. To contribute to this the Heritage Council commissioned Mr George Lambrick to examine aerial archaeology in Ireland. Aerial Archaeology is the practice of using aircraft (or in some cases satellites) to provide a high-level view of the landscape based on conventional photography and a range of remote sensing technologies. That review is presented here.

The Heritage Council thanks the author and those who allowed their images to be produced. The Council hopes that this report will demonstrate that aerial archaeology has a fundamental role in the discovery, understanding, management and presentation of Ireland's historic landscapes.

Michael Starrett

Preface

The project on which this book is based began in 2001/2 and the results initially presented in 2003 have been updated in the light of various stages of discussion and consultation, notably a very informative day conference held in December 2005 and subsequent public consultation, which was one of various initiatives that stemmed from the initial conclusions of the study. During the final preparation for publication, further updating has taken place. Over this long gestation period the picture of aerial archaeology in Ireland has changed, with several research initiatives by the Discovery Programme, Universities and the Heritage Council and greater use in major infrastructure developments such as road schemes. Some of this work has been developing and using cutting edge methodologies.

Externally, commentators still see Ireland as a country where there has not been much interest in using and developing aerial archaeology (Musson and Horne 2007, 4, 68). As this book seeks to show, this is far from true. But questions nevertheless remain as to whether aerial archaeology can yet be considered to be as firmly embedded in mainstream research and management of the heritage in Ireland as it deserves to be. While external perceptions may well reflect insufficient exposure of what has been achieved to international audiences, it is also the case that there are still problems of relative inaccessibility to some key sources of aerial imagery and more training and collaboration between practitioners and national bodies responsible for research and heritage management is needed. It is hoped that this book will help raise awareness of how the foundations that have already been laid can be used to build more strategic approaches to maximise the considerable potential of aerial archaeology for discovering, interpreting and presenting Ireland's rich heritage.

Acknowledgements

It would not have been possible to research and write this book without the generosity of the many people listed in the appendix at the end who have shared their expertise, experience and opinions with me. It will be noted from the picture credits that many of these individuals and organisations have also kindly provided the images that illustrate the book. I would also like to thank Roberta Reeners who has been an effective editor. I am particularly grateful to the Heritage Council for commissioning the project and especially Dr Charles Mount and Ian Doyle, who as successive Archaeology Officers have been most helpful and supportive in innumerable ways.

George Lambrick
February 2008

SUMMARY AND RECOMMENDATIONS

Background

What is Aerial Archaeology?

Aerial archaeology is the practice of using aircraft (or, in some cases, satellites) to provide a high-level view of the historic environment based on conventional photography and a range of remote sensing technologies. It is relevant to all stages of archaeological work – reconnaissance, interpretation, analysis, publication and dissemination, and is one amongst many methods. All periods, from the Neolithic to the present day, are potential subjects of interest. Aerial archaeology relates to all forms of survival (cropmarks, soilmarks, earthworks, structures, buildings, landscapes and townscapes). It is useful for research, conservation, development control (both strategic and site-specific), education and public outreach. It has a uniquely sensitive capability of recording evidence of the past at a landscape scale – and is applicable to all landscape types.

History of Irish Aerial Archaeology

The first application of aerial archaeology in Ireland was a 1927 initiative of the Ancient Monuments Board in Northern Ireland working with the RAF. Raftery (1944) cited the first use of archaeological air photography in the Republic in 1934, and called for 'proper collaboration in surveying... archaeological sites all over this country'. In the 1950s, the National Monuments Advisory Council commissioned aerial archaeological surveys by the Air Corps. J.K. St Joseph undertook two main campaigns of flying in Ireland – in 1951-5, and more particularly 1963-73. From the 1970s onwards, much has been done by the Ordnance Survey Ireland (OSi), Geological Survey of Ireland (GSI), the Office of Public Works (now the National Monuments Section/NMS of the Department of the Environment, Heritage and Local Government), and individuals (the late L. Swan, D. Pochin Mould, G. Barrett and others). From the 1980s onwards, aerial archaeology has been carried out increasingly in the context of research through the Discovery Programme and some academic initiatives, enhancement of the national Sites and Monuments Record (SMR), and development-led archaeology for pipelines and road schemes.

Making the Most of Aerial Archaeology

The Irish archaeological resource is characterised by a wide variety of field monuments. Aerial archaeology is an excellent means of identifying less well-known and hidden aspects of monuments, carrying out surveys, and research and presenting Ireland's rich heritage to the public. Recent pre-development archaeological work has continued to highlight the large numbers of sites and monuments with little or no above-ground visibility that, in many cases, are unlikely to be revealed by other methods. The use of aerial survey for coastal and marine heritage is also increasingly important.

In the face of the pressure of major development and land-use change but limited resources for new survey, the rapid technical developments in aerial survey make it a crucial and increasingly cost-effective means of detecting sites and monuments to enhance the archaeological record, carrying out basic surveys, and monitoring the condition of monuments. It is also an ideal means of recording the historic character of the Irish countryside and many urban areas. Accordingly, aerial archaeology has a fundamental role to play in the discovery, management and presentation of Ireland's heritage.

Key Priorities for Aerial Archaeology in Ireland

Following a public seminar in December 2005 and a lengthy period of consultation in 2006, the following priorities have been identified:

1. Establish a steering group to champion the value of aerial archaeology and develop initiatives to progress the work identified in this report (Recommendation 1).
2. Provide an online guide and improved access to existing sources of aerial photography and remote sensing (Recommendation 2).
3. Do more to define and promote best practice standards and provide training (Recommendations 3 and 10).
4. Reinforce and supplement the work of the Archaeological Survey of Ireland to enhance the capture of existing data and undertake new reconnaissance (Recommendations 4, 5, 7 and 8).

Work undertaken in these areas, or developing from them, will also have major benefits for improved strategic collaboration in the management of environmental change. This includes the potential for attracting more partnership funding through strategic studies (Recommendations 4, 5, 7 and 8). There are also likely to be benefits for the development of inter-disciplinary approaches to conservation and research (Recommendation 6) and greater public awareness of Ireland's heritage (Recommendation 9).

The main possible initiatives identified in relation to each recommendation, as well as those listed at the end of this summary, are intended to be of strategic value in making the most of the particular strengths of aerial archaeology for a variety of purposes. It is unlikely that all of the suggested action points under each recommendation could be pursued simultaneously. It is important to note, however, that enhanced benefits are likely to be gained through an integrated approach. The benefits of pursuing such initiatives would extend far beyond the restricted confines of this particular methodological approach.

Co-ordination and Development of New Initiatives

It was not within the scope of this study to initiate the discussions that would be necessary to develop the suggested action points needed to pursue each recommendation. The first key point is to establish the means by which such initiatives can be developed. The Heritage Council needs to play a key role in developing this in collaboration with other bodies.

Recommendation 1: Establish a Steering Group to co-ordinate initiatives which maximise the public benefits to be gained from aerial archaeology, both for knowledge and understanding, and the conservation and management of the historic environment in Ireland.

- *The range of suggested initiatives will maximise the public benefits of aerial archaeology in a manner that is fully integrated with broader research, conservation and outreach objectives. These initiatives will need to be developed and co-ordinated by a small group of specialists who are charged with developing outward-looking, interdisciplinary and collaborative projects which are supported by multiple sources of funding.*

  Key organisations – Heritage Council; Royal Irish Academy; NMS

Archival Sources of Aerial Archaeology

Maintaining and updating aerial photographic archives, as well as ensuring good public access to them, is fundamental to ensuring maximum benefit from them. The main public collections are the Ordnance Survey Ireland (OSi), the National Monuments Section (NMS) of the Department of the Environment, Heritage and Local Government (DoEHLG), the Geological Survey of Ireland (GSI), the Air Corps, the Marine Institute, the National Museum of Ireland and local authorities. Research collections include those at Cambridge and some other universities (*e.g.* Cork), and the Discovery Programme. Private collections include those of Swan, Pochin Mould, Barrett and others, together with private archaeological contractors. Commercial collections include Aerofilms, BKS Surveys, the former Fairey and Hunting Surveys and some other companies. Some of the most comprehensive collections are not among those which are most easily accessible. Despite this wealth of archival material, there is no comprehensive national guide to sources of existing aerial archaeology such as the guide to National Air Photographic Libraries in the UK. Access is often problematic.

Recommendation 2: Greater support is needed for maintaining and updating aerial photographic archives and facilitating public access.

- *An online guide to air photographic collections in Ireland should be developed which recognises their value for multiple user groups.*

  Key organisations – Heritage Council; DoEHLG; Society of Surveying, Photogrammetry and Remote Sensing

- *NMS should be funded to increase staff resources to incorporate the results of the growing yield of air photography into the SMR.*

  Key organisations – NMS

- *Support for the OSi and NMS is required to develop better public access to their air photographic collections. This would be done through: ongoing work in digitising air photographs which are generated by publicly funded surveys; developing digital indexes and GIS systems; and better search room facilities for material not made available digitally.*

  Key organisations – OSi; NMS

Methods and Standards

A wide variety of methods and standards of aerial photography – in addition to remote sensing, interpretation and mapping – are suitable for different purposes. While there is much experience of varied uses and applications in Ireland, there is no practical handbook which highlights the strengths and limitations of different approaches for different purposes. Such a handbook would provide practical guidance or set out generally recognised standards of best practice. The broad-brush review presented in this report (together with case studies and publications referred to and/or presented at the conference in December 2005) provides a possible framework of applications within which more practical guidance might be developed. Other technical papers such as those published by the Aerial Archaeology Research Group (AARG), as well as summaries of legal and safety issues, also need to be considered. The adoption of recommendations concerning other issues set out below may also contribute to this process, and it should be seen as needing periodic up-dating, not simply a one-off publication.

Recommendation 3: Models of current best practice in the methods used in aerial photography and remote sensing in archaeology and heritage management should be developed and disseminated.

- *A practical handbook in archaeological aerial photography and remote sensing in Ireland and other means of promoting best practice (see also Recommendation 10) need to be developed.*

  Key organisations – Heritage Council; Royal Irish Academy in collaboration with Institute of Archaeologists of Ireland; DoEHLG; AARG

The Value of Reconnaissance and Potential for Updating the Record

The discovery of additional earthwork remains is affected by reconnaissance altitude, lighting and vegetation. Cropmark sites are affected by seasonal weather and cropping patterns, and their discovery is cumulative over several 'good' years, not single exceptional years. The 'yield' of new discovery is further affected by levels of reconnaissance. Documented cases in Ireland indicate 50% to 400% increases in site identification from thorough desk studies and/or reconnaissance. There is some material in private – and some public – collections and archives which is not covered in the original compilation of the national SMR which, of necessity, focused on the main sources. There is significant scope for enhancing the record, both from archival material and new reconnaissance, but efforts need to be clearly targeted on key areas and issues, and undertaken in ways that systematically help to clarify the nature of the evidence. For example, it would be useful if all new initiatives were tasked with identifying and mapping inherent trends and distortions in the pattern of aerial discovery (especially in respect of cumulative observations and possible reasons for absence of evidence), both as an indication of reliability of evidence and potential areas needing further aerial reconnaissance.

Recommendation 4: Further work is needed to assess the full potential for enhancing the SMR from as yet unarchived aerial photographic material and recent surveys, and to develop a strategy for new reconnaissance.

- *A strategic policy for new aerial reconnaissance for archaeology in relation to land-use change should be developed and agreed. This should include the potential for developing specific projects focussed on key areas and issues.*

  Key organisations – Heritage Council; DoEHLG (Planning); NMS; Representatives of local authorities and other land-use regulators

Interpretation and Mapping

Archaeologists would like to see more effort put into detailed mapping and interpretation of evidence from aerial archaeology. Some innovative work is being done in Ireland, for example by the Discovery Programme and others, including Redfern (1998, 2002), and Shell and Roughley (2004); a range of other methods is being used by practitioners. While it may not yet be realistic to embark on a major national mapping programme such as that which exists in England, it is important that progress be made in this area. The Discovery Programme and other research bodies define their own research-led needs. In relation to more general purposes, minimum standards for mapping and presentation of the results of aerial survey need to be developed to ensure that results are commensurate with the main uses to which the data will be put. For example, in relation to regulating development and land-use change, interpretive mapping might be less detailed than would be needed for a major research project.

Recommendation 5: Further development of mapping (rectification, transcription, image enhancement and integration with terrain models) should be encouraged, and a strategy developed for strategic mapping of the results of aerial reconnaissance in areas under pressure of development, especially where subject to Strategic Environmental Assessment (SEA).

- *As part of work arising from this report's other recommendations, priority should be given to enhanced GIS-based mapping of existing and new imagery of sites in areas under significant pressure of development or other land-use change.*

  Key organisations – NMS; various

Research

Norman and St Joseph (1969) showed how aerial archaeology could contribute to several research themes. From the late 1970s onwards, aerial archaeology has been an important element of some research projects within these themes (e.g. prehistoric settlement; early ceremonial centres). The Discovery Programme in particular has adopted an explicit policy of integrating aerial archaeology into its projects. There are several instances in which aerial archaeology has played an important role in large projects, some of which have lasted for over a decade. It can often be the initial clue from which fundamental advances in research spring. Despite this, and although it could make a valuable contribution, aerial archaeology is still not seen as having a mainstream role in much archaeological research in Ireland. Current concepts of landscape archaeology and historic landscape characterisation leave a gap in holistic studies at farm or sub-townland level. Aerial archaeology is ideally placed to help fill such gaps.

Recommendation 6: In the light of the proven research value of aerial archaeology, existing models of good practice should be emulated and developed in future programmes, thereby maximising new opportunities.

- *Bodies which fund archaeological research should continue to develop topics that have benefited particularly from previous aerial reconnaissance (e.g. early medieval settlements revealed by cropmarks); or for which particular potential is offered by new technical developments in aerial archaeology (e.g. freshwater, coastal and inshore areas); or where particular insights into long-term social and environmental change may be gained (e.g. multi-period complexes; historic landscape characterisation).*

  Key organisations – Royal Irish Academy; Heritage Council; Royal Society of Antiquaries of Ireland; Discovery Programme

Aerial Archaeology in Development Planning

Unlike big infrastructure projects, smaller scale developments are seldom the subjects of aerial archaeology. Yet it is these very developments which may have an incremental effect on larger areas (especially urban expansion and minerals). While the timing of individual developments may not suit the conditions required for successful aerial reconnaissance, recent national statistics on construction output indicate rapid and continuing growth in the pressure of development. Aerial archaeology's potential has not been fully realised in the strategic survey of earmarked areas or those which may be threatened by development. The use of aerial archaeology for major development – especially roads – has been growing rapidly, and lessons might be learned from this. The EU Strategic Environmental Assessment Directive also gives a new impetus for encouraging the use of aerial archaeology in strategic planning.

Recommendation 7: The considerable potential for aerial archaeology's contribution to strategic land-use planning should be examined through a series of pilot studies.

- *A series of pilot studies covering different types of development threats and different areas should be developed. In collaboration with, and partly funded by, relevant regulatory authorities and industry, these studies would examine the value of, and establish basic methodologies for, the review of aerial archaeology as a key means of enhancing baseline knowledge of areas potentially affected by development.*

  Key organisations – DoEHLG (Planning and NMS); relevant local authorities; relevant industry representative bodies; other specialist bodies

Rural Land-use Planning and Monitoring Monument Condition

The Archaeological Features at Risk Surveys (AFARS) grant-aided by the Heritage Council, as well as other surveys of monument condition commissioned by the NMS, have emphasised the pressures on many rural areas from non-development changes in land use. These studies highlight the need for better monitoring of pressures created by land-use change and the need to monitor the condition of sites and monuments. The destruction of known sites has accelerated dramatically, often as the result of land improvements for intensive farming. The potential contribution of aerial archaeology emphasises that SMR and Inventories of monuments are only starting points for assessing the whole historic environment of a land holding, especially since reviews of existing air photographs and/or new reconnaissance are likely to reveal significantly more sites. Aerial archaeology provides a more holistic perspective on the historic character of the landscape, in terms of both extant and relict features – including field patterns. The quality of both satellite imagery and low-altitude aerial photography (such as that undertaken to illustrate the Inventories and research projects) indicates that there is a potential for condition monitoring.

Recommendation 8: Aerial archaeology's potential contribution to achieving a better understanding of the historic character, and to monitoring the condition of the rural and maritime environment, should be developed to identify needs for future management.

- *Remote sensing and low-level aerial surveys should be carried out to: (a) enhance previous monument condition surveys; (b) develop methods for nationwide monitoring of rural environment pressures; and (c) monitor adherence to Rural Environmental Protection Scheme (REPS) agreements.*

  Key organisations – DoEHLG and the Heritage Council, in partnership with the Department of Agriculture and Food

- *The results of recent surveys of inshore waters and coastal areas should be reviewed to consider the implications for incorporating results into the Record of Monuments and Places and developing a strategy for the management of coastal and maritime heritage.*

  Key organisations – DoEHLG Underwater Archaeology Unit; Heritage Council; in collaboration with the Geological Survey of Ireland and Marine Institute

Publication and Public Outreach

This study has found examples of excellent exhibitions and publications which make good use of aerial archaeology and which are clearly appreciated by the public. However, it is noted that Norman and St Joseph (1969) commented on the limited use of aerial archaeology in two standard text books – and the latest equivalents are, if anything, worse. Archaeological textbooks and books for the general reader could make more use of the results of aerial archaeology.

Recommendation 9: The results of aerial archaeology should be communicated more effectively to the public, students and practitioners through books, exhibitions and other media.

- *A new travelling exhibition on aerial archaeology and landscape should be commissioned.*

  Key organisations – Heritage Council; NMS; Royal Irish Academy

Organisation and Training

Despite the growing interest in and practice of aerial archaeology, there is little formal exchange of experience and training.

Recommendation 10: Better opportunities for training and the exchange of views and expertise in aerial archaeology in Ireland should be developed.

- *Following the public seminar initiated by the Heritage Council in December 2005, there should be further conferences on aerial archaeology in Ireland to initiate greater exchange of ideas and experience.*

  Key organisations – Heritage Council; Aerial Archaeological Research Group; Irish Society of Surveying, Photogrammetry and Remote Sensing

- *The possibility of holding regular (e.g. annual?) regional training workshops in aerial archaeology should be explored.*

  Key organisations – Heritage Council; Institute of Archaeologists of Ireland; Discovery Programme

Other Specific Initiatives

A range of more specific possible initiatives, each of which would help to take the foregoing recommendations forward, is set out below.

1 Assess the gain in archaeological sites which have been identified from desk studies using archival air photography and from new reconnaissance for road schemes in relation to outcomes of fieldwork.

  Key organisations – National Roads Authority; NMS

2. Review the sample areas covered by the AFARS and other monument condition surveys. This is required to assess the completeness of SMR coverage of archival air photography. Undertake new low-level aerial reconnaissance of these areas to assess the potential for enhancing the data.

  Key organisations – Heritage Council; NMS

3. Assess private air photographic collections to establish how much archaeology they cover that is not otherwise recorded in the SMR.

  Key organisations – Heritage Council; NMS

4. .Review the range of existing interpretation mapping and GIS techniques and development of standards to ensure cost-effectiveness commensurate with their intended use

  Key organisations – NMS; Discovery Programme; Heritage Council

5. Any new strategy for reconnaissance should include a specific review of how such mapping could be incorporated into SEAs of national and local land-use allocation.

   Key organisations – NMS; DoEHLG (Planning); representatives of local authorities and other land-use regulators

6. Review how aerial archaeology might act as the core of a whole landscape approach at farm and townland level. This will enhance the understanding of both long-term past and current environmental and social change in the countryside.

   Key organisations – Heritage Council; University Archaeology and Geography Departments

7. Fully assess all low-level archival air photography. If appropriate, new reconnaissance should be part of SEA baseline studies for two or three development plans or programmes. These would involve housing, commercial and infrastructure development, covering at least one tillage area and one pastoral area.

   Key organisations – DoEHLG (Planning and NMS); relevant local planning authorities

8. Review and map archaeology as revealed by all available air photographs in areas covered by the GSI Minerals Potential Mapping (so far available for Donegal, Meath and Wicklow). This would act as a pilot study for SEA studies of minerals development.

   Key organisations – DoEHLG (Planning and NMS); GSI; relevant local authorities; Concrete Federation

9. Review the potential of aerial photography and remote sensing in the assessment of the archaeological potential of peat deposits.

   Key organisations – Bord na Móna; NMS

10. Review the archaeological 'yield' and the standard of survey and reporting on aerial archaeological desk studies and reconnaissance undertaken for highways schemes, correlating these with outcomes from fieldwork.

    Key organisations – NRA; NMS

11. Assess the potential use of aerial survey as a method for monitoring the impact of development on the cultural heritage.

    Key organisations – DoEHLG (Planning and NMS)

12. Conduct a pilot study of the methods for using new aerial archaeology and/or remote sensing surveys in undertaking Indicative Forest Strategies.

    Key organisations – Department of Agriculture, Fisheries and Food/Forest Service in collaboration with NMS

13. Carry out a pilot study which examines the potential of using low-level ortho-photography with GIS overlays to generate agri-environment plans covering all historic, archaeological and natural features and character.

    Key organisations – Department of Agriculture, Fisheries and Food; Heritage Council in collaboration with NMS

1 BACKGROUND

1.1 What is Aerial Archaeology and How is it Used?

Aerial archaeology represents one among many methods of discovering, investigating and disseminating information and knowledge about physical remains of the past. It uses aircraft (or in some cases satellites) to provide high-level views of the historic environment and is based on conventional photography and a range of remote sensing technologies. Not limited to any particular stage of the archaeological process, it can apply to all – from reconnaissance, measured survey, interpretation and analysis through to publication and dissemination. All periods, from Neolithic to the present day, are potential subjects of interest, as are virtually all forms of remains and states of survival (cropmarks, soilmarks, earthworks, structures, buildings and landscapes, and townscapes).

Aerial archaeology has numerous applications: research; monument conservation; control of development and other land-use change both at a strategic and site-specific level; and wider education and public outreach. This is becoming better recognised across Europe (Musson and Horne 2007).

Although dominated by photographic recording methods, aerial archaeology is not synonymous with air photography. Other forms of remote sensing are increasingly relevant, and interpretive skills both in the air and on the ground often rely on the use of other sources of data.

Aerial archaeology has a vital role to play in understanding the historic environment in all its forms. It has a uniquely sensitive capability of recording evidence of the past at a landscape scale, the complexity of which almost defeats any attempt to simplify and transcribe such complex and intricate evidence onto maps (Figures 1, 2).

Figure 1: This oblique aerial view conveys the sense of how this Anglo-Norman motte and bailey at Shanid, Co. Limerick, on a high natural hillock, dominates the landscape. An earlier ringfort can also be seen on the summit (Department of the Environment, Heritage and Local Government)

As a means of discovering archaeological remains, especially those which are unlikely to be revealed by other methods, aerial archaeology has a fundamental role to play. While much can be achieved through aerial archaeology as a method of working in its own right, it is often seen as complementary to other archaeological and historical techniques of examining the past. It is arguably most powerful as a tool to be combined with other forms of archaeological work, and indeed with other disciplines of history, geography and environmental studies. Much aerial archaeology can be seen not as a specifically archaeological science, but as part of a wider process of multi-disciplinary interpretation of landscape which combines geology, topography, ecology and archaeology to understand natural and anthropogenic forces of change (Mitchell and Ryan 1990; Aalen, Whelan and Stout 1997).

Figure 2: An early 19th-century artillery fort in Reenavanny, Whiddy Island, Co. Cork (Markus Casey)

1.2 A Brief History of Aerial Archaeology in Ireland

Although some air photography was undertaken in the British Isles in the early years of the 20th century, the earliest serious consideration of its use for archaeological purposes in Ireland was outlined by Chart (1930). It was Chart who reported a 1927 initiative by the Ancient Monuments Board in Northern Ireland — working in collaboration with the Royal Air Force — to explore the value of the technique. This reconnaissance, mainly aimed at known sites, clearly demonstrated the value of air photography in identifying, recording and illustrating earthwork sites in the context of a range of key monuments in Northern Ireland. The sites targeted included the Dorsey Entrenchments (for which a vertical photo-mosaic was created) and a number of other well-known monuments, such as Navan. Other sites were also identified and recorded by the RAF team, adding to the known targets.

Raftery (1944, 120) referred to Chart's paper and the early use of air photography by the simple expedient of using hand-held cameras over the side of an open cockpit in 1929-30. Although there are earlier images of archaeological sites (*e.g.* Figure 3), he cites the earliest archaeological air photography carried out in the Republic as being work done by the Army Air Corps in 1934. This was prepared in connection with archaeological excavations that were set up as part of a government scheme for the relief of unemployment. Up until 1944, further work had been sporadic, and Raftery called for an initiative 'to plan proper collaboration in surveying many important archaeological sites all over this country. For it is by such planned co-operation that any valuable results can be obtained…'. Raftery stressed the importance of matching up the skills of the aerial photographer in understanding how good photographs may be obtained, with those of the archaeologist in identifying and interpreting features to be recorded.

Figure 3: An Irish Army Air Corps view of Tara, Co. Meath, from 1924 (Royal Society of Antiquaries of Ireland/Government Stationery Office)

Drawing on the work of O.G.S. Crawford and others working in England, Raftery (1944, 121-2) outlined the basic distinctions between shadow, soil- and cropmarks. He drew attention to the technical importance of factors such as height, weather and lighting in determining whether archaeological sites are visible from the air and the clarity of images that could be obtained. Raftery also commented on the relative value of vertical and oblique photography. He drew attention to the potential for identifying underwater sites, both in lakes and shallow coastal waters, which have 'not been sufficiently exploited' and the potential for 'ancient road systems, buried fortifications, and obscured burial places'.

An early example of the use of air photography in the Republic of Ireland that illustrates most of Raftery's points had been published in the report of a survey and excavation project carried out in 1940 at Caherguillamore, Co. Limerick (Ó'Ríordáin and Hunt 1942). The air photography, taken by the Irish Air Force, was found to reveal a great deal more archaeology than was known from the Ordnance Survey map. An interpretation plan published alongside the air photography was integrated with ground observations to provide an overall commentary, adding a valuable interpretive context for the results of the excavation of two medieval houses.

In the 1950s, the National Monuments Advisory Council commissioned the Air Corps to undertake some aerial archaeological surveys — such as the 1950 vertical photography of the Brusselstown Ring hillfort in Co. Wicklow (Condit 1992). The Air Corps remained an important contributor to the development of aerial archaeology in Ireland until the 1970s.

A more important development came when the challenge was taken up by J.K. St Joseph. The founder of the Cambridge University Committee for Air Photography (CUCAP), St Joseph was one of the greatest exponents of purposive archaeological and other landscape air photography in Ireland — as he was in England, Wales and Scotland. At the invitation of archaeologists at the National Museum of Ireland, the Royal Irish Academy and the National Monuments Advisory Council, he undertook two main campaigns of flying in Ireland — in 1951-5, and more particularly 1963-73 — when the CUCAP aircraft was based at Dublin airport for about ten days each year. This remains the most extensive accessible collection of purposive archaeological air photographic reconnaissance in Ireland, with over 10,000 images captured by 1968 (Norman and St Joseph 1969), and over 11,000 in all (for examples of the range of coverage, see Figures 10 to 13, 22, 38, 44, 45, 52).

Interest in the potential of aerial archaeology (including a brief résumé of techniques and sources of photography) was presented to the 5th annual seminar of the Association of Young Irish Archaeologists (Patrick 1974).

In terms of vertical photography taken for general purposes, important early surveys were undertaken by the Army Corps, mainly between 1950 and the early 1970s. The provision of this service for civil purposes was then transferred to the Ordnance Survey Ireland (OSi). It remains the principal body carrying out such work, though on an increasingly commercial — and competitive — basis. The GSI (from the 1970s onwards) and the Marine Institute (from 1998 to present) have also undertaken important vertical surveys, and in the last ten years, increasing general use has been made of remote sensing techniques, though these have yet to figure in the practice of aerial archaeology in Ireland.

Since St Joseph's pioneering work, there have been other important private initiatives. These include those of the late Leo Swan in the 1970s to 1990s, and Dr Daphne Pochin Mould (1978, 1981, 1991) from the 1960s to present, each running to thousands of images (*e.g.* Figures 4, 15). From the 1980s onwards, many others have carried out analysis of air photography and/or aerial reconnaissance in a variety of contexts, including the compilation of the SMR and County Inventories, regional or other surveys, large-scale development projects, and a range of research projects (see below).

The 1990s and 2000s have seen a spate of new initiatives. These include the research reconnaissance of the Barrow Valley and other parts of Ireland by Dr Gillian Barrett, and successive projects by the Discovery Programme, and various universities. Latterly, the Heritage Council and the National Roads Authority (NRA) have sought to develop aerial archaeology as an integral element of research and heritage management. But this work is not as widely recognised as it deserves to be, with Ireland still being perceived externally as somewhere that has had little interest in the development and use of aerial archaeology (Musson and Horne 2007, 4, 68).

Figure 4: Kells, Co. Meath, showing the curving street pattern indicative of the town's early medieval monastic origins (Leo Swan Archive)

2 PRINCIPAL SOURCES OF AIR PHOTOGRAPHY IN IRELAND

2.1 Guides to Air Photographic Collections

There is no general guide to air photographic collections in Ireland. However, the second edition of a directory of accessible collections of aerial photography held in the United Kingdom (NAPLIB 2001) includes a number of collections which cover parts of the Irish Republic as well as Northern Ireland. There is no comparable guide to air photographic collections held in Ireland.

In compiling this source, responses to questionnaires were widely circulated over a two-year period, with additional investigation of sources and detail added by NAPLIB members and colleagues from many professional associations. The Directory identifies many new collections over the previous edition and demonstrates a great diversity of topics tackled by aerial photography. These range from marine navigation to the coverage of sporting events, as well as the staples of recording the built and natural environment which dominated the earlier edition. The Directory is organised by United Kingdom Post Code, source name and dates of cover. It also provides guidance on the interpretation of aerial photography, tracing the locations of photography from long disbanded organisations and on copyright clearance.

2.2 Public Archival Material

National Monuments Section of the Department of the Environment, Heritage and Local Government

The National Monuments Section of the DoEHLG holds a range of air photographic archival material (*e.g.* Figures 5, 6, 19, 24, 26, 27, 28, 44, 51, 55). This collection comprises:

- *Prints of OSi's full national coverage through black-and-white aerial photography at 1:30,000 scale, flown in 1974.*
- *Aerial colour photography of Co. Dublin flown at c. 1:5,000 scale in the 1980s, and some other vertical aerial photography of limited geographic areas (e.g. East Limerick West/Tipperary medium altitude survey – Doody 2001).*
- *Prints of relevant photographs from a variety of archive sources (chiefly GSI, OSi, CUCAP; some BKS), and material taken in the course of archaeological survey for the Archaeological Survey of Ireland by a number of individuals. These prints are mainly black-and-white (both vertical and oblique), with some oblique colour photography. They are held, together with ground-level photographs, within the individual site files for the SMR.*
- *A separate collection of photographs, taken by the National Monuments Section photographic unit over many years, consists of important national monuments, national parks, other significant places, and key sites covered by the County Inventories. These include low-level oblique aerial photography (both black-and-white and colour). Most were taken for combined purposes of record and illustration/publicity. It is not possible to estimate the quantity of aerial photographs in this material since the aerial images are filed and catalogued with ground-level photographs of the same sites; it is certainly a significant collection, although only a minority of the sites include aerial photography. A separate part of this collection includes low-level air photography taken in colour transparencies, which again includes a variety of nationally important sites and places, and reflects particular projects (e.g. a survey of the Shannon navigation and other waterways, Phoenix Park, Dublin, some nationally important landscape areas).*

In terms of reconnaissance and record, the National Monuments Section undertakes regular aerial reconnaissance flights amounting to c. 10-20 hours per year. These provide a service in support of the work of the archaeological survey teams, together with some monitoring of potential cropmark areas in the tillage counties. The NMS continues to undertake a significant amount of low-level photography of important sites and places for the purposes of illustrative and publicity material, especially connected with publication of the County Inventories (Figure 6). A high-quality, single-user Zeiss Stereoscope (without camera) used for photo viewing and interpretation is available for internal use.

Figure 5: Rathcoran hillfort enclosing the summit of Baltinglass Hill, Co. Wicklow. The scale of the hillfort ramparts is appreciated from an aerial perspective (Department of the Environment, Heritage and Local Government)

Figure 6: Concentric enclosure at Corracreigh, Co. Roscommon (M. Moore/ Department of the Environment, Heritage and Local Government)

As there is no digital archive of the NMS's material, it is not possible to give an accurate estimate of its size. The Sites and Monuments Record is available for consultation on Mondays, by prior appointment, at the Archive Unit at 6 Ely Place Upper, Dublin 2 (Telephone 01 888 3093). Copies of the NMS's own photography can be ordered (there were approximately 126 such requests in 2001). Indexing is by location name.

The GIS Unit at NMS also has substantial aerial and remote sensing resources. These include:

- *Full aerial photographic print coverage of Ireland at a scale of 1:40,000 flown 1995.*
- *Full aerial photographic print coverage of Ireland at a scale of 1:40,000 flown 2000.*
- *Aerial photographic print coverage of the Greater Dublin Area at a scale of 1:15,000 flown July 2000.*
- *Colour and black-and-white aerial photography at various scales (predominantly 1:20,000 and 1:10,000) of Special Areas of Conservation (SAC) sites.*
- *Other vertical aerial photography at varying scales of limited geographic areas.*
- *A large number of oblique aerial prints for SAC sites.*
- *A set of Corine satellite imagery.*

Equipment includes a Zeiss P3 analytical photogrammetric plotter which allows detail to be plotted from the vertical aerial photography directly to ArcInfo coverage format. ERDAS Imagine software is used, running on a high-specification workstation with A3 and 35mm scanners capable of carrying out a full range of photogrammetric, remote sensing and imaging tasks, which are also fully compatible with the ArcInfo GIS system. All aerial imagery derived from the above sources is capable of full integration with the GIS and digital mapping resources. However, it is understood that at present there are insufficient GIS/photogrammetry technical staff to manage and operate this resource to its full potential. These facilities are not available for use by the public.

National Museum of Ireland

While the National Museum of Ireland does not normally commission air photography, it has acquired a variety of material from other sources. This includes copies of the CUCAP coverage deposited with the museum by Professor St Joseph (which is held as a stand-alone indexed collection) and a good deal of more miscellaneous site-specific photography by a variety of individuals. This is held mainly in the museum's topographical files of sites and locations.

Access to these sources is by appointment, and the museum's topographical files and the St Joseph collection are widely regarded as standard sources of information for research or desk study assessments. There is no digital index.

Ordnance Survey Ireland

The Ordnance Survey Ireland (OSi) holds a major archive of air photography and provides an active aerial reconnaissance and mapping programme for updating standard maps at a variety of scales, and on a commercial basis for other users, mainly in the public sector (*e.g.* Figures 27, 28, 39).

The main series of complete coverage of Ireland is provided by four sets of full stereoscopic (60% forward overlap) black-and-white and colour vertical photography taken in 1973 (at 15,000 feet, approximately 1:30,000); in 1995 (at 20,000 feet, approximately 1:40,000, taken in very clear conditions in June); in 2000 (20,000 feet, approximately 1:40,000); and in 2004-5 (at 20,000 feet, approximately 1:40,000, taken over the summer months).

There is also extensive but not full coverage of the country in lower level photography (1:10,000, 1:5,000 1:4,000 scales) taken on many different occasions for the purposes of routine map revision. Coverage is typically of built-up areas, although it covers extensive lowland rural areas in all parts of the country. This low-level coverage generally excludes mountainous areas.

The vertical coverage is used both for general map revision purposes and for generation of ortho-photographic coverage (a photographic map derived from a vertically corrected, seamless digital vertical mosaic).

As a largely commercially based public service, a significant amount of air photographic coverage held by the OSi is generated through commissions from other bodies — notably local authorities, agriculture and some road-building projects.

There is also a substantial collection of oblique aerial photography of a very general nature, taken on an *ad hoc* basis during the course of systematic vertical surveying. This type of coverage was never systematic and now figures less in current operations than it did formerly.

The 1995, 2000 and 2004-5, vertical coverage has been scanned and is digitally indexed by grid reference. Earlier vertical coverage is indexed on 1-inch maps showing flight traverses and film/frame locations, but it is intended to work back through the earlier material to add it to the database once recent indexing is complete. For viewing purposes, prints of the oblique photography are stored in albums arranged by locality.

User enquiries are geared largely to identifying coverage for a specific area of interest. OSi have created a digital image archive system known as Geovault which sales staff can use to search coverage by location, date and other parameters. Prints can be ordered. There is no public search room where users can routinely view imagery prior to ordering copies. Public access is by special arrangement, subject to an appointment when the inquiries desk is not too busy. Although a few aerial archaeologists (such as the late Leo Swan) have made use of this facility on a regular basis, this is very unusual. Archaeologists observe that viewing arrangements can be quite restrictive, since it is not necessarily clear what the range of coverage for a particular area might be. It is therefore impossible to judge how useful the available material might be for archaeological purposes without seeing it. It is also too expensive to order copies purely in the hope that they might be useful. The OSi is seeking to make more material available digitally through e-commerce, but it is unlikely that these will include all the archival material that can be of interest to archaeologists.

The OSi does not hold infrared or satellite imagery. In 2005, OSi invested in both a terrestrial (ground based) and an aerial lidar (LIght Detecting And Ranging) unit. Training on the units was completed in June 2005. OSi completed two projects in 2005, the first tasks being the creation of a height model for Limerick City and an archaeological survey for the NRA in Co. Roscommon.

Geological Survey of Ireland

The principal collection available at the Geological Survey of Ireland (GSI 1983; M Parkes pers. comm.) is a complete set of 60% forward and 25% sideways overlapping stereoscopic black-and-white vertical coverage of Ireland, flown in 1973-77. The first complete air photographic survey of Ireland, it was undertaken by the Institut Nationale of France. Photos were taken at a scale of 1:30,000 with Wild RC8 and RC10 cameras with a 6" focal length. Photogrammetric vertical and planar location is recorded as being accurate up to + 1.5m.

Figure 7: Geological Survey of Ireland 1:30,000 vertical photograph of the Boyne Valley showing megalithic tomb of Dowth and associated monuments (5 April 1973, Geological Survey of Ireland/Ordnance Survey Ireland)

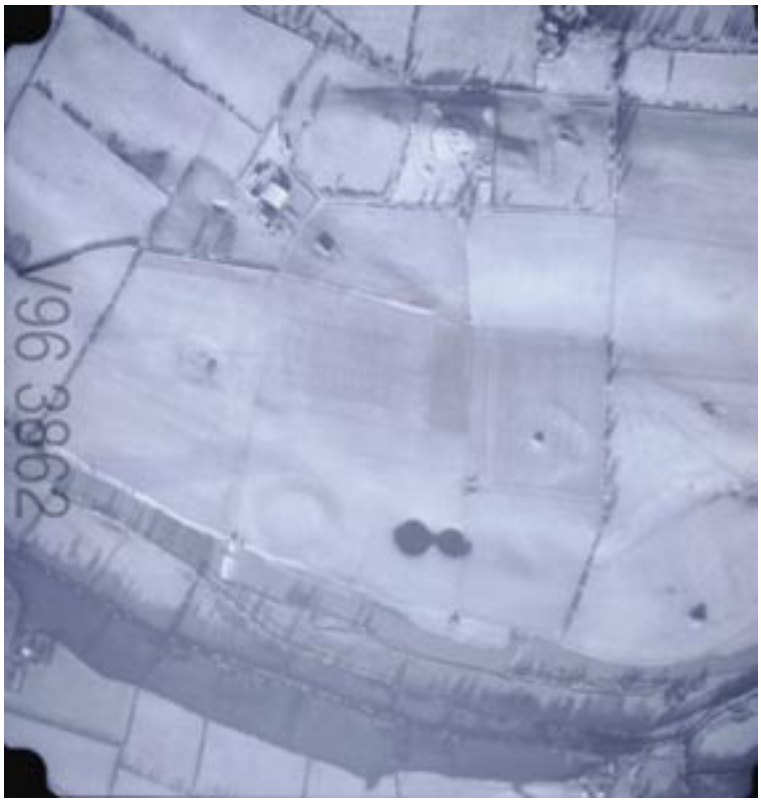
Other material held by the GSI includes a set of non-stereoscopic Air Corps photos taken in the 1950s, although this is not a complete national coverage. A set of 1995 vertical photography flown at a scale of 1:5,000 was recently purchased from the OSi as the basis for 1:50,000 ortho-photography creating a digital mosaic map. There is a small amount of satellite imagery for Co. Mayo. The GSI does not hold a significant set of oblique photography.

The GSI collection is available for viewing purposes only; copies of photographs are available from the OSi which is currently scanning the images for GSI. The collection can be accessed during normal office hours, and there is a viewing charge of €13 (Student €4). An index for the photographs based on the National Grid is also available. A search service is provided, with simple stereoscopes available to assist viewing. The majority of users are archaeologists. Although there are no records of actual figures, this pattern of use is reported to be very marked, and is borne out by comments from archaeologists themselves. Several have noted the relative ease of access to the GSI collection, compared with the OSi. Many archaeologists also ask to use the Air Corps photos taken in the 1950s, although that set is not complete national coverage.

The GSI is responsible for the Irish National Seabed Survey data, including airborne lidar surveys (Section 3.4) off the west coast of Ireland. Three areas have been surveyed: Mulroy Bay, Northern Donegal; Clew Bay, Co. Mayo; and Killalla Bay, Co. Mayo. While the data has been used primarily for bathymetric purposes, field boundaries and disused jetties are clearly visible in the imagery. For Phase 2 of the Survey, key bays and priority areas around Ireland have been targeted for integrated survey work. The areas have been selected after intensive consultation among the various stakeholders, including the Underwater Archaeology Unit of DoEHLG.

Air Corps, Baldonnell

The Air Corps holds a significant collection of historic aerial photography, virtually all dating from before the early 1970s when responsibility for civil air photography was passed to the OSi. Reconnaissance for these purposes ceased in about 1978, though reconnaissance and training for military purposes continue.



In terms of vertical air photography, there is coverage of various areas dating from *c.* 1951 to the mid 1970s (*e.g.* Figure 8). None of this represents complete coverage of Ireland, and the emphasis tends to be on coastal areas. Nevertheless, coverage is fairly extensive, totalling around 200 rolls of up to 200 @ 9 x 9 inch frames, mostly taken at 10,500 feet and some at 5,400 feet, mostly in stereoscopic format with 60% overlap.

Figure 8: Air Corps vertical photograph of Newgrange, Co. Meath, taken during low-angled sunlight on 20 December 1972 (Government Stationery Office)

In addition, there are around 2,000-3,000 black-and-white oblique photographs, including some of historic sites and places; some date back to the 1930s and a few to the 1920s. These are mostly 5x4-inch negatives, some on glass.

Copies of both vertical and oblique images may be obtained, and viewing of the vertical cover can be arranged on application. Those who access the collection include geographers interested in landscape change and coastal erosion. Inquiries generally need to be specific about whether oblique as well as vertical photography is relevant, and whether more than one set of coverage is needed. Otherwise, information for any given area is provided in terms of details of film references, height, date and time taken. About a third of the 2-3 inquiries per week involve viewing, but this does not apply to the oblique photography.

The Air Corps no longer does reconnaissance for civil purposes, and training of air photographers and interpreters is geared to military priorities.

Marine Institute

A total of over 10,000 images (*e.g.* Figure 9) are published on eight CDs covering the whole of Ireland's coast (Louth, Meath, Dublin 486; Wicklow, Wexford, Waterford 846; Cork 1,742; Kerry 1,206; Limerick, Clare 803; Galway 1,247; Mayo 1,532; and Sligo, Leitrim and Donegal 2,319). The Institute's website[1] originally described the survey as follows:

'Ireland's coastal zone contains a wealth of natural resources which have economic, social, cultural and environmental value. The highly sensitive nature of the coastal zone is increasingly subject to pressures resulting from multiple use. The 8 National Coastline Survey CDs provide the visual information needed to assist in the effective and sustainable management of the coastline and coastal resources.

Each of the 8 CDs provides colour infrared digital images of the coastline of a number of Irish counties, with the series covering the entire coastline of the Irish Republic. The CDs also include CoastView image viewing and retrieval software. The CoastView image viewing tool allows thumbnails of the aerial photographs to be accessed from a coastal map showing image coverage; the full image to be viewed in infrared and pseudo natural light; and variable magnification allows the images to be zoomed.

Potential uses include soft coast/dune management, mapping coastal vegetation, erosion, urban expansion and tourism developments (caravan sites, golf courses etc), environmental impact assessments (EIA), and as an image overlay with other data sets within Geographical Information Systems.

Coastal managers, local authority planners, aquaculture operators, boating organisations, tourism authorities and developers are but some of the potential users of this series of CDs. As the CDs are readable from a home PC, it is also expected that local interest groups and individuals will utilise the CDs for a variety of other purposes.

Images are produced in colour infrared format as the infrared spectrum has been shown to be particularly useful in identifying and interpreting coastal features and assessing vegetation type and health (a stronger red/orange hue is related to vegetation health and growth). Image size is typically 30cm x 30cm.'

[1] *See http://www.marine.ie. For viewing the areas covered by the CDs and ordering copies, go to http://krypton.clickandbuild.com/cnb/shop/thermarineinstitute?op=catalogue-products-null&prodCategoryID=6*

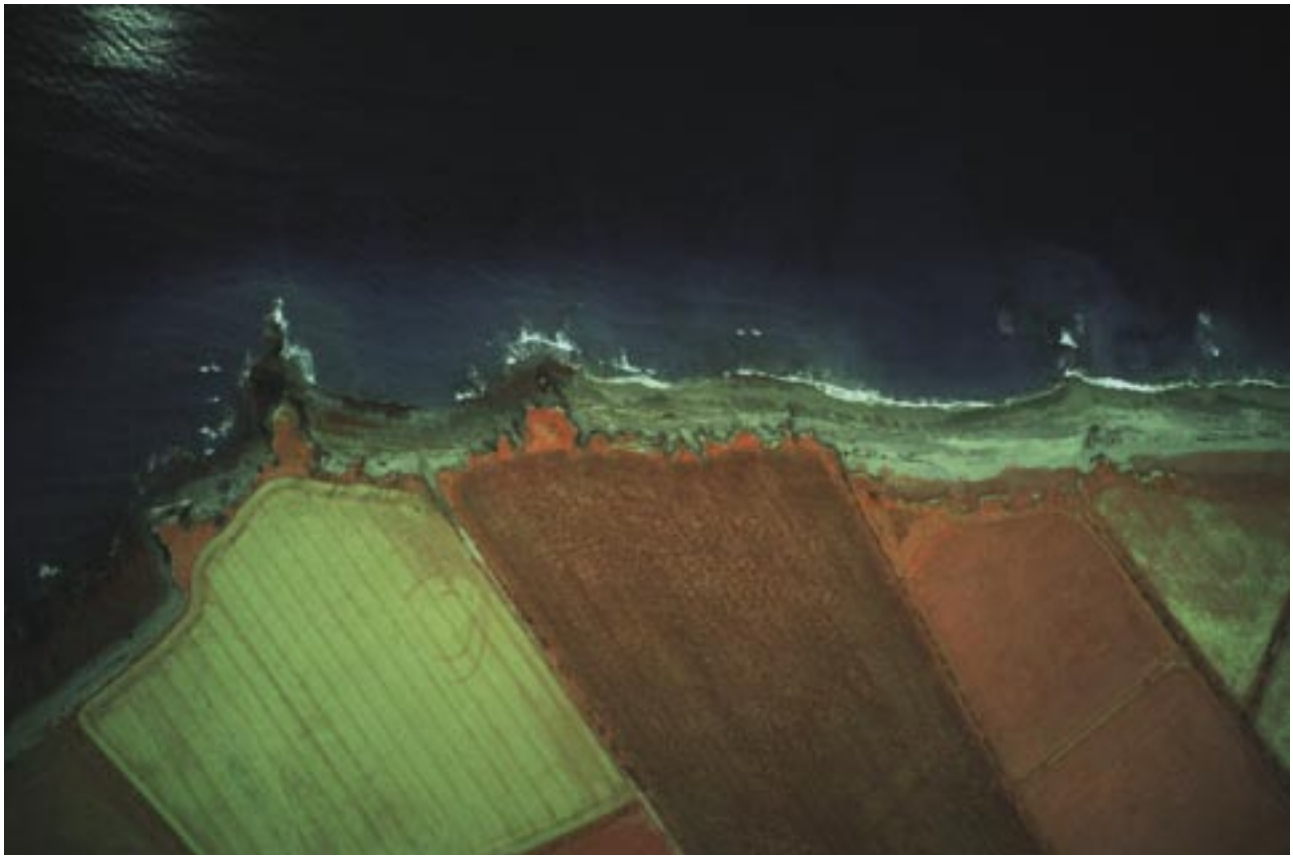


Figure 9: An infrared vertical image of an enclosure on the coastline at Ballymadder, Co. Wexford (Marine Institute, National Coastline Survey)

Department of Communications, Marine and Natural Resources

The engineering division has a number datasets of vertical and oblique aerial photographs of the Irish coast.

Local Authorities

Most local authorities hold collections of vertical air photography which are used for land-use planning and other purposes. General coverage tends to duplicate that of the OSi, or will often have been commissioned for the authority from OSi or other suppliers. Project-based archives — especially for roads — are also held by local authorities and the National Road Design Offices. Coverage varies from one authority to another, but few hold significant material taken for archaeological purposes.

2.3 World War II Aerial Photography

There is growing Europe-wide interest in both British and US collections, as well as in captured German air photography of World War II. The main collections, including captured German material, are held in the United States National Archives 2, Maryland, though some are at Keele University in the UK. By 1944-45, millions of Luftwaffe reconnaissance photographs had been taken, mainly over Britain, but also Ireland and other European countries. Most were taken from about 13,000 metres, typically using cameras with focal lengths varying between 200mm, 500mm and 750mm (Chris Going, pers. comm. 23 March 2007). Collections are largely uncatalogued and their potential for Irish studies has not been assessed (Going 2002; Crawshaw 2001). However it is becoming clear that there is little or no Irish material at Keele, and any Irish material is to be found at the National Archives (NARA) in Washington DC, USA. Preliminary indications are that there is vertical photography taken by the German air force in 1940-41 covering Dublin and Derry. The Dublin coverage ran about 35 miles to the north of the city, 35 miles south along the coast, and a short distance inland (M. Albicht pers. comm. 5 November 2007).

2.4 Collections held by Universities and other Research Institutions

A number of British and Irish universities hold collections of aerial photography relating to particular research programmes and the interests of research staff. These vary considerably in extent and scale. For example, Dr Barrie Hartwell of Queen's University Belfast has built up a substantial collection of material covering Northern Ireland (NAPLIB 2001). The archaeology department at Galway University say they do not have an air photographic collection as such, and although material retained will be for some particular research projects, Waddell (1983) stated that the photography taken in conjunction with Gerry Bracken for research on the Rathcrogan complex was given to the National Museum.

Another example of a project-specific archive is that relating to the major study of the Carrowmore area in Co. Sligo. This was carried out by Professor Göran Burenhult of Gotland University College, Visby, Sweden (Burenhult 1980; Burenhult *et al.* 1984; Bergh 1995). Professor Burenhult has stated (pers. comm. 2002) that the project archive contains

'...a large series of aerial photographs over the Knocknarea Peninsula, Sligo, within the Carrowmore Project during the prospecting and survey work in 1979 (The Swedish Archaeological Excavations at Carrowmore, Excavation Campaigns 1977-1982 and 1994-1998). Most of the images are in infrared colour and b/w film material. Samples from the aerial survey have been published in the Carrowmore reports (Theses and Papers in North-European Archaeology 9 and 14, Stockholm University). The final report on the second excavation campaign 1994-1998, with a synthesis on the whole project, is planned to be published next year, and the full aerial series will be enclosed with the report on a CD-ROM disc...'

Cambridge University Unit for Landscape Modelling

The collection held by the Cambridge University Unit for Landscape Modelling (formerly the Cambridge University Committee for Air Photography, and still widely referred to as CUCAP, as in this report) includes the largest and most accessible body of purposive archaeological photography taken by a single institution in Ireland. This was almost entirely the product of two campaigns of aerial photography carried out by Professor St Joseph for the CUCAP in 1951-5 and 1963-73.

Figure 10: Oblique photograph of Ardskull Grave Yard, near Athy, Co. Kidare, showing traces of three cropmark enclosures around the central upstanding enclosure (CUCAP 9 July 1969)

Figure 11: Oblique photograph of Trim, Co. Meath, showing the topographical positions of the Abbey (left), Castle (centre) and Cathedral (right) in relation to the town which grew up at a strategic crossing point of the River Boyne (CUCAP 9 July 1969)

The aims and objectives of these aerial survey campaigns were described in Norman and St Joseph's book, *The Early Development of Irish Society: the Evidence of Aerial Photography* (1969). The work was partly initiated by archaeologists from the National Museum of Ireland and other institutions who sought coverage of particular places and themes. While these requests provided an initial framework, St Joseph was clear that he would apply the well-developed approach that he had used elsewhere and which had achieved a much broader basis for research. As a result, he revealed much previously unrecognised potential for aerial archaeology — and indeed a strong theme of Norman and St Joseph's book was demonstrating that aerial archaeology had a worthwhile part to play in research for all periods and all parts of Ireland. (Figures 10-13, 22, 26, 37, 43, 44 illustrate something of the range of St Joseph's interests in archaeology, landscape and geology.)

Figure 12: Oblique photograph showing traces of rundale farming at Fawnglass, Clare Island, Mayo (CUCAP 18 July 1967)

Figure 13: Excavations in progress at the later prehistoric hillfort of Dún Ailinne, Knockaulin townland, Co. Kildare, in 1969 (CUCAP 9 July 1969)

In the last few years, the Heritage Council has grant-aided the Cambridge University Unit for Landscape Modelling in conducting a lidar survey of the Loughcrew area (Shell and Roughley 2004; Figure 30).

The Unit for Landscape Modelling has recently established a powerful online digital map-based catalogue to their collections covering Great Britain, but this does not yet extend to Ireland.

Prints of the vast majority of photographs of archaeological value from St Joseph's work are held by NMS, where they are stored in the relevant site-by-site files as part of the national SMR archive. Sets are also held by the National Museum of Ireland, where they are held as a specific collection with relevant indexes provided by CUCAP. The museum collection is principally from the 1963-1973 campaigns, and consists of 121 albums, each containing around 100 oblique/panorama photos and three/four verticals (*i.e.* a total of c. 12,600 images). The card indexes facilitate access by county/townland, subject, and cropmarks (by county). Copies of prints have to be ordered directly from the Cambridge University Unit for Landscape Modelling.

University College Cork Archaeological Survey Unit

In 1982, the Archaeological Survey Unit was established under the auspices of the Department of Archaeology at the University of Cork to undertake survey work in south-west Ireland on behalf of the Office of Public Works (now the National Monuments Section of DoEHLG). It is still funded by the NMS and forms part of the Archaeological Survey of Ireland. It is primarily (but not exclusively) concerned with recording archaeological sites in counties Cork and Kerry, and has published the four-volume *County Inventory for Cork*. The unit is currently preparing the inventories for South County Kerry and South County Sligo.

The SMR for Cork was compiled using existing archival air photographs – principally the Geological Survey and Cambridge collections, together with some reference to Dr Daphne Pochin Mould's collection. This was supplemented by additional *ad hoc* reconnaissance, mostly responding to periods of especially favourable conditions for recording of cropmarks. This continued during the compilation of the County Cork Inventory, usually in collaboration with Dr Pochin Mould (*e.g.* Figure 15). By 1993, this amounted to a total of about 40 hours' flying (Power 1993).

Ursula Egan (pers. comm.) notes that the collection held by the Archaeological Survey Unit amounts to about 3,000 x 35mm colour transparencies and a further 3,000 x 35mm black-and-white photographs (mostly duplicating the subjects covered by the colour photography). The collection is stored in filing cabinets, ordered and indexed by 6" map sheets and locality. They are also cross-referenced as appropriate to the national SMR. The content is mostly archaeological, especially cropmarks and soilmarks, but also includes coverage of towns and villages.

The Discovery Programme

The Discovery Programme holds a small collection of aerial photography related to its own research, notably the North Munster Project (Grogan 1993, 1996) and Ballyhoura Hills Project (Doody 1993c, 1995, 1996). The photography taken for the Tara Project (Newman 1997) was by Con Brogan of NMS. Recently, the Discovery Programme commissioned high-resolution, large-format photography for North Roscommon from BKS Coleraine (Figure 14) as part of their Medieval Rural Settlement Project, and for Mullaghfarna, Co. Sligo, funded by the Heritage Council as part of Dr Stefan Bergh's research (Figure 32).

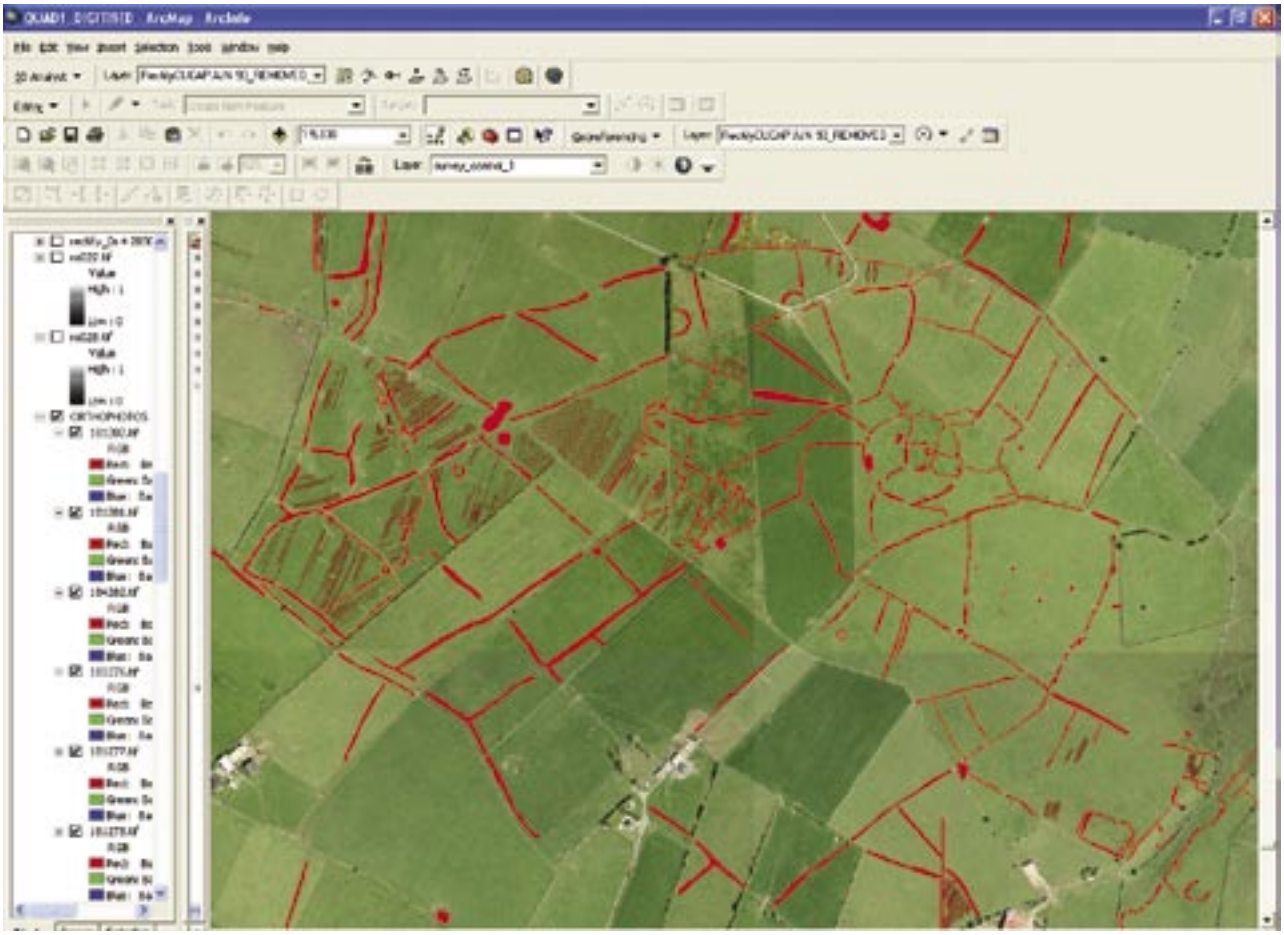


Figure 14: The Discovery Programme's Medieval Rural Settlement Project is investigating the O'Conor lordship in north Roscommon. Data is being investigated using GIS and a photogrammetric aerial survey as a base data set. At Carns, Roscommon, relict early medieval and medieval field boundaries and settlements (AD 600–1600) are shown superimposed on a 1:7500 aerial photograph (Discovery Programme/BKS Ltd)

2.5 Private Collections

Dr Daphne D.C. Pochin Mould

Dr Pochin Mould is an author and flying instructor with an interest in archaeology. Based in Co. Cork, she has been taking oblique aerial photographs for over 40 years (*e.g.* Pochin Mould 1972; 1981; 1991) and has an extensive collection covering mainly counties Cork, Kerry and Tipperary, but extending over parts of southern Ireland in general. It is understood that the collection runs to many thousands of images, and is catalogued. For about two years in the 1980s, the Cork Archaeological Survey commissioned regular flights and are kept abreast of new discoveries. The collection is kept privately, and is not open to public access. Photographic prints of particular sites and places may be made available for an appropriate fee.

Figure 15: In the bright, low December sun, the outline of the enclosing bank of the early medieval ecclesiastical site at Tullylease, Co. Cork, is revealed. This enclosure is very difficult to detect at ground level (Dr Daphne Pochin Mould, 19 December 1992)

Dr Leo Swan

The important, and extensive, collection of the late Dr Leo Swan has been acquired by the National Museum of Ireland and is understood to be in the process of archiving and cataloguing. The collection reflects Dr Swan's interests in medieval settlement and landscape development (Figure 4) but also contains more general material. In due course, the collection will become accessible, as with other material held by the museum.

Dr Gillian Barrett

Dr Gillian Barrett of Wolverhampton University has been carrying out archaeological and geographical research based on her own aerial photographic survey since 1989. Her collection consists of oblique photographs mainly in the form of colour slides. There are sets of colour prints for some years (and black-and-white for 1991) taken with hand-held 35mm cameras: Nikon F601 and Pentax K1000. The collection now amounts to *c.* 7,000 oblique colour slides/prints, and a further *c.* 1,000 black-and-white images.

The collection is stored in plastic storage sheets in folders and filing cabinets at Dr Barrett's home. A general index summarises the areas covered for each flight, and index sheets are also available for each film. Individual images or groups of images are indexed for location, with a substantial proportion fully catalogued. These indexes are typed sheets and are not in database format.

The collection is mainly oriented to a research interest in the role of aerial survey as a technique for archaeological discovery and the analysis of settlement pattern, particularly through the detection and recording of cropmarks (Figures 16, 32, 40, 49). The collection also includes a wide range of landscape panoramas (Figure 52), major categories of archaeological and historical sites, ecological and natural features, and villages and towns.

The collection reflects research interests in the river valleys of the Barrow and Nore, including substantial coverage for counties Kildare, Laois, Carlow and Kilkenny, as well as Co. Louth. Other areas covered are: Meath (including the Boyne Valley); the Aran Islands; the Dingle Peninsula; coastal areas of east Cork; the River Blackwater in Co. Waterford; and coastal areas in Co. Waterford and Co. Wexford. There is more sporadic coverage for counties Tipperary, Roscommon, Galway and Clare.

The collection is not publicly accessible, but copies of photographs are provided when requested (*e.g.* to archaeological consultants undertaking assessments in advance of development, and also postgraduate researchers) but this is rare.

Figure 16: Traces of enclosures and field boundaries visible as cropmarks within a ripening cereal crop at Ardfinan, Co. Tipperary (Gillian Barrett collection)

Figure 17: Low earthworks and a mound interpreted as a motte are visible in winter light adjacent to Fethard Castle, Co. Wexford (Billy Colfer collection)

Other Commissioned or Personal Material

It is increasingly the case that individual practitioners and archaeological contracting companies are being commissioned to carry out archaeological air photography for a variety of public bodies and private developers (Figures 2, 21, 37, 54, 62 by Markus Casey for the Heritage Council; Figures 47 and 49 by Margaret Gowen and Co. Ltd for the NRA). For the most part, copies of such material will normally be deposited with the body for whom work was undertaken (M. Casey, M. Gowen, J. Schmit, D. Nellis, pers. comms.). Access is then largely dependent on the commissioning body. Such collections as the originators may retain are not normally publicly accessible or available for inspection, though specific inquiries can usually be acknowledged. Some collections are nevertheless quite significant (*e.g. c.* 3,000 images estimated by Jorg Schmit of Valerie Keeley Associates). Much of this material will have been incorporated into archives held by local authority roads departments or other public institutions. In some cases, copies will be deposited with bodies such as NMS, either directly or through reports submitted to NMS. Some will remain with commercial developers. Some collections are more purely personal initiatives, such as Billy Colfer's (2004) research into the archaeology and history of *The Hook Peninsula* and at Fethard, Co. Wexford (Figure 17).

2.6 Commercial Collections

Two well-established commercial companies have some significant archival collections of Irish aerial photography. Both companies are also active in providing aerial survey and remote imaging services on a commercial basis.

Simmons Aerofilms

Simmons Aerofilms grew out of the partnership of the former Aerofilms Ltd (founded in 1919) and Simmons Mapping (UK) Limited. It provides a range of specialist aerial imaging services, including ortho-photography, lidar, thermal imaging and photogrammetry. This includes the Aerofilms own material, as well as that from other air photographic archives. Their website[2] states that:

'Aerofilms remains a pioneering company in the field of vertical photography, widely used for surveying and mapping. Simmons Aerofilms' archive comprises a small number of Aerofilms pre-1939 surveys, much of the Hunting Surveys/Aerofilms photography from 1946 to date, and the archive of Fairey/Clyde Surveys (1963-98).'

The company reports that their oblique photography covers all parts of Ireland. For the Republic, this amounts to *c.* 4,000 black-and-white photographs, with a similar quantity of colour images. The vast majority are prints, although there are some slides. Much dates from the 1960s and 1970s, with a further important campaign of flying in about 1984 for the publication of *Ireland from the Air*. This included Dublin, with further coverage taken in 2001. For Northern Ireland, there are another *c.* 4,000 black-and-white images, but fewer colour. Virtually all the coverage is from commissioned work, coupled with some speculative photography taken in the course of these flights. Vertical air photographic coverage of Ireland is very limited, though this includes coverage of Dublin and Cork at *c.* 1:10,000 scale. Some new photography is carried out for specific purposes, usually in connection with development and infrastructural projects.

The Aerofilms' collection is indexed by location. As a commercial service, it is not accessible as an archive, but prints can be purchased (in 2002, this was typically St£24-27 [€37-42] for 8"x8" obliques, St£40-65 [€62-100] for verticals, plus postage etc). A variety of aerial photography, thermal sensing, infrared imagery and lidar surveys can be commissioned. However, it is understood that there is now only limited demand from Ireland, and contact with archaeologists is reported as being virtually non-existent.

BKS Surveys Ltd

BKS (founded 1956) is based in Coleraine, Northern Ireland. Traditionally an aerial survey company, it has become one of the largest independent digital mapping companies in the UK. They introduce their collection and services as follows.

'Mapping mudflats. Monitoring toxic spills. Risk Management. Environmental Impact. Network planning. Preserving historic monuments. Updating National map archives. Whatever your challenge, BKS provides spatial data to help you access and manage information more effectively. Data may come from existing records, photographs, satellite images or ground surveys; it may be 2-dimensional or 3-dimensional; it may be stored as a few feature codes or intricate topological data. Whatever the application and specification, BKS has the experience, resources and creativity to understand your requirements and develop solutions to match.

BKS has an extensive library of black-and-white and colour aerial photography dating from the 1960s to the current year. This imagery offers clients a cost-effective solution for numerous applications including site/boundary disputes, photo interpretation, mapping and natural resource planning. Our photo archive includes extensive imagery of UK, Ireland, Isle of Man and Jersey and complete coverage of English counties such as Hampshire, Cornwall and Norfolk.

[2] *http://www.simmonsaerofilms.com/aboutus.html*

An ever-increasing interest in the environment and its conservation features widely in modern life, and spatial data has a special role to play in both monitoring and managing environmental change. By using aerial or satellite imaging, digital mapping or data conversion techniques, accurate locational and elevation data can be created to provide a wealth of information on changes in our world.

BKS works both independently, and as part of Private Finance Initiatives, to deliver spatial data solutions that facilitate the integration of a Planning Authority's information into an active GIS. With available technologies, BKS creates databases to hold information of Local Land Charges, Land Terrier, Council House Sales, Planning Applications, Conservation Orders etc. in a digital form, thus facilitating storage, retrieval, updating and measurement and ultimately the monitoring of urban growth.' [3]

The size of the oblique archive collection is difficult to ascertain, but a representative of the company reports that it may amount to *c.* 2,500 to 3,600 images. Vertical photography is mainly project-based and has recently included a major resurvey of the whole of Ireland for the OSi. Other surveys include city-based coverage at 20-25m resolution of Dublin, Cork, Galway, Limerick and Waterford. Vertical coverage also relates to specific types of development or land-use change (roads, housing, industry, pipelines, forestry, and general development planning).

Contact with archaeologists seeking archival material is reported as being virtually non-existent, though certainly a number of photographs were commissioned or accessed during the compilation of the SMR. The material is not publicly accessible for inspection, but inquiries are handled over the internet.

Recently, the Discovery Programme and Heritage Council have commissioned BKS to undertake air photographic and lidar surveys by (see above; Figures 14 and 27).

Fairey Survey and Hunting Surveys

These two commercial operators, leading exponents of vertical survey in the 1960s to 1970s, ceased to trade in the 1980s. Copies of some of their surveys (*e.g.* the 1971 Fairey Survey coverage of Ireland) are held in various Irish public archival collections (see above), but much of the original archives were destroyed. (Aerofilms hold some Hunting material; Engineering Surveys hold some Fairey Survey material.)

Other Companies and Internet Resources

A number of other small commercial companies occasionally take archaeological air photos to order (*e.g.* Redmonds of Roscrea have taken photographs in the Limerick/Tipperary/Kildare area which are included in the SMR files). In many cases, these were commissioned for particular requirements such as book illustrations. They do not operate as public archives. There are also several web-based collections, some of which contain some aerial photographs of specific places, such as Joe Kenny's low-level images of Fethard, Co. Tipperary,[4] and more general collections.[5, 6]

Another extremely valuable online resource is that of Google Earth.[7] This site offers basic cover of most of the world from what appears to be Landsat TM images. Superimposed on this are blocks of much higher quality material with a resolution of 1-2m (Figure 18).

[3] *http://www.bks.co.uk/*
[4] *http://www.fethard.com/mainpages/aerial.html*
[5] *http://www.picturresofplaces.com/Europe/ireland.html*
[6] *http://www.jasonhawkes.com/servlet/Public?page=search&search=ireland*
[7] *http://maps.google.co.uk*

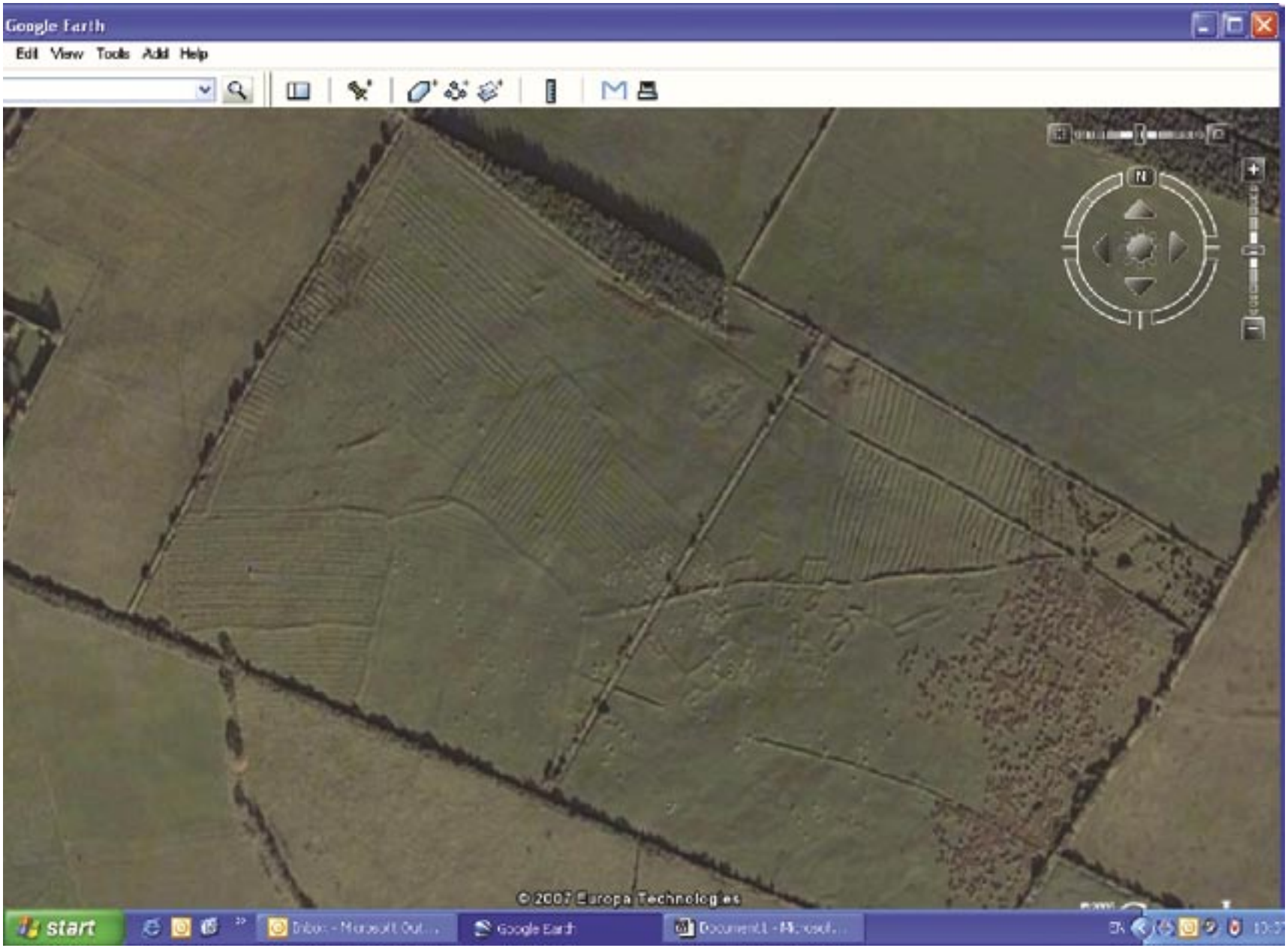


Figure 18: Google Earth satellite image of a post-medieval farming settlement at Carrignagower, Co. Wicklow

3 METHODOLOGICAL ISSUES IN CAPTURING AND HANDLING AERIAL IMAGING DATA

The ways in which the historic environment can be observed, recorded and interpreted from the air or from space vary according to its survival. This depends substantially on past and present land use, which in turn depends substantially on natural conditions of soils, topography and climate. Whether or not archaeological remains, buildings and structures are detectable and interpretable depends further on physical characteristics such as their size, form and state of survival, topography, soil, vegetation and moisture conditions.

These factors also affect the technical imaging methods that are used. They include:

- the part of the radiation spectrum being exploited (visible and infrared optical, thermal or radar).
- the choice of imaging 'platforms' (aircraft, satellites or very low-level methods).
- the methods of capture used (*e.g.* vertical/oblique photography; lidar; multi-spectral imaging).
- the scale and resolution of imagery (determined by height of platform as well as technical clarity of imagery).
- the timing of survey (especially for optical resolution, the direction and height of sunlight, weather including cloud cover, and water clarity for underwater sites).

3.1 Aerial Imagery: Using the Spectrum

Aerial archaeology is based on the fact that the spectrum of radiation reflected by the Earth's surface can reveal traces of past human activities. Soils, vegetation, rocks, buildings and water all have different and highly variable physical properties, including composition, shape and surface textures. As a result, they reflect light and other radiation, emit heat, absorb radio waves and reflect sound at different rates. This means that very subtle differences can be picked up by different kinds of sensors mounted in aerial platforms such as aircraft or satellites (see below).

Photography, infrared and thermal methods rely on the passive measurement of different parts of the spectrum which are naturally reflected from solar radiation. Three further methods — lidar, radar and sonar — are based on measuring the reflections of artificially induced pulses of laser light, radar beams or sound which are fired at the ground or through water. Within all of these basic methods, there are numerous variations which determine how they are best used for specific applications in different environments.

Various forms of remote sensing (using visible light, infrared and thermal radiation, radar, multi-spectral imagery and sonar) from both aircraft and satellite platforms have the potential to assist archaeological reconnaissance and interpretation. The most common and most familiar part of the spectrum to be used in aerial archaeology is visible light as captured through conventional photography. Some other methods have also been explored in some detail (*e.g.* Fowler and Darling 1998; Holden *et al.* 2002; Donoghue *et al.* 2002; Fowler 2002; Oltean 2002; Shell 2002; ERA-Maptec *et al.* 2005).

Infrared sensitive film allows those parts of the spectrum that are particularly sensitive to changes in vegetation to be used. This can provide enhanced imagery of subsoil archaeological remains, but it is not used very commonly. Thermal imaging tends to be most effective in vegetation mapping but subsoil features may also be detectable because different sediments may hold more moisture and thus have a temperature different from surrounding soils. Multi-spectral scanners can usefully detect a range of different wavelengths. The induced pulse methods have greater potential for penetrating superficial cover. Lidar is capable of penetrating darkness, vegetation cover and clear water. Radar can penetrate darkness, cloud cover, thick vegetation canopies, and even the ground. Sonar is especially appropriate for detection through water.

The issue of scale and levels of resolution — which a number of respondents saw as obstacles to archaeological use of airborne remote sensing, and satellite imagery in particular — have become less problematic in recent years due to technical advances.

3.2 Aerial Platforms

The equipment required to capture these various forms of aerial imagery can be mounted on a range of different aerial 'platforms'. While aircraft are most commonly used, satellites orbiting the Earth at a much higher level are also becoming more important. Various means of raising equipment above the ground at much lower levels can also be used for specific applications where fine detail is needed.

Helicopters and Fixed-wing Aircraft

There appears to be divergent opinion in Ireland on the relative merits of using helicopters or fixed-wing aircraft for oblique photography. In terms of cost, hiring helicopters is significantly higher, though some claim that this is partly offset by the ability to manoeuvre swiftly into the best position to obtain ideal lighting conditions, rather than having to circle extensively. For the purposes of taking high-quality photographs for publication and other uses in illustration and publicity, Con Brogan of the NMS uses helicopters. Some practitioners argue that the advantages of helicopters in terms of manoeuverability, accuracy of positioning and low-level operation make them so superior to fixed-wing aircraft that they would not consider using a fixed-wing platform. But for others, fixed-wing aircraft offer the considerable advantages of cost and range. These are crucial considerations, particularly for general reconnaissance. The close collaboration and mutual understanding between the photographer and the pilot of a fixed-wing aircraft – which Raftery (1944) highlighted in the first years of aerial archaeology in Ireland – can also go some way in offsetting the advantages of helicopters in terms of positioning.

There is no single right answer to the question of helicopters versus fixed-wing aircraft. It is not only a matter of cost, as it also involves individual experience and the purpose for which the photography is being undertaken. It is ultimately the quality of the imagery that counts. As a 'user' of the results of aerial survey in the context of advising the National Roads Authority on archaeological issues, Ronan Swan (pers. comm.) observed that taken as a whole, there are no obvious differences in quality attributable to the use of helicopters or fixed-wing aircraft. Quality issues more often tend to concern photographic skills, and the quality of descriptive identification, interpretation and pinpointing of site localities in ways that are useful for further stages of work.

Figure 19: Two stone-built enclosures at Carrig Aille, Co. Limerick, part of the Lough Gur complex. From this high-quality, low-level aerial imagery, the form of the monuments and their prominent position on a rock promontory are clear. It is also possible to see that the monuments are in generally good, stable condition in appropriate land use, with no serious problems of rutting, poaching, erosion or scrub encroachment (Department of the Environment, Heritage and Local Government)

Satellites

The potential for using satellite imagery in archaeology has been recognised for over ten years (Fowler 1996), though it is only in the last five years that the availability and cost of high-resolution imagery has made it an obvious alternative to aircraft-based vertical photography. As discussed below, and as with conventional aircraft, satellites can be used to provide imagery based on optical (visible light, near infrared, shortwave infrared), thermal and radio wavelengths. A range of satellites is used to provide such imagery. They are generally positioned at altitudes of 400km to 700km in polar, sun synchronous orbit, with a typical repeat overpass of one to 16 days.

Depending on the particular satellite and the services offered, they can provide imagery at low resolution (*c.* 1km or more), medium resolution (*c.* 100m to 1km), high resolution (*c.* 5m to 100m) and very high resolution (*c.* 5m or less). Although medium resolution can provide valuable general vegetational mapping, it is the high (and more particularly very high) resolution systems that are of most value for archaeological applications, as outlined below.

Available High Resolution Satellite Imagery (Source: M. Critchley, ERA-Maptec Ltd)

Satellite	Resolution (m)	Bands	Type
QuickBird colour infrared (pan merge)	0.60m	NIR, R, G	Colour
QuickBird multispectral	2.44m	NIR, R, G, B	Colour
IKONOS colour infrared (pan merge)	1m	NIR, R, G	Colour
IKONOS multispectral	4m	NIR, R, G, B	Colour
Spot 5 (pan merge)	2.5m	NIR, R, G	Colour
Spot 5 (pan merge)	5m	NIR, R, G	Colour
Spot 5 (multispectral)	10m	SWIR, NIR, R, G	Colour
Landsat ETM	15m	SWIR, NIR, R, G	Colour
Radarsat	10m	C-Band	Radar
ASTER	18m/30m	SWIR, NIR, TIR	Colour, Thermal

Abbreviations for wavebands: SWIR = shortwave band infrared, **NIR** = near infrared, **TIR** = thermal infrared; **R** = red; **G** = green; **B** = blue; **C-Band** = C-band radar

As noted earlier, the Google Earth internet site now offers basic cover of most of the world, but with blocks of much higher quality resolution of about 1-2m which can be of some use archaeologically. For Ireland, this imagery now covers major population centres and various other areas and swathes of landscape including, for example, a significant part of Kerry. It compares well with relatively high-level vertical photography.

Very Low-level Aerial Imagery

At the most detailed, low-level end of the scale, the use of remote-controlled cameras (less often other scanners) mounted on small, unmanned aircraft (*i.e.* balloons, kites and radio controlled model aircraft) or on top of manoeuverable poles and masts has been an established, though not mainstream, form of aerial archaeological photography since the 1970s. This continues to be developed by some practitioners, and is becoming increasingly refined as the technology of remote controlled photography and control of miniature flying platforms improves (*e.g.* Knisely-Marpole 2001 on kites; Schönherr 2001 on model aircraft). For example, in recent years, the Discovery Programme has been making good use of both balloons and telescopic masts (Figures 19, 20), though others said they had experimented with kites for site photography without much success.

Figures 20 a-b: The use of balloons for low-level aerial photography
a: Acquisition of aerial imagery using a Skyshot kite/balloon on an excavation trench at Carns, Co. Roscommon (Discovery Programme Medieval Rural Settlement Project)

b: Ortho-rectified balloon-mounted imagery created using Topcon PI-3000 photogrammetry software (Discovery Programme Medieval Rural Settlement Project, 2007)

Figure 21: Vertical photograph of a souterrain at Roestown, Co. Meath, on the route of the M3 motorway. This was taken using a remote controlled Nikon D2X camera on a Jeep mounted telescopic mast at a height of approximately 23m (Hawkeye Photography for Meath County Council/National Roads Authority and Archaeological Consultancy Services, 27 October 2006)

3.3 Conventional Photography: Geographical Limitations and Potential

Over the whole of Ireland, archaeological sites survive as earthworks and structures that can be recorded, analysed, interpreted and illustrated using aerial survey. Aerial photography has a particular role in helping to identify features that may be difficult to see on the ground, and where a clearer view of their context assists identification (*e.g.* slight traces of field systems, small low barrows where viewing of stereoscopic photography or low-level lighting coupled with low vegetation enhances visible relief). The visibility of features from the air is enhanced by careful timing to coincide with times when vegetation is low, weather is clear, and the sun is low in the sky. This can be enhanced by extreme weather conditions (drought, frost or snow). Lidar techniques (see below) overcome several of these limitations, although they are relatively expensive.

In many areas, particularly on poorer soils and where agriculture has not been intensified (or in the case of the Burren where ancient land use led to soil depletion), archaeological survival is particularly high. In such areas, there tends to be a more complicated palimpsest of overlain remnant features than elsewhere. These reflect long-term changes in land-use practice, with the traditional idea of discreet archaeological 'sites' becoming increasingly dubious. Aerial archaeology is especially well-suited to providing the basis for landscape interpretation in these areas (Herity 1987, 1988; Barrett 1997/8, forthcoming b; Kelleher 1995). Barrett (1993; 1997b; 1997/8) has used air photography in Kerry, Roscommon and elsewhere to show how vulnerable such palimpsests are to agricultural clearance (Figure 22).

J.K. St Joseph (Norman and St Joseph 1969) graphically revealed how formerly upstanding sites that have been flattened by ancient or recent agricultural clearance are still detectable as sub-soil remains which are revealed by crop and soilmarks in the tillage counties of eastern and southern Ireland (Figure 23). Although no longer upstanding, such remains nevertheless add significantly to the overall archaeological resource and its potential for research (Barrett 1980, 1982b, 1984).

Figures 22 a-b: Improved and unimproved fields at Brideswell, Co. Roscommon (Gillian Barrett, May 1991)

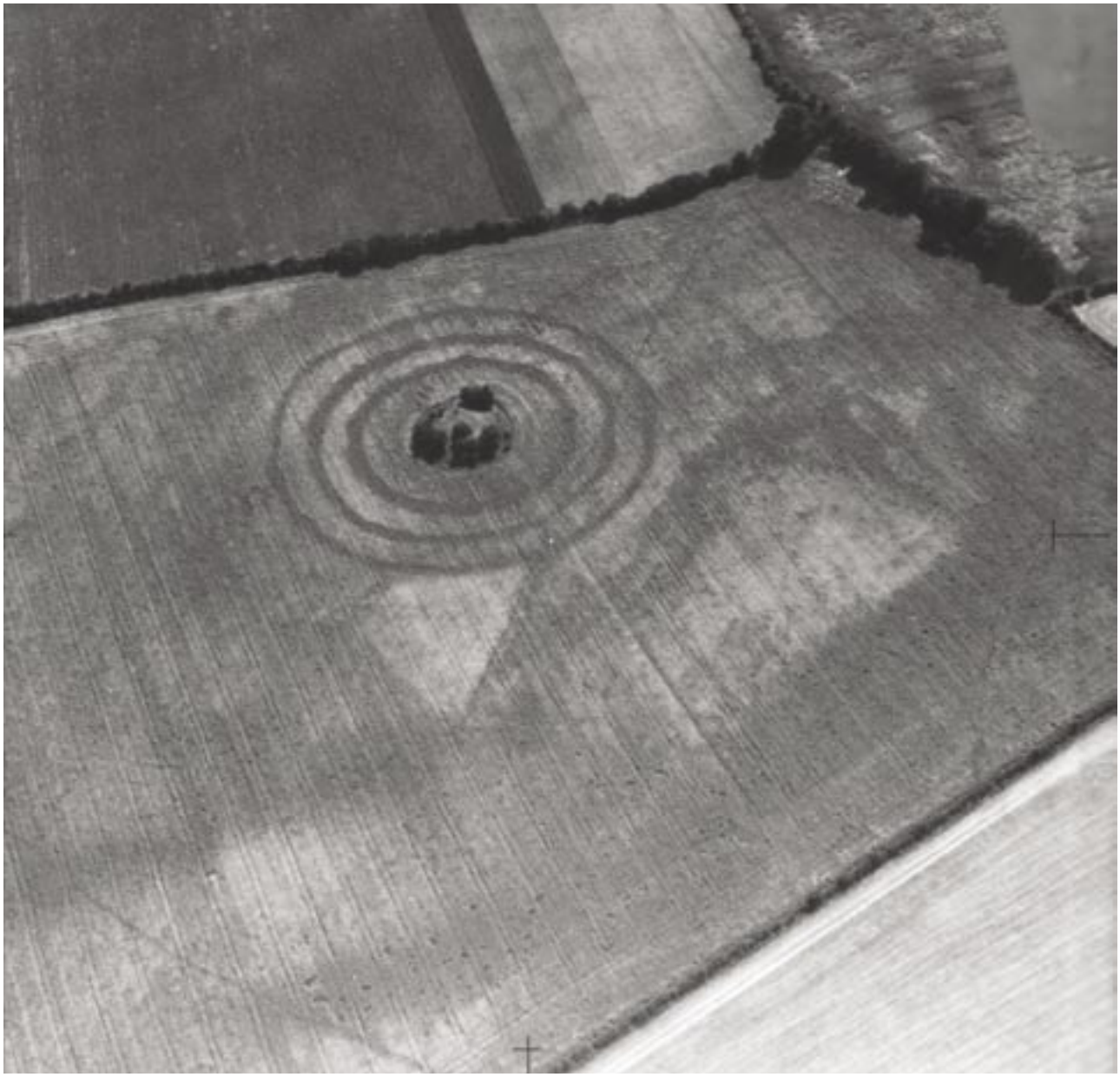


Figure 23: The true form of the large trivallate barrow at Fenniscourt, Co. Carlow, was revealed by air photography which captured the cropmark evidence of three ditches surrounding the upstanding tumulus (CUCAP 16 July 1971)

As noted above, the aerial survey of earthworks can be enhanced by choosing ideal timing and weather conditions (*e.g.* Figures 24, 27, 28). Cropmarks, however, are even more dependent on climate and seasonal weather patterns, as well as cropping patterns, for their appearance. Soil moisture deficit is a crucial factor. This varies on a highly seasonal basis, from one year to another, and from one locality to another. Coupled with variations in cropping patterns, this makes the appearance of cropmarks highly capricious.

Figure 24: Low-level oblique photography of a ringfort near Newgrange. Note how differential melting of the frost and the shadows cast by the varying height of the adjacent hedge help to highlight the slight earthworks and modern plough furrows picked out by the low winter sunlight (Department of the Environment, Heritage and Local Government)

In the UK, there is increasing evidence that the combination of agricultural intensification and probable climatic change (coupled with some reduced restrictions on flying) have resulted in a high continuing rate of new discovery of cropmark sites. This even applies to areas such as the Thames Valley where aerial archaeology has been intensively undertaken for nearly 70 years (Benson and Miles 1974; Fenner and Dyer 1994). In Ireland, there seems to have been a largely unspoken assumption among many archaeologists – at least until recently – that St Joseph 'did' the country in terms of cropmark photography. Coupled with the generally better survival of field monuments in a predominantly pastoral farming economy, this has meant that there has been rather less general interest in what might be termed cropmark archaeology, and less concern to ensure systematic aerial reconnaissance. In fact, St Joseph himself stressed that he had only sampled some areas and considered he had only illustrated the potential (Norman and St Joseph 1969). The exceptional year of 1989 in particular showed that considerably more buried archaeology was still to be found through aerial photography of cropmarks (*e.g.* Figure 41; Barrett 1990, 1995a, 1995b; Power 1993).

With the example of a 16km^2 study area around Dunmanoge, Co. Kildare, Barrett (1995b, 1997a, 2002) has further illustrated the cumulative, capricious way in which sites are gradually revealed by cropmarks. Here, a total of 19 archaeological sites are known: three marked on the 1837 1st edition OS 6" map; one chance find in 1960; five cropmark sites identified by St Joseph in 1971; one site excavated on the Cork-Dublin pipeline in 1982; and as a result of further aerial reconnaissance by Barrett, three further cropmark sites discovered in 1989, another three in 1990, and three more in 1991 (Figure 25). Thus 14 of the 19 monuments known in the area are cropmarks, although they were discovered in four separate years.

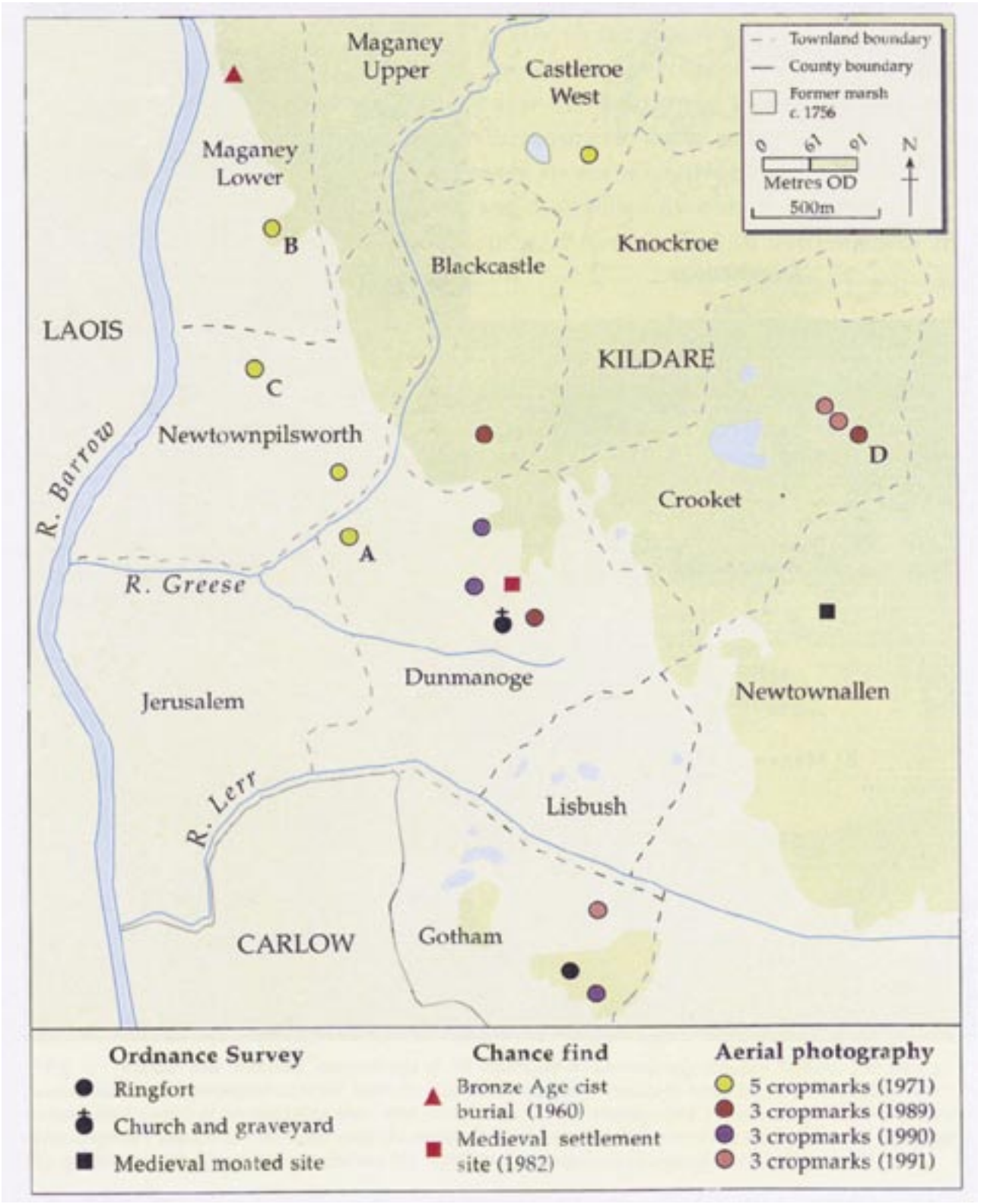


Figure 25: The cumulative impact of aerial discovery between 1971 and 1991 has changed our understanding of the archaeological resource at Dunmanoge, Co. Kildare (after Barrett 1997)

In another case study, this time of a 20km^2 area in the Barrow Valley near Linkardstown, Barrett (forthcoming) notes that a total of 20 sites were recorded in the *Archaeological Inventory of County Carlow* (Brindley and Kilfeather 1993). These consist of 12 monuments derived from cartographic sources, two chance finds and six CUCAP cropmark sites. Between 1989 and 1996 Barrett recorded a further 28 cropmark sites, so that in all, 34 of the 48 known sites were derived from air photography. The cumulative effect of air photography is even more apparent here than at Dunmanoge, with new sites being recorded from aerial surveys in 1967, 1969, 1971, 1989, 1991, 1995 and 1996.

A third example (Barrett 2002, 18) illustrates similar phenomenon at Castleroe West and Castleroe East in Co. Kildare, where two monuments recorded on the 1837 OS map were supplemented by discoveries from aerial surveys in 1971, 1989, 1991 and 1995 which added a group of five ring ditches and five enclosures (two conjoined and another a previously unknown outer enclosure of a ringfort).

Even in wetland areas and shallow water, archaeological sites can be discovered and recorded through aerial survey. In river valleys, air photography can dramatically reveal how settlement has avoided floodable land (Figure 26). Within the areas of extensive raised bog of the Irish Midlands, aerial archaeology is in some respects more limited as a means of observing archaeology. Nevertheless, it is said that differential frost patterns can reveal buried archaeological remains, and much can be discerned from the location of possible dry-ground areas and features within bogs, causeways etc., allowing some prediction of where remains may survive (*e.g.* Condit 1997, Pl 21).

Figure 26: At Ennis, Co. Clare, the floodwaters of the River Fergus reveal how settlements have been positioned on dry ground. On the left of the photograph, the remains of medieval Clare Abbey can be seen occupying the tip of a low ridge surrounded by flooding (Department of the Environment, Heritage and Local Government)

As Raftery (1944) noted, aerial archaeology has proved valuable for detecting archaeology in lakes and shallow coastal waters (see Figure 43; Williams 1996; McErlean *et al.* 2002; O'Sullivan *et al.* 1997; Condit 1997, Pl 14; M. Casey pers. comm.). Lidar provides further opportunities in this area (F. Fitzpatrick pers. comm.; see Section 3.4). One of the problems with its use in relation to lakes can be the opaqueness of peat-derived waters.

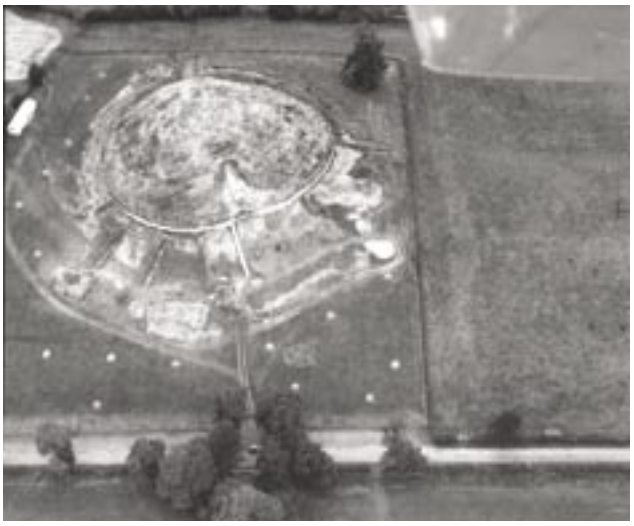
3.4 Conventional Photography: Different Scales and Approaches

Different scales and types of aerial imagery, together with different land uses, lighting conditions and viewpoints, all affect how useful both historical and recent photography can be for different purposes (*e.g.* Figures 24, 27, 28). In this section, some of the pros and cons of different kinds of imagery for some common uses are discussed.

Figures 27 a-d: Comparative viewpoints, land use, scales and lighting conditions in historic and recent aerial photography at Newgrange, Co. Meath in the Boyne Valley

a: An Irish Army Air Corps view in 1924. This photograph of the area immediately west of the main passage tomb was taken when most of the land was improved pasture. It shows only indistinct hints of archaeological features such as the large circular monument in the bottom right corner by the river (Royal Society of Antiquaries of Ireland/ Government Stationery Office)

b: An Ordnance Survey vertical photograph taken at altitude of 20,000 feet during the dry summer of 1995. This slightly wider view of the area, now more intensively farmed for arable crops, includes Newgrange itself and shows numerous cropmarks, including a much clearer impression of the monument by the river (Ordnance Survey Ireland)



c: The Newgrange passage tomb undergoing conservation works in 1967. Despite the clarity of the image, the flat lighting fails to highlight the form of the monument and the presence of surviving standing stones (CUCAP 15 July 1967)

d: The Newgrange passage tomb after conservation work. This view taken almost at right-angles to morning sunlight makes the most of the contrasts of light and shade to reveal the form of the mound and the surviving standing stones (Department of the Environment, Heritage and Local Government)

Identification of Archaeological Remains

One of the most fundamental and common applications of aerial archaeology is for identification of archaeological sites and monuments. While most respondents referred to the GSI as a readily accessible primary source, there was also widespread acknowledgement that the 1:30,000 scale limits the usefulness of that coverage, a point that has also been made in print (Swan 1978; Waddell 1983; Kirwan 1993; Condit 1997, 46; Doody 1993a, 2001). This widespread recognition of the limitations of small-scale general vertical coverage is tempered by its relative accessibility and comprehensiveness of coverage. The frequent use of the GSI collection (mainly by archaeological consultants and contractors) appears to be related more to its ease of access — *e.g.* compared with the OSi — than to the relative merits of the photography available at these two institutions or the Air Corps. Few respondents referred to the value of the OSi low-level vertical photography (or the older archival material at the Air Corps) as a routine source, although this has certainly been recognised in relation to some archaeological complexes such as Rathcrogan (Waddell 1983; Herity 1983, 1987, 1988). It was used, at least for some areas, in the compilation of the SMR and the County Inventories.

Apart from issues of scale, much of the general national vertical coverage is hampered by not being taken in ideal conditions of low lighting. Various studies have drawn attention to the enhanced value of medium-to-low altitude vertical photography taken in ideal lighting conditions (*e.g.* Wilson 2000; Norman and St Joseph 1969; Gowen 1988; Doody 2001). The value of re-examining existing archival collections has been demonstrated by Herity (1983). He has reviewed the coverage of high-level GSI and OSi vertical cover (1:30,000), medium-level Air Corps cover (1:10,560) and low OSi verticals (very clear 1:4,000 images), and St Joseph's low-level oblique photography. Technical advances offer further potential in re-analysing existing photographic coverage (see below). Changes in land use have had complicated influences on the value of aerial archaeology (*e.g.* Figure 27).

The scale of additional information to be gained from medium and low altitude vertical photography has been most clearly documented by Hartwell (1987), Gowen (1988) and Doody (1993a, 2001).

Hartwell (1987) examined a series of vertical Ordnance Survey photographs which covered an area 6x8km west of Armagh. Photographs were taken in 1966, 1967, 1974, 1975, 1977 and 1983 (variously in May, June, August or November, two at 1:20,000, three at 1:1,000, and one at 1:9,000). Careful stereoscopic viewing revealed 76 archaeological sites, of which only 15 were previously recorded in the SMR for Northern Ireland, and thus representing a five-fold increase.

Gowen (1988) has reported on a two-stage aerial reconnaissance programme which was part of a survey of a gas pipeline route in the valley of the Morningstar River. First covering a 1km-wide route selection corridor flown at 1:10,000 scale, it was followed by 1:5,000 coverage of the route itself, flown in ideal lighting conditions in November 1984 following a dry summer. Up to 200 new 'ring-barrows', typically 10-15m in diameter, were identified around Garryspillane. At Elton, a cemetery group of nine barrows visible on the ground was increased to a possible 27 barrows detectable from the air photography. It was also found that some of the possible sites identified from the 1:10,000 coverage could be dismissed with the better-lit, and more detailed, 1:5,000 cover. Much of the newly discovered archaeology was skirted by the pipeline, but some unavoidable sites were validated by excavation. Gowen's report emphasised the need for a wider spatial (rather than linear) survey to clarify the implications of such discoveries for wider distribution patterns.

This suggestion was effectively taken up by an aerial photographic trial in 1986, organised by the then Office of Public Works in conjunction with Cork University. Doody (1993a, 2001) has reported the results of this study, which covered an area 20.2 x 26.4 km (532km^2) centred on Herbertstown, Co. Limerick. The area was flown under ideal weather conditions in early morning sunlight to maximise visibility of low earthworks. Detection was further enhanced through a 60% stereoscopic overlap in the 280 images taken (Doody 2001, 13). The area was chosen for the known richness of its archaeology — with 1,490 known sites on the SMR. The medium-altitude survey added a further 1,074 sites, an increase of 69%. Doody's breakdown of sites by types showed that the increased identifications were much higher for some types — although they were negligible or non-existent for others (the increase in undefined earthworks was 138%; hut sites, fields settlements 117%; barrows 104%; enclosures 87%).

Vertical versus Oblique Photography

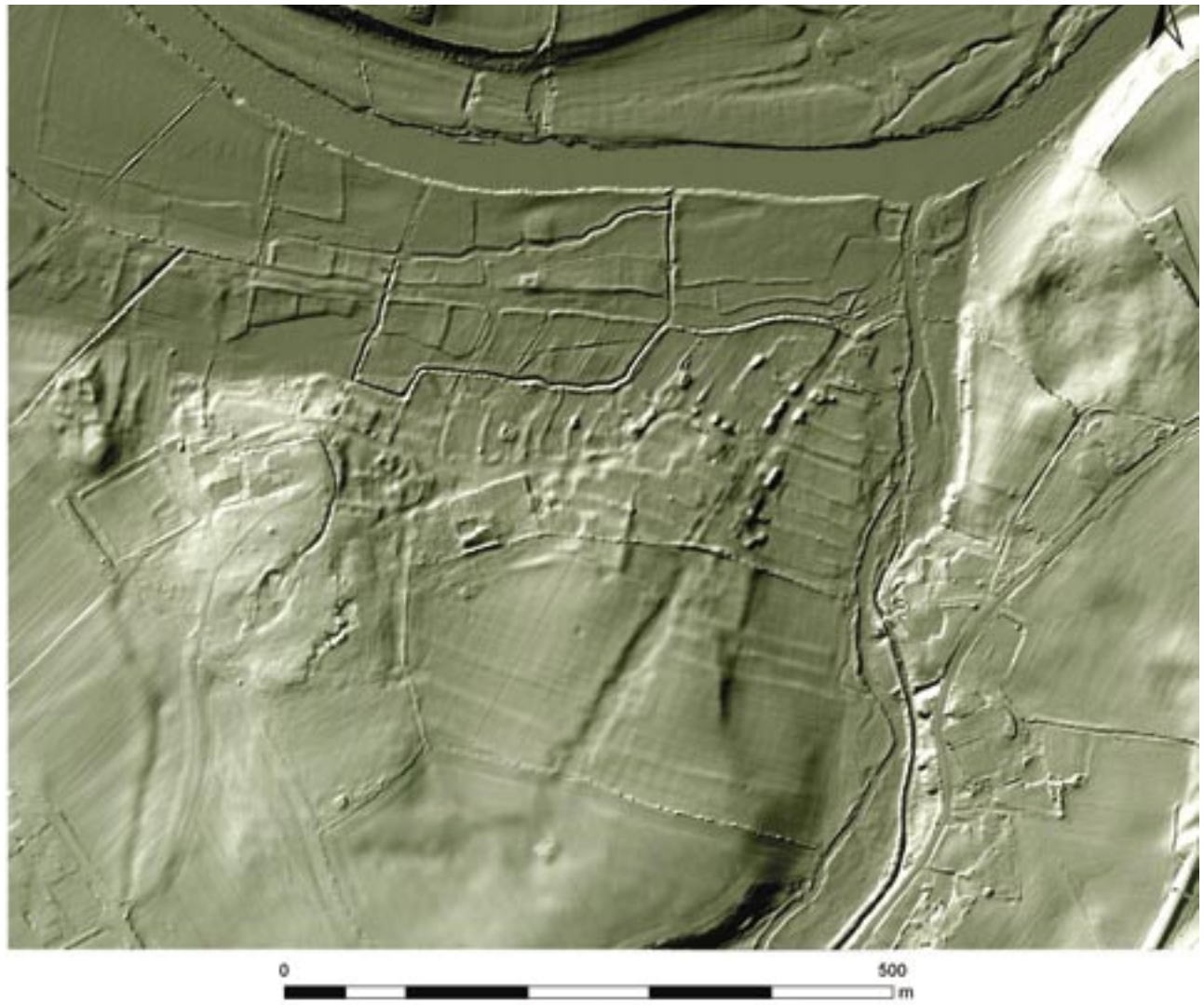
The relative merits of vertical and oblique air photography have been matters of debate since their inception, and continue to be a highly relevant consideration for any survey work (Chart 1930; Norman and St Joseph 1969; Doneus 2000; Crawshaw 2001b; Doody 2001). In the Irish context, there is a good deal of practical evidence of this (Figures 27, 28). It includes the difference of detail to be observed between general vertical cover of complexes such as Tara and the extremely high detail that can be obtained by low-level oblique photography in the right conditions (Norman and St Joseph 1969; Swan 1978; Newman 1997). St Joseph – often regarded as the greatest exponent of oblique photography – was quite clear about the value of vertical imagery, commenting that oblique photography was '*the most economical of flying time*' but that '*for many aspects of scientific study overlapping vertical photographs are the most valuable of all...*' (Norman and St Joseph 1969, 3).

In addition to assessing the value of medium-altitude vertical photography, the Bruff survey also compared these results with specially commissioned low-level oblique photography of a smaller, 20x8km area within the main study area (Doody 2001). Both sets of commissioned photography were taken in favourable conditions of clear weather and low lighting. The vertical cover was taken in May 1986, with the obliques in March of the following year. Of the total 114 sites recorded in the area, 80 were visible on both vertical and oblique sets of photographs, nine only on the verticals, 13 only on obliques, and 12 on either. Differences were considered to arise from seasonal factors, including height of vegetation (lower in March).

Figures 28 a-c: The deserted medieval borough of Newtown Jerpoint, Co. Kilkenny, at the confluence of the River Nore to the north and the River Arrigle to the east. A comparison of standard vertical coverage, specially taken oblique images and lidar imagery of the same area displays remarkable differences in the extent and clarity of the remains

a: A medium-level 1995 vertical photograph reveals no obvious trace of the deserted settlement (Ordnance Survey Ireland)

b: An oblique photograph in low winter light of the same area captures the complexity of the surviving earthworks of regularly laid-out property boundaries and hollow ways (Michael Moore, Archaeological Survey of Ireland, Department of the Environment, Heritage and Local Government)



c: A lidar survey carried out in 2007 has revealed slight earthworks covering a much larger area with significantly more detail and more coherence in the layout of streets, house platforms and plot divisions. (Survey by BKS Ltd for the Heritage Council and the Discovery Programme)

Metrical Survey

As Doody observed, the simple question of 'yield' in terms of the number of sites identified is only part of the issue. Compared with identifying sites, there is a big difference in the relative value of oblique and vertical photographs for accurately locating and surveying them, as we have seen (Figures 26, 27). While oblique photography is better at exploiting lighting effects to maximise clarity (Wilson 2000), vertical photography offers other advantages. It is more systematic, and offers enhanced stereoscopic viewing and greater ease in rectifying and plotting results (including, for example, digitally integrating scanned photographic images with terrain modelling). It may also be noted that very high-resolution colour and panchromatic satellite imagery such as QuickBird can now produce imagery in the visible spectrum to 0.6m resolution, which is better than standard OSi ortho-photographic mapping (Section 3.6).

Much depends on what levels of accuracy are needed. Oblique photographs are often better for identification in terms of visibility of features. They can also be rectified to provide approximate positions on medium to large-scale maps, if that is all that is needed. But their use as a means of accurately surveying and measuring a monument to a high degree of accuracy (*e.g.* to within a few metres) is often suspect, especially on non-flat ground. For example, rectifying oblique aerial images to 1:10,000 or larger scale maps will result in inaccurate locations for sites due to the errors in the base map itself, the change in scale throughout the image, and the errors due to relief displacement. Not all of this can be allowed for, even in bespoke rectification software, without the additional information provided by digital terrain models.

In the past few years, the Discovery Programme has undertaken various aerial survey projects – notably at North Roscommon and Mullaghfarna, Co. Sligo – which show the considerable potential of large-format vertical photography in mapping archaeology (Figures 13, 32). Each of these projects was carried out using professional photogrammetric software. Medium and/or low-level photography were commissioned, with ground control provided by DGPS. The resulting mapping has produced true ortho-photos to a very high level of accuracy (each pixel covering 0.16m x 0.16m on the ground) that is better than base mapping tolerance. The new mapping has revealed a level of archaeological landscape and monument detail that was well beyond expectations. In the North Roscommon Project, it was found that oblique images could only be rectified to a good level of accuracy when additional control points, identified from ortho-photography derived from vertical images, were used.

3.5 Lidar

Principles and Strengths of Lidar

This technique generates high-resolution elevation data derived from a special airborne instrument that samples the underlying ground height using the return time of a laser pulse across a swathe of land (Figure 29). The data are automatically geo-referenced by means of an on-board receiver linked to the Global Positioning System (GPS) provided by earth-orbiting satellites. Sample points are typically interpolated at 2m horizontal intervals, with a vertical error range of only 10-15cm which compares very favourably with conventional vertical photography. This provides a reasonably accurate means of gathering 3-dimensional co-ordinates of the ground surface to produce Digital Terrain Models (DTMs), though the resolution is not as good as detailed ground-level surveying. Lidar data often contain a degree of background noise. Vegetation, buildings and other objects may need to be removed to detect the true land surface, and this can be achieved by filtering and interpolation techniques relevant to the actual application.

For each point recorded, the lidar data provides the horizontal position of each measurement point at horizontal intervals of *c.* 0.5m on the ground, and first return and last returns of the laser pulse and their intensity. This allows both solid (ground) profiles to be distinguished from vegetation and measured to within 15cm absolute accuracy. The intensity measurements help to establish different types of vegetation or structure.

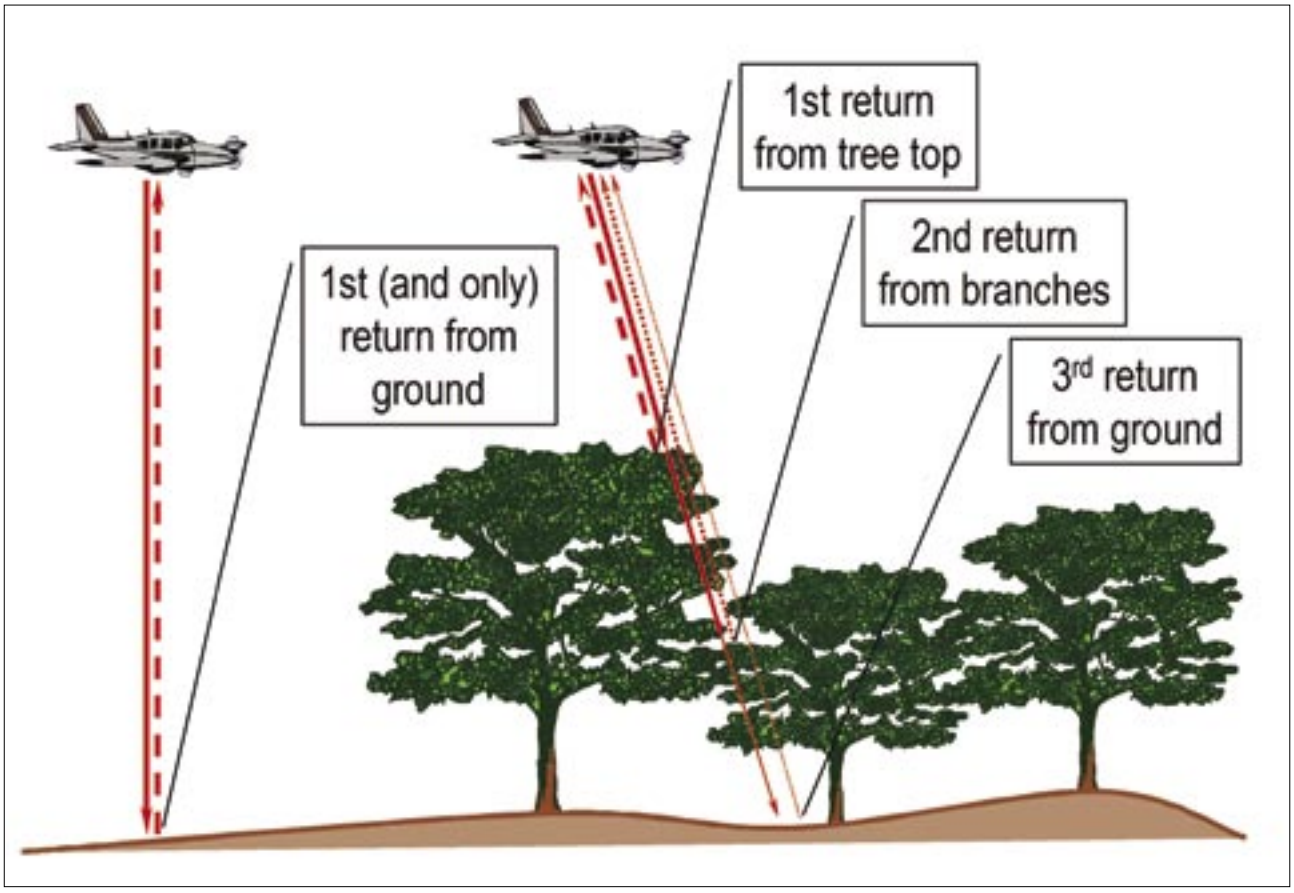


Figure 29: Diagram demonstrating the principles of lidar (H. Mangan)
Using an aircraft flying at a constant height, with its exact position being tracked by a high resolution global positioning system, rapid pulses of laser beams are fired at the ground. The timing of the first, second and third return reflections off vegetation, buildings and the ground measures their height and position, providing 3-dimensional mapping of sufficient resolution to reveal small undulations in the ground surface. The data can be filtered to remove first and second return reflections, leaving only the ground surface measurements, and thereby effectively seeing through tree cover

Advantages of the lidar data include its potential to show up very indistinct earthworks which cannot be seen as easily on the ground. This is assisted by the facility to apply low-level 'lighting' of the digital terrain model from any angle and enhancement of images by exaggerating the vertical scale and using the image intensity data. This does not make ground survey redundant, but it does make a major difference to how it can be targeted on aspects and areas that need more detailed information (Figures 28, 35).

A less well-known application of lidar is for mapping the seabed. Fiona Fitzpatrick of the Marine Institute has provided the following comments. This application of lidar utilises red and green laser light pulses emitted from an aircraft flying at typical heights of 200m to 400m to determine water depth. The laser pulses reflect from the sea surface and the seabed back into receiving optical instruments mounted on a stabilised platform. The time difference between the sea surface return and seabed return is used to determine the water depth. The systems can give detailed bathymetric data (accurate to IHO Order 1) very quickly over large areas at a sounding density of about 2m to 5m within the survey area. A typical maximum depth penetration for lidar is about 40-50m in clear water, 20-40m in coastal waters, and less than 20m in more turbid inland waters.

Commercial companies, such as the Tenix LADS (Laser Airborne Depth Sounder) Corporation,[8] claim that the lidar technique is the fastest, most cost-effective tool for accurate bathymetric survey in coastal waters. They state that it is capable of surveying complex areas up to 20 times faster than survey ships and at 20% of the cost. Tenix's case studies include a number of surveys that have identified a significant number of wrecks off the Florida coast and elsewhere. The LADS system has been audited by Land Information New Zealand (LINZ). Similarly, Optech's SHOALS lidar system[9] offers the ability to survey shallow waters,

[8] *www.tenix.com*
[9] *www.optech.on.ca*

shoreline and topography (ground elevations) simultaneously, integrating land and water measurements in the same data set. Submerged wrecks, structures and other objects (down to 2m x 2m x 2m dimensions) have been recorded. Based in the UK, Admiralty Coastal Surveys is another group involving the UK Hydrography Office which offers coastal and marine airborne bathymetry using lidar.

The Use of Lidar in Ireland

An important study commissioned by the Heritage Council has examined the value of lidar coupled with conventional imagery and field survey in the Loughcrew area. More recently, the OSi have undertaken a detailed lidar survey of the Rathcrogan complex and BKS Ltd has undertaken a survey of Newtown Jerpoint, Co. Kilkenny, for the Heritage Council and the Discovery Programme (Figure 28). The value of lidar for marine archaeological survey is also being developed.

The Loughcrew study was undertaken by Colin Shell and Corrine Roughley of the University of Cambridge in conjunction with Elizabeth Shee Twohig of the University of Cork (Shell and Roughley 2004; Shell *et al.* 2004). They applied lidar scanning to a 5x6km core area (83 million points measured in 25 swathes) within a wider 10x12km area covered by conventional photogrammetry (65 vertical photographs taken for the purpose at a scale of 1:12,500), tied in to 101 ground control points tied in to the Irish National Grid through GPS and OSi data. The photographic coverage was ortho-rectified and mosaicked into a continuous, colour rectified image. Using GIS, both the lidar and photogrammetric images could be combined and manipulated and overlaid with historic map evidence and archaeological data available from the SMR. The results have clearly demonstrated the value of the technique for archaeological site identification and analysis, in addition to understanding at the landscape scale even in an area that is already well-known and has been intensively surveyed. About 160km of linear archaeological features were analysed and digitised from the lidar data, only 10% of which were previously included as Recorded Monuments. In addition, new discoveries include: three possible barrows and 13 other round mounds; three larger mounds and five sub-circular banks; four square mounds; and a substantial moated site (Figure 30).

The GSI and the Marine Institute have commissioned a lidar survey for Stage 2 of the Irish National Seabed Survey over three years (2006-9). Key bays and priority areas around Ireland have been targeted for integrated survey work. The areas were selected after intensive consultation through the various stakeholders, including the Underwater Archaeology Unit of DoEHLG. Included within the priority bays are areas that have high archaeological potential (*i.e.* piers, harbours, fish traps and wreck sites). Where possible, airborne lidar has been selected as the preferred tool for mapping the inshore areas. Following the successful location and mapping of wrecks in shallow waters off Donegal using lidar and side-scan sonar, the results of these surveys are likely to be of significant interest for coastal and inshore underwater archaeology. The programme will be reviewed at the end of the three years.

So far, the direct application of such techniques to archaeology has been inhibited by the relatively high cost of new survey imagery. The availability of specialists able to process the data can also prove problematic, as is the lack of general coverage of the country at suitable levels of resolution. Despite the undoubted quality of outputs (which in many respects exceed what is available through conventional photography), these issues remain significant barriers to the more general use of lidar. However, this is likely to change rapidly as the technology and its availability improve and costs are reduced. Perhaps even more pertinently, further rapid change is likely as the value of integrating archaeology with other objectives becomes more widely appreciated.

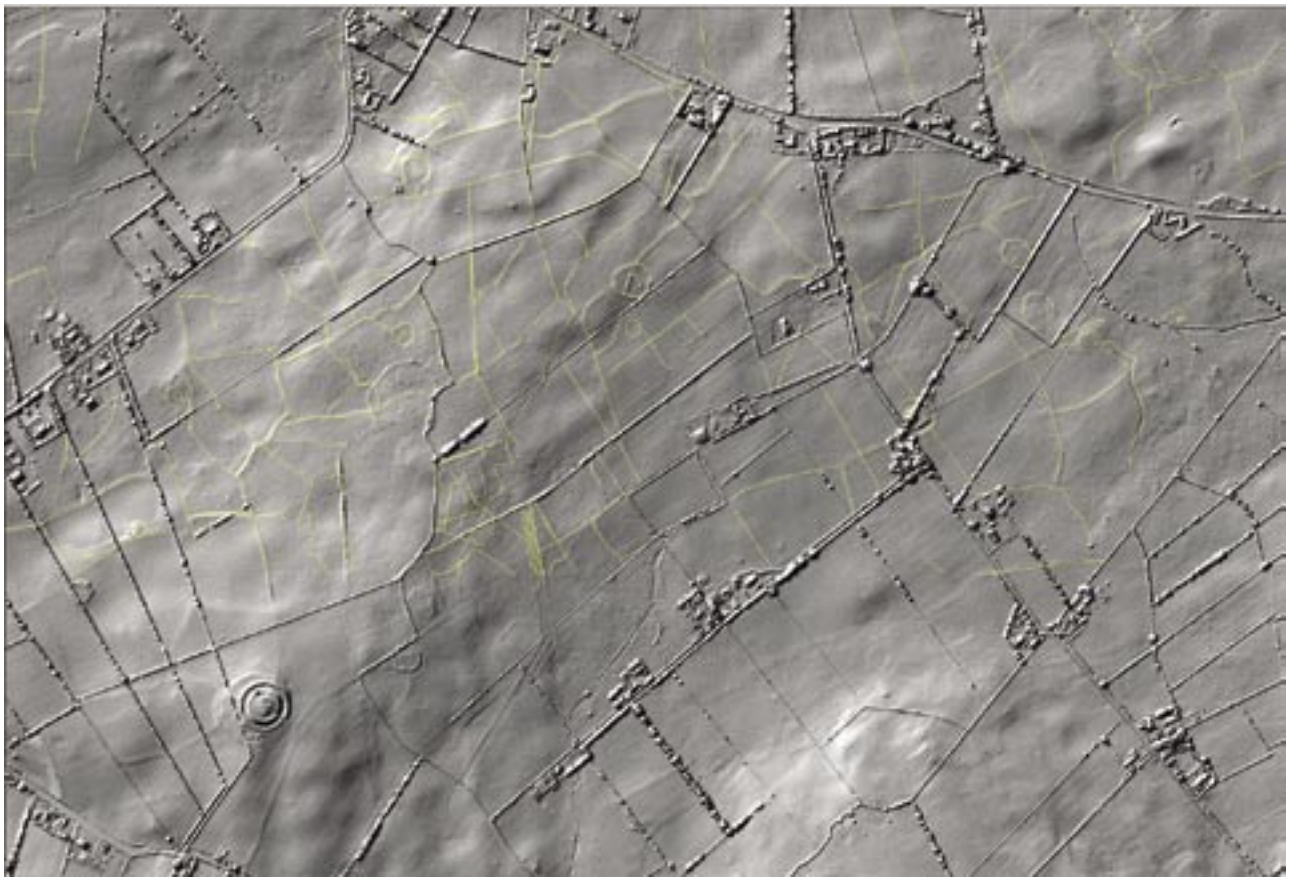


Figure 30: Lidar survey of the area around Loughcrew, Co. Meath, showing the transcription of surface features such as relict field systems and enclosures (Colin Shell, University of Cambridge)

3.6 Satellite and Airborne Colour Infrared Imagery

In Ireland, an increasing amount of satellite-based remote sensing work is already being done. It is being used to look at issues of environmental change, and increasingly for direct archaeological recording and interpretation in environmentally sensitive areas. Although a number of satellite images were used in the presentation of reports by the Wetland Archaeological Survey (*e.g.* Moloney 1993), the available resolution was more illustrative of geographical context than informative about the archaeology of the areas. It is only in recent years that sufficiently high-resolution imaging which is suitable for primary archaeological survey has become readily available.

A pilot study commissioned by the Heritage Council used colour infrared satellite imagery to survey the problem of scrub encroachment on a major part of the Burren (ERA-Maptec *et al.* 2005). The objective was to demonstrate the value of such methods for habitat monitoring and archaeological site identification and mapping as a basis for developing strategic approaches to land-use change and conservation (Figure 31). The study covered a 460km^2 area and was based on:

- *Literature review and desk study of sources of data for both habitats and archaeological sites and monuments.*
- *Fieldwork covering seven 1km x 1km squares fully surveyed using air photographs and satellite images, and hand-held GPS unit to navigate and provide locational data on sites and monuments recorded.*
- *Analysis of historical aerial photographs (1974, 1995 and 2000 vertical coverage).*
- *Specially tasked QuickBird satellite imagery at 0.6m resolution.*

The fieldwork showed that the general pattern of scrub growth on the Burren is coincident with the main distribution of archaeological monuments. Of the recorded monuments, 71% were directly affected by scrub, with the threat increasing. The field survey of the five 1km squares that were fully examined added 48 new sites to the 40 previously recorded — an increase of 120%. Of the new monuments recorded, 50% are being affected by scrub. In some areas, most were found in open areas because of the serious difficulty of access and visibility in dense scrub. The report states that

'...an assessment of the satellite imagery has shown it to be more detailed and clear than the aerial photography examined but it does not, unfortunately, indicate the extent to which the satellite imagery increased the number of monuments or locational accuracy or clarity of those known, though it is clear that the imagery has potential for both, as well as clearly showing innumerable relict boundaries...'

Martin Critchley, seminar presentation December 2005

The aerial and satellite imagery also showed that rates of scrub encroachment had slowed down and then risen rapidly over the last ten years, from 1.9% per annum in 1974-1995 to 0.8% in 1995-2000 and 5.8% in 2000-2005 (Figure 31b).

The Burren has a density of 4.3 recorded monuments per square kilometre, compared with a national average of 1.4. No other area has such a high density over such a large area, and this does not include the extensive evidence for the evolution of the landscape provided by relict boundaries and field systems (ERA-Maptec *et al.* 2005).

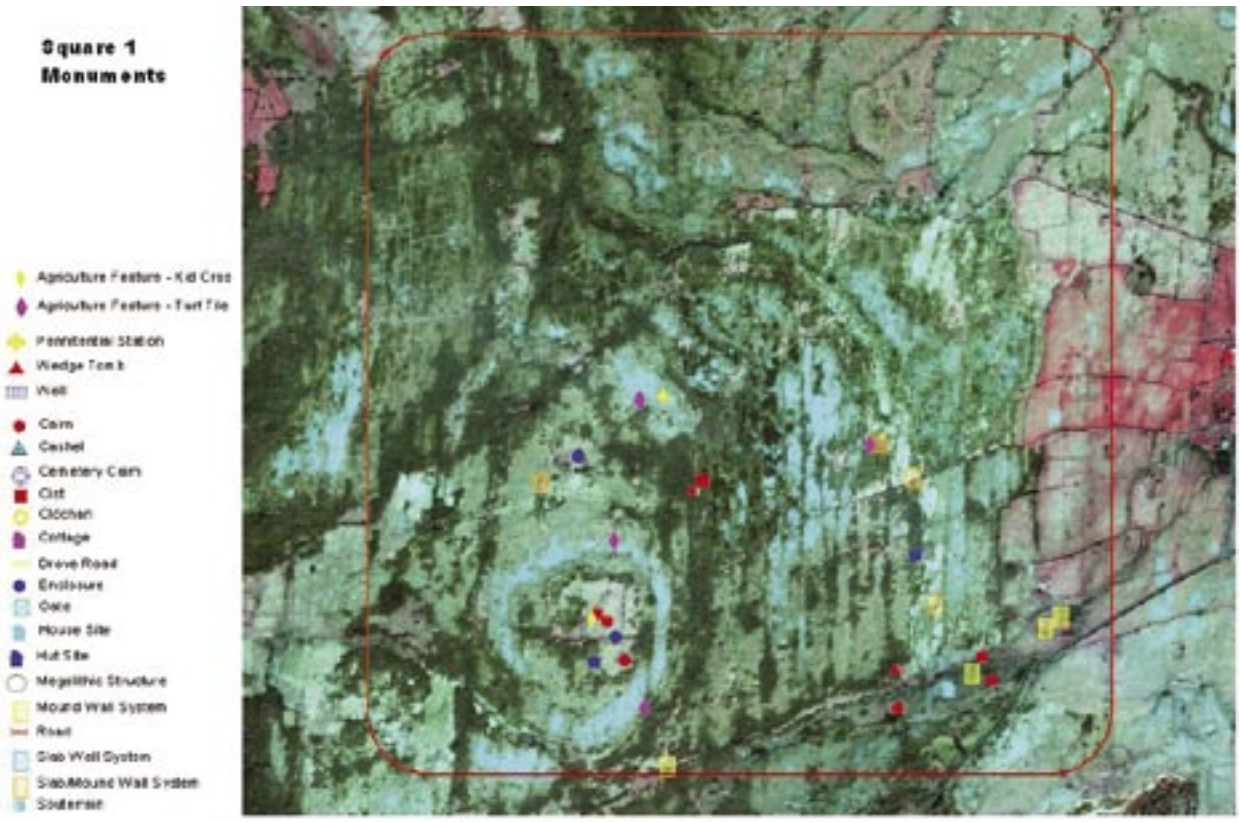
The results of the Burren study demonstrate the need for management plans which protect physical conservation, visibility and access to this exceptionally rich area. The report recommends further analysis of the satellite imagery, both as the basis for identifying monuments to be checked and inspected on the ground, and repeated imagery for habitat monitoring. In view of lidar's potential to see through vegetation, and the major effort that would be entailed in carrying out detailed fieldwork, it would be sensible to do further trials to establish which technique would be best suited to establishing a detailed record and how far basic monument categorisation could be carried out from such data, including the possibility of using pattern recognition techniques to assist in this (Redfern 2002).

The study has also shown the more general potential for archaeology to be integrated into imaging which is being carried out primarily for other purposes, and it is clear that more could be done in his area. For example, remote sensing by satellite is being used for checking types of crop in cultivation at a single land parcel level. It can also distinguish between rough grazing, temporary grass, forestry, mineral and peat extraction, and urban development. Since cropping is one of the key factors affecting archaeological survival (O'Sullivan *et al.* 2001), this type of data could be combined with archaeological data to map areas under particular pressures of change, especially from agriculture. The technology includes the capability to map change through time. A recent project commissioned from the OSi by the Department of Agriculture has been using ortho-photography combined with satellite imagery to relate boundary loss to land use at the level of single land parcels.

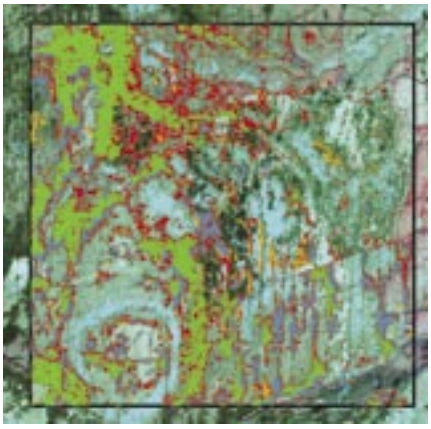
A similar approach can be achieved with aircraft-based thermal imaging equipment such as the Daedulus AADS 1230 Airborne Thermal Line Scanner. This generates thermographic data which can be combined with aerial photography or other digital GIS data for a range of environmental purposes, including land-use analysis, environmental pollution, energy efficiency and other resource studies. The Compact Airborne Spectrographic Imager (CASI) is a 'passive' sensor which records spectral radiance in visible and near-infrared wavelengths. The Countryside Survey 2000 in England is an example of strategic landscape monitoring. It also involved detailed field survey which was based on the integration of thermal imaging of vegetation cover with a digital terrain model derived from lidar topographical profiling.[10] CASI data were recorded at a 3m spatial resolution, and in wavebands selected around the red and infrared spectral regions, to give optimum information for vegetation analysis of 568 selected 1km squares and a land cover census of the whole country using satellite data.

[10] *http://www.cs2000.org.uk/Report_pdf/chap10.pdf*

Figures 31 a-b: QuickBird satellite imagery has been used to map archaeological monuments in relation to encroaching vegetation on the Burren (ERA-Maptec, Sharon Parr and Christine Grant on behalf of the Heritage Council, 2006)



a: A 1km² area of the Burren west of Carran showing the range of recorded archaeological monuments. Extensive relict field patterns and other features are also clearly visible. Vegetation cover: red/pink = grass; grey/dark grey = scrub and trees; pale blue = bare rock



b: The same 1km² area showing the spread of hazel scrub as determined from aerial photographs between 1974 and 2005 (green = 1974; blue = 1995; orange = 2000; red = 2005)

3.7 Other Remote Sensing Techniques

SAR (Synthetic Aperture Radar)

Another technological development that is likely to prove useful in the near future is the application of inferometry data from SAR. These data can be delivered from an airborne or satellite platform, at a rather lower accuracy than lidar. However, satellites can cover a much larger area than aircraft, which makes it feasible to construct a more accurate national-level data-set than is currently available from conventional vertical photography, and with fewer technical constraints than lidar. These techniques have been used to some effect in examining relatively large-scale features at Angkor Wat and associated sites in SE Asia.[11],[12]

Ultra wideband SAR achieves higher resolution and also some ground penetration, and is, for example, being developed by the UK-based Mineseeker Foundation to locate buried plastic mines from a slow-moving airship platform.[13]

[11] *http://pnclink.org/annual/annual2003/programme/presenpdf/110810.pdf*
[12] *http://airsar.jpl.nasa.gov/*
[13] *http://www.mineseeker.com/*

Sonar Bathymetry

Although there are airborne sonar techniques, ship-borne, high-resolution side-scan sonar now provides considerably improved knowledge of coastal and marine archaeology. In addition, it can be coupled with other ship-borne remote sensing techniques (including multibeam echo sounding and geophysics) to provide valuable insights into buried/drowned coastlines, as well as locating and managing areas of the seabed that have high archaeological potential. While high-resolution side-scan sonar is currently the preferred method for detailed marine archaeological survey, airborne bathymetry can provide important contextual information. For relatively shallow waters, airborne lidar is increasingly seen as a complementary, if not an alternative, method of achieving high-resolution results.

3.8 Digitisation, Image Processing, Mapping, Classification and GIS

Johnson (1998) has noted the following:

'Given the continuing advancement of analytical techniques for studying aerial photographs, reassessment of existing photographs may prove to be very successful. Kelleher (1995) reported a high success rate in identifying previously unrecorded sites through the use of computer enhancement and mapping programmes to analyse aerial photographs. The results were particularly impressive in identifying field systems and associated enclosures in marginal areas. The study employed the Bradford Air-Photographic Rectification System and MORPH (a programme designed for studying morphological aspects of the landscape from aerial photographs) – programmes extensively used in Britain for identifying and mapping archaeological sites (Kelleher, pers. comm.).'

The main effort made in interpreting and mapping sites detected from aerial photography (both general vertical cover and specialist oblique photos) has been through the compilation of the SMR and County Inventories over the last 20 years or so, leading to the official Record of Monuments and Places (RMP). Resources have not been made available for the development of a national mapping programme as pursued in England (Bewley 1995). The method of recording sites in the SMR files has been to include prints of photos, together with transparent interpretive overlays within the file for each site. In some cases, particularly complex areas have been studied in greater detail, and larger-scale rectified plotting (sometimes using GIS) has been undertaken.

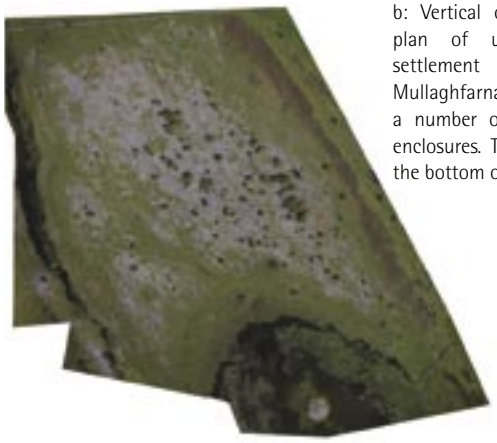
Rectification and Image Enhancement and Plotting

Rectification of oblique photography – and of vertical cover to achieve true ortho-photographic images – is essential if sites are to be accurately located not only on maps but also on the ground. In the 1970s and early 1980s, manual methods were mainly used (*e.g.* Patrick 1974; Barrett 1982b), but from the late 1960s onwards, computer rectification was being investigated and was fully developed through the late 1970s until the present. Two bespoke software packages have become mainstream applications – AERIAL (Haigh 1996 – *e.g.* used by Barrett 1995b) and, with the longer pedigree, AIRPHOTO (Scollar 2002). Other techniques are being investigated by Redfern (1998; 2002), who has developed a low-cost approach to combined rectification, image enhancement and digital terrain modelling system using the Rathcrogan area as the testbed. Practitioners also say they use other rectification systems with less sophisticated image manipulation packages available through GIS and image processing packages. Digital photography is increasingly used in the air. This not only allows images to be checked while still in the air but also assists in the subsequent processing.

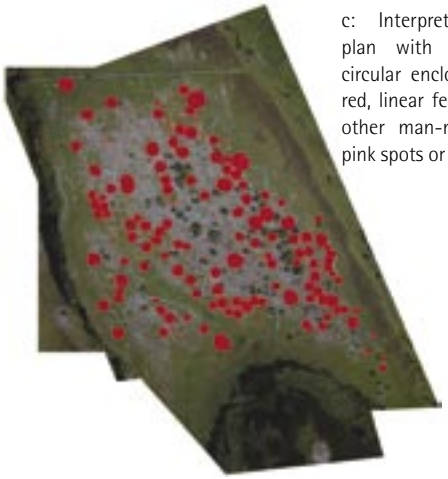
Photogrammetry (the generation of topographic data from stereoscopic vertical photography) is a long-established technique for cartography. It was one considered insufficiently accurate and too time-consuming to have been of much use in aerial archaeology. That perception has completely changed with modern technology, especially where medium-to-low level photography and high-quality photography are used to give very high definition images. Digital photography (or scanning of conventional images) further allows a more varied range of image enhancement and manipulation. For example, the Discovery Programme's work at Mullaghfarna, Co. Sligo and North Roscommon has been using large format (23cmx23cm) images scanned to a high resolution such that each pixel represents 0.16m on the ground (Figures 13, 32). This provides exceptional clarity and detail, and allows ortho-rectification and use as a layer with other data in a GIS system, as well as a digital elevation model as a by-product of the photogrammetry. Oltean (2002) has explored rectification in conjunction with satellite imagery.

Figures 32 a-e: Detailed aerial archaeological survey at Mullaghfarna, Co. Sligo (Stefan Bergh, NUI Galway, Discovery Programme and BKS Ltd)

a: General view from the north. A cairn is clearly visible on the northern tip of the high promontory above the broad platform where the settlement was located

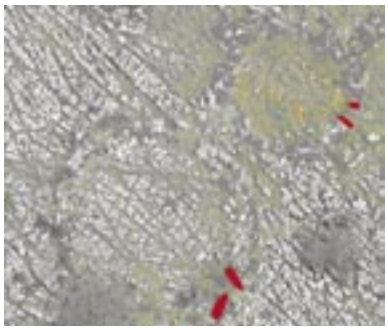


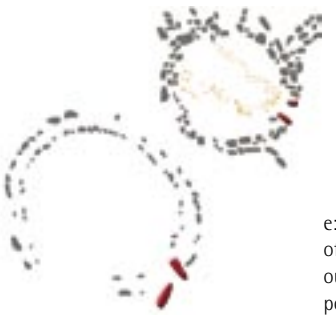
b: Vertical ortho-photographic plan of upland prehistoric settlement complex at Mullaghfarna, Co. Sligo, showing a number of house sites and enclosures. The cairn is visible at the bottom of this image



c: Interpretive photographic plan with house sites and circular enclosures indicated in red, linear features in blue, and other man-made elements as pink spots or pale green crosses

d: House or hut Sites 55 and 56, with *in-situ* stones of structural walls in dark grey, entrance stones in red and interior features in orange





e: Preliminary interpretation of Sites 55 and 56 picking out the deliberately positioned stones

Both Kelleher (1995) and Redfern (1998, 2002) have explored the use of digital image enhancement techniques to some effect. Input of topographic data into a GIS allows the development of highly realistic 3D models of the landscape surface. The two main forms are known as digital elevation models (DEMs) which are based on actual elevation, and digital terrain models (DTMs) which use the data to create surfaces that can be manipulated more extensively. DTMs are extremely useful visualisation and modelling tools. They can be integrated with rectified digital air photography to 'drape' a photographic image over a 3D model. This has been explored extensively by the Discovery Programme (Doody 1993c, 1995, 1996; Newman 1997).

Redfern (1998, 2002) has gone on to develop a system that derives a digital terrain model directly from digitised photography. This also incorporates an image enhancement facility to maximise the clarity of the features. The system further allows for the generation of 3D horizontal and vertical measurements and a pattern recognition system allowing classification of features (see below).

Even more recently, Shell and Roughley (2004) have demonstrated the value of lidar imagery to develop highly detailed digital terrain models with considerable flexibility of highlighting features and their position in the landscape through manipulation of height exaggeration, artificial low-level lighting from any angle and viewshed analyses. They have combined lidar with photogrammetry to generate photographic terrain models allowing enhanced understanding of landscape context, a technique also used by the Discovery Programme in the Mullaghfarna project and elsewhere.

Context Mapping

An important issue for interpretation often involves understanding the visibility of archaeology – or to be more precise, mapping features in relation to apparently 'blank' areas. Such areas may not be devoid of archaeology, but may be just under different land uses that are not susceptible to revealing earthworks and soilmarks – or cropmarks. It remains extremely rare for such non-susceptible areas to be mapped systematically as part of the context for understanding the distribution of sites. Barrett (1980, 1982, 1995a, 1995b) has come closest to this in analysing and mapping the distribution of cropmark sites in relation to soils and topography. This, however, does not extend to mapping how modern land use may have constrained the development of cropmarks.

The work on digital terrain modelling, along with soil mapping, aspect and other parameters, has a clear use in mapping and understanding archaeology within its physical topographical context, for which GIS applications as used by the Discovery Programme are ideal. So far, this has been developed much more for the identification and interpretation of earthworks than it has for crop- and soilmarks.

Morphological Interpretation and Classification

Interpreting archaeological sites as revealed by aerial photography is a skill that has many pitfalls. It demands an understanding of soils, crop growth conditions, agricultural practices, geological formations, modern and spurious features, and real archaeological monuments of all ages (Wilson 2000). Interpretations are not always simple or clear-cut. Even those of recognised specialists may be open to question on occasion – especially if the interpretative context is outside their specialist period or geographical area of research. A possible example of this may be illustrated by a 1989 photograph of a rare type of cropmark site for the area forming part of a 'Bronze Age funerary landscape' at Chapelstown, Co. Carlow, recently published by Gillian Barrett (2002, 11 Pl 6). It shows an oval ditched enclosure (indicated by a dark linear feature) with two large, solid circular dark marks about 20m across which 'from the air were interpreted as pits' (Figure 33). Subsequent archaeological assessment in advance of development showed the large dark marks to be 'deposits of gravel and rounded and weathered stones' (O'Donovan and O'Neill 2003). By analogy with other barrow cemeteries, these areas could well have been ploughed-down mounds of a pair of round barrows set within or surrounded by an elliptical enclosure similar to examples known in the Thames valley (*cf* Barclay *et al.* 1995, Figure 39, field X, site 3).

Figure 33: Pits or mounds? A pair of probable round barrows enclosed by an elliptical ditch with other possible ring ditches nearby, forming part of a Bronze Age funerary landscape at Chapelstown, Co. Carlow (Gillian Barrett, July 1989)

There has been considerable debate over the years about the classification of site morphologies as interpreted from aerial photography. In Ireland, Barrett has consistently challenged over-simplistic classifications of ringforts that do not take account of the complexities that can be revealed by cropmarks – raising a basic point about whether any earthwork form can be regarded as complete. Monk (1989) recommended adoption of the English MORPH classification system (Edis *et al.* 1989), and this was taken up by Kelleher (1995). Nevertheless, it has remained controversial, and Barrett (1995) considered the application of a sophisticated system of morphological mapping and classification during the early years of the River Barrow aerial survey project to be inappropriate. Instead, a simple morphological classification was adopted which provided an initial summarising device and a preliminary sorting of the main categories of new cropmark discoveries. However, given the subsequent expansion of aerial survey, the need for more progress in mapping and morphological assessment is now considered an important priority, both for new photography and for the full evaluation of the CUCAP archive which remains an under-exploited resource in Irish archaeology (Barrett 2002). While MORPH seeks to be objective, like all classificatory systems it does involve subjective interpretation and choice. It has also been criticised for being too cumbersome in dealing with sites of any complexity.

Using the Rathcrogan complex, Redfern (1998, 2002) has explored the possibility of classifying sites digitally by using pattern recognition techniques based on defined parameters as part of a software package that provides rectification, image enhancement and terrain modelling. He compared the digital classification to standard classes used by the County Inventories and found reasonably good correlation. The use of pre-determined digital recognition parameters offers potential to make the approach more objective than traditional archaeological judgement, but its interpretive value has yet to be tested fully. In general, morphological classification is not seen as a high priority compared with clarifying other issues of form and sequence in complex sites.

Interpreting Chronology and Sequence

There is relatively little inherent evidence of chronology to be discerned from aerial imagery, though the relative sharpness of cropmarks and earthworks may reflect different chronologies of levelling or erosion of original features (Figure 34). Chronology is more often based on morphological categorisation, but it can also be discerned – or at least hypothesised – from spatial patterns. In well-developed interpretive models, such chronologies and sequences may indicate significant stages in how the landscape has changed and which can be tested by fieldwork on the ground. The Discovery Programme has been exploring this in their work on medieval rural settlement in Co. Roscommon. In other cases, chronology may need documentary and other clues, even to distinguish modern from ancient features.

Figure 34: Analysis of ringforts in tillage areas has shown that what remains visible above ground is only part of much more complicated sequences. This overgrown ringfort in the townland of Knocktopher Manor, Co. Kilkenny, has a cropmark of an oval enclosure immediately to its south among former field boundaries which appear to have been part of the extant field system around the site and may have been laid out to respect both monuments (Ian Doyle, 25 July 2005)

3.9 Integration with Other Types of Archaeological Survey

It is widely recognised that aerial archaeology is only one of a suite of techniques that are available for all stages of archaeological investigation and dissemination of results. Johnson (1998) noted:

'As a surveying technique, aerial photography is a complementary tool and not a replacement for fieldwork. In most cases, a follow-up field visit on the ground will be required to assess the nature of the site.'

In commenting on the high rate of discovery of new sites in 1989, Power (1993) pointed out that the apparent cost-effectiveness of the method was substantially compromised by the need for ground verification.

Almost all use of aerial archaeological survey for research purposes is combined with other techniques. Swan (1985) combined aerial archaeology with map interpretation and fieldwork to analyse the form of early ecclesiastical centres. Herity (1983) and Waddell (1983) both combined aerial survey with documentary evidence and field survey to explore the Rathcrogan complex. Working in the context of pipeline development, Gowen (1988) integrated aerial reconnaissance with desk studies, field survey and excavation to cast new light on prehistoric settlement. The Discovery Programme has undertaken several projects with the specific aim of integrating a variety of archaeological techniques, including aerial archaeology (Doody 1993c, 1995, 1996; Grogan 1993, 1996; Grogan *et al.* 1995; Newman 1997) and their recent work on medieval rural settlement in North Roscommon. This has also been a hallmark of the Carrowmore Project (Burenhult 1980; Burenhult *et al.* 1984; Bergh 1995).

Ground inspection of sites has also featured in recent surveys funded by the Heritage Council. These include Markus Casey's work on promontory forts (Casey 2001, 2002, 2003), Colin Shell's work on Loughcrew (Shell *et al.* 2004, Shell and Roughley 2004), Stefan Bergh's work with the Discovery Programme at Mullaghfarna, and the assessment of landscape change and archaeology using satellite imagery of the Burren (ERA-Maptec *et al.* 2005).

3.10 Current Practicalities of Data Handling

The size and character of existing holdings in the SMR and other archives are outlined in Section 2. It is not possible to give an accurate estimate of the rate at which new general-purpose vertical photography surveys are being undertaken and which are likely to be of potential use to archaeology. It appears to be significant, however. Similarly, it is not straightforward to estimate the rate of purposive archaeological reconnaissance being done, given the wide range of institutions, individuals and purposes involved. However, with the combination of work by the Archaeological Survey of Ireland within NMS, the growing use of aerial archaeological reconnaissance of road schemes and other development, some ongoing research and work grant-aided by the Heritage Council, and the continuing work by individuals, a significant number of sites are being discovered each year (Figure 35). Even more may be awaiting discovery through aerial photography and remote imaging carried out for other purposes.

Figure 35: Dry conditions in July 2005 revealed a previously unrecorded barrow cemetery in the townlands of Ballyda and Dundaryark, Co. Kilkenny. Ensuring that the National Monuments Record is kept up to date with new discoveries requires active liaison between practitioners and the NMS (Ian Doyle, 26 July 2005)

While the Archaeological Survey of Ireland routinely integrates the results of its own aerial survey work into the SMR and is constantly seeking to integrate the results of other work, there is currently no requirement – nor is it an automatically recognised good practice standard – that the results of other people's work funded from public sources should be made available to the SMR. This is not a simple issue because it raises basic questions of intellectual property rights, but these could be addressed through suitable contractual obligations and grant conditions in respect of work funded by or undertaken for public bodies.

But the general increase in data, and any improvements in its accessibility, does not take account of the need for more interpretive mapping and more sophisticated analysis of landscape change; this has hardly been touched on, except in the context of specific research projects. As the quantity, technical sophistication and diversity, and rate of output in aerial imaging grows, so the scale and unrealised potential of un-accessed data increases rapidly. At present, there is no means of monitoring these trends, as there is in relation to excavations through the annual excavations index.[14]

The increasing use and potential of digital methods of photography and remote sensing, of digitising existing records, developing digital databases of holdings (as the NMS and OSi are doing), and of rectifying, enhancing and analysing digitised images represent highly significant ways of improving data handling and provision of information about existing archives, which is an essential precursor to maximising effective use of these extremely rich sources of data. As the sources of data become more sophisticated, there is an increasing need for a more holistic approach to developing and maximising the benefits of these approaches, ensuring that data handling becomes more efficient, and that archival standards (Bewley *et al.* 1998) are met.

Now that digital imagery has become the norm for most major surveys, there is also a growing need to ensure that the archaeological importance of older archival photographs is not lost. In particular, there remains considerable potential for further use of existing archives and collections (both public and private) to enhance the record. The next section examines in more detail how aerial archaeological evidence has contributed to the Record and the ways in which it has been used for research, conservation, and the wider appreciation of the historic environment.

[14] *http://www.excavations.ie/Pages/HomePage.php*

4 ROLES IN RESEARCH, CONSERVATION AND EDUCATIONAL ACCESS

4.1 Understanding the Archaeological Resource

Reconnaissance, identification and making a record

Air photography has formed an important part of the compilation of the SMR and County Inventories over the last 25 years, including both systematic assessment of existing air photographic collections (*e.g.* Kirwan 1993), and some new photography. New discoveries and interpretations have been reported in articles about individual areas or features of interest, approaches and methods, and in the published Inventories (*e.g.* Condit 1992, 1993, 1995; Condit and Gibbons 1991; Condit *et al.* 1991; Power 1988; Power *et al.* 2000; Gosling, 1993; Alcock *et al.* 1999). Some reconnaissance remains a standard part of the compilation and updating of the SMR, the publication of the Record of Monuments and Places, and the County Inventories.

Since primary sources of information are not a searchable field within the SMR database, the overall contribution that aerial archaeology has made to this process cannot be quantified easily. In any case, this varies from one county to another. This is due not only to the basic geographical considerations, but also because the organic, incremental way in which the SMR was developed means that there was some variation in approach from one county to another as the compilation of the original record proceeded. For example:

- 32% of the 783 sites identified in the SMR for Co. Limerick were identified from aerial photographs, compared with 20% represented on Ordnance Survey six-inch maps, 35% identified through fieldwork, 8% from excavations and 5% from chance discoveries (Kirwan 1993).
- 8.5% of entries in the Inventory for Co. Wicklow cite air photographic sources (Grogan and Kilfeather 1997).
- 7% of entries in the Inventory for Co. Carlow cite CUCAP air photographic sources (Brindley and Kilfeather 1993; Barrett 2000, 3).
- 8% of entries in the Inventory for Co. Louth cite CUCAP air photographic sources (Buckley 1986; Buckley and Sweetman 1991; Barrett 2000, 3).

But within such generalised figures, there is considerable variation in relation to types of site and location which may be exacerbated by issues of classification:

- In the Wicklow Inventory, air photographic sources are cited for a much higher proportion of enclosures (27%) and settlements (18%) than other types of site.
- 65% of ring-barrows included in the SMR for Co. Limerick were identified from aerial photographs, compared with 4% represented on Ordnance Survey six-inch maps, and 31% identified through fieldwork (Kirwan 1993, 142).
- Stout (2001) gives the following figures for the sources of identification cited for 'ringforts' on the County Inventories. Presumably, this does not include cropmark and other sites classified as 'enclosures' which may be levelled or ploughed-down ringforts (the *c.* 4% difference between the first six counties in Leinster and the remaining two elsewhere was not considered significant).

County	No. Ringforts	No. identified from APs	% identified from APs
Carlow	767	73	9.5
Dublin	1129	113	10.0
Kilkenny	2234	216	9.7
Offaly	1753	211	12.0
Wexford	2209	261	11.8
Wicklow	1321	145	11.0
Leitrim	1620	130	8.0
Waterford	1925	100	5.2

- By contrast, Barrett suggests that 35.5% of ringforts in Co. Louth have been identified from air photography, though this varies from 3% to 39% with topographical altitude and from 0% to 51% with soil type (Barrett 1980, 1982a, 1982b).

These figures largely reflect the results of desk studies without much new aerial reconnaissance having contributed to the process. As Power (1993) observed:

'...work on aerial photographic material has increased greatly in recent years and has been an integral part of the "paper survey" SMRs, in many cases producing interesting results. However actual aerial reconnaissance is still rarely used in Ireland...'

The compilers of the SMR, which forms the basis of the published Record of Monuments and Places and County Inventories, do not claim (and could not reasonably be expected) to have provided definitive coverage of all possible sources of air photography. Although some of the available medium and low-altitude vertical photography was consulted in the compilation of the SMR and Inventories, this does not appear to have been consistent for all areas. In general, it appears that the GSI and CUCAP sources were routinely covered, and use was often (but not always) made of the coverage of the OSi and Air Corps material. Where these sources were used, it is not clear whether all sets of available material were accessed – though Kirwan (1993) does refer to the use of low-level OSi 1:5,000 photography. It was not within the capacity of the survey teams to cover all private and commercial sources, though in the case of Cork, the collection of Dr Daphne Pochin Mould was accessed. In other areas, it is perhaps unfortunate – but given resources and time constraints, not very surprising – that some potentially important non-public sources were not systematically covered, even though access was offered (G. Barrett pers. comm.).

It is clear from respondents that there is wide recognition that the SMR and Inventories are not necessarily definitive and that for any given locality under investigation, recourse should be made to examining original aerial photographic material. It may also be noted that a number of practitioners also recognise that the re-interpretation of identifications is possible; this may either enhance or diminish the archaeological significance of known or suspected sites. For these purposes, the SMR and Inventories provide helpful direct referencing to individual photographs that were used in their compilation. It remains a problem, however, that there is usually little or nothing else to indicate which sources or sets of photography were – and more particularly were not – consulted, and hence which might have most potential for identification of additional material.

This issue is also relevant to how the data compiled for the SMR is used to interpret distributions and types of different monument classes, but it is an unknown variable that cannot readily be assessed. As indicated below, the number, character and density of known sites can depend heavily on the quality and intensity of aerial coverage.

Enhancing the Archaeological Record

The technical limitations – as well as the merits – of the few collections of aerial photography that are routinely consulted in Ireland are widely recognised. Although users of air photography are generally well aware that intensive reviews of existing sources of aerial photographs and new reconnaissance can lead to new discoveries, there seems to be less awareness of quite how much difference well-formulated projects of this type can make. This has been demonstrated by several different studies in Ireland.

- From a review of existing vertical photography, Hartwell (1987) reported discovering 60 new sites of all types within an area of 40km^2 (500% increase on previously known 15 sites).
- From new oblique reconnaissance, Barrett (1990, 1995b) reported discovering 106 new cropmark sites within an area of 900km^2 (330% increase on previously known 32 sites).
- From new medium-altitude vertical photography, Doody (2001) reported discovering 1,074 new sites of all types within an area of 533km^2 (69% increase on previously known 1,490 sites).
- From new oblique reconnaissance, Power (1993) reported discovering 200 new cropmark sites within an area of approx. 256km^2 (increase not quantified).
- From his survey of coastal promontory forts, Casey (2001, 2002, 2003) has reported that out of a total of 408 sites recorded, 199 were known already, while 90 were definite new ones (an increase of 45%). A further 119 possible examples were noted that at the time of reporting still needed checking on the ground (possible total increase of 105%). This does not include other types of site.
- Shell and Roughley (2004) have reported that previously recorded sites account for only 10% of the length of features transcribed from their lidar survey of the already well-surveyed Loughcrew area. Although much of this relates to ancient field boundaries rather than individual monuments, the newly identified archaeology includes 13 small round mounds, three larger mounds, five circular or sub-circular banks, a moated site, and a tripling of the number of square enclosures from two to six.
- At Mullaghfarna, from a starting point of 47 house sites and other features identified in 1911, Grogan (1996) brought the total to 82 identified from air photographs, with 60 recorded on the ground. New detailed photogrammetry and fieldwork in 2004 (Stefan Bergh, conference presentation December 2005) identified a total of 153 sites and features (an increase of 325% on the original survey).

In terms of research, the potential to enhance the archaeological record and pose new questions related to landscape inter-relationships has been rather better understood and embraced in a whole range of university-based research programmes and the Discovery Programme (Section 4.2). The Heritage Council's support for surveys by Markus Casey (2001, 2002, 2003) and Colin Shell (Shell and Roughley 2004) also demonstrates their awareness of these issues.

But the overall strategic implications of such significant increases in known archaeology have yet to be fully translated into a clear perception of how the strengths of aerial archaeology should be harnessed for wider understanding, conservation and management of the archaeological resource.

Where this has been taken on board – as was the case for a number gas pipeline schemes from the 1980s onwards (Cleary *et al.* 1987; Gowen 1988), and as is now becoming more routine for infrastructure schemes – the value of the technique as a means of identifying sites (and of reducing the risk of unexpected discoveries) is clearly recognised (Figure 36). It is also clear that some of this reconnaissance not only identifies previously unknown sites, but can also reveal much more detail or greater extent of those that are known. As the use of aerial archaeological surveys has become more routine for particular types of work, notably road schemes, there is now great potential for a more detailed analysis of the extent and implications of the range and scale of new discoveries, looking particularly at different types of archaeological remains in relation to terrain, soils and reconnaissance methodologies.

Figure 36: Newly identified cropmark sites at Oldtown, Co. Laois, photographed in August 2001 at the route selection stage of the M7 Portlaoise–Castletown/M8 Portlaoise–Cullahill motorway scheme in response to the outbreak of foot-and-mouth disease. The motorway scheme was subsequently redesigned to avoid the cropmarks (Margaret Gowen & Co. Ltd, courtesy of the NRA)

However, the implications of enhancing the archaeological record to inform the management of pressures of land-use change at a more strategic level (*e.g.* in relation to agriculture, forestry, housing and minerals) is still in its infancy. There is increasingly clear evidence that existing knowledge is very partial. The problem is that there is insufficient institutional recognition that policies and programmes of cost-effective, strategic aerial reconnaissance and mapping should be formulated and implemented.

Recognition of this issue may have been inhibited by a number of negative factors which relate to the absence of information, and hence to a lack of clear rationale for action. These include:

- Undue complacency about the supposed completeness of older archival sources (GSI, OSi CUCAP) in revealing what there is to be recorded from air photography.
- Lack of appreciation of the capriciousness of technical seasonal and land-use factors in dictating whether or not archaeological remains are revealed by aerial imagery.
- Previous lack of attempts to synthesise the well-documented and published data for the 'yield' of air photographic review and reconnaissance to bolster anecdotal awareness of its value as a means of enhancing the record.
- Lack of data about what archaeology has been destroyed because it had not been identified and recorded from air photography, or was mistakenly classified as 'destroyed' in the SMR because it was only discernible from air photography.

The process of ensuring that the results of air photography are reported and properly recorded is increasingly important, but it does not fall within the definition of an 'archaeological object' which must by law be reported under the National Monuments Acts. A clearer best practice obligation on practitioners to report the discovery of sites, not just objects and results of excavation, would help ensure that the public record is enhanced. Making this a requirement for all reconnaissance funded by public bodies or for public works would help.

Roles and potential in relation to historic buildings and industrial archaeology

Aerial archaeology is little used at present in relation to reconnaissance and conservation of the architectural heritage (G. Browner pers. comm.). It is often used, however, in conveying very clear impressions of the built heritage for illustrative purposes of both individual buildings and structures and townscapes (Figures 37, 38). Nevertheless, examples both within Ireland (Condit 1997) and elsewhere (Driver 2002a, b) suggest that there is further potential for development in this area.

Figure 37: The 'Black Castle' at Castlepoint, Co. Cork, commands the narrow bridge that links the island to the mainland (Markus Casey)

For example, the Mining Heritage Trust in Ireland is beginning to consider greater use of aerial photography as a means of helping to interpret the relationships of buildings to other archaeological and landscape features, thereby enhancing the understanding of the totality of industrial processes (M. Parkes pers comm.). Other respondents also commented on the potential of aerial survey to contribute to industrial archaeology (M. Casey pers. comm.), and this is partly reflected in NMS's aerial survey of the Shannon navigation. In England, work by English Heritage has demonstrated the value of air photography as a contributory means of recording very large buildings or building complexes (*e.g.* industrial, ecclesiastical and hospital complexes).

There is considerable low-level aerial photographic coverage of Irish towns and cities held not only by the OSi but also by the NMS, local authorities and commercial companies like Simmons Aerofilms, BKS of Coleraine, and even small private initiatives such as that of Joe Kenny of Fethard, Co. Tipperary.[15] These offer significant potential for studying urban topography (Swan 1983, 1985) and how urban development in the last 30 years has affected the historic structure and architecture of urban centres (Figure 38).

[15] *http://fethard.com.mainpages/aerial.html*

Figures 38 a-b: Contrasts in urban topography as revealed from the air

a: Strokestown, Co. Roscommon, showing the planned streetscape clearly focused on Strokestown House. As Figure 38a illustrates, this was only part of a very extensive designed landscape intended to emphasise the wealth and social and economic importance of its owner (CUCAP 15 July 1967)

b: Kilkenny: the historic town viewed from the north. St Canice's Cathedral with its round tower is visible in the foreground, and Kilkenny Castle stands beside the River Nore (top left) at the other end of the medieval town. The heart of the medieval town is viewed along the axis of the main street, with long burgage plots visible to the right. The ruins of the Abbey of St Francis stand in the modern brewery complex beside the Nore on the left of the picture (CUCAP 17 July 1967)

Figure 39: This vertical photograph of Strokestown, Co. Roscommon, shows a complex palimpsest of landscape development. The mansion in its park stands as the focal point for the planned town which, together with the straight roads and parts of the rectangular fields, were imposed on a more ancient pattern of countryside still evident from the numerous ringforts and remnants of older fields and woods. There is also evidence of the impact of modern farming (Ordnance Survey Ireland)

Roles and potential for historic townscape and landscape assessment

Historic landscape and townscape characterisation is an emerging approach which aims at a more holistic conservation of the historic environment in Ireland, as it is in Britain and other parts of Europe (Fairclough and Rippon 2002). The traditional — and still predominant — approach to heritage conservation has been through the identification and protection of single sites or features. Approaches based on characterisation seek to take a more holistic view. These recognise that the historic character of places (much of which is perceived and valued intuitively rather than consciously) cannot be identified adequately through single scattered features. Instead, it relies more heavily on long-term patterns of how people have used and adapted an area to suit their needs, sometimes powerfully reflecting differences in social status and local political power (Figure 39).

As indicated below, there is a need to do more to develop concepts and methods of applying aerial imagery more directly to understanding and characterising landscape change than can readily be done through the traditional approaches based on the concept of using archaeological 'sites' as the main building blocks of research and heritage management. In a sense, this concept is not new — it has already been explored by Swan (1983, 1985), Barrett (1992, 1995a, 1997b, 1997/8, 1999) and Kelleher (1995). However, new technologies (better rectification and terrain modelling, satellite imagery, lidar, GIS) coupled with concepts of historic landscape characterisation offer opportunities for taking this much further.

Mapping and Interpretation

The current policy at NMS is to ensure that the basic air photographic information, together with an interpretive sketch plot, is included in the SMR files along with descriptions, drawings and ground-level photography. This has been a pragmatic way of ensuring access to the aerial photographic data, with a minimum need for additional staff resources spent on plotting and mapping, and physical storage of mapping.

Apart from having been cost-effective in the compilation of the SMR and Inventories, this approach has a number of advantages. Through the SMR files, the air photographic evidence is integrated with other data. Prints of the photographs are directly available, as is an interpretive plot (rather than relying more on secondary interpretive plotting). Disadvantages are that, while there are cross-references within the record, there is little overall mapping of complex areas. The danger here is that evidence of context and relationships with other sites might be neglected. This is especially relevant for strategic assessments of land-use policy and development. As the NMS points out, under the National Monuments Acts 1930-2004, the SMR is (and must be) 'a list of known and potential monuments; it is not, nor is it intended to be, a list of contextualised landscapes'. This, of course, does not preclude the development of other non-statutory interpretative mapping, characterisation and other elements (*e.g.* Figure 40). Indeed, with modern methods, the inclusion of layers within the NMS/GIS system which provides ortho-photography and other basic geographical data can already provide important elements.

Such presentations help to provide basic transcriptions and approximate locations for sites within their landscape context. Modern GIS methods offer more sophisticated digital techniques that can amalgamate different data sets and provide more accurate, higher resolution plotting, but they still rely on conceptual clarity of analysis and presentation.

As the data from the Record of Monuments and Places becomes available online[16] (temporarily withdrawn for correction at time of writing), there is at least potential to make aerial imagery more available. Ongoing scanning of photographs in the archive for incorporation into the NMS/GIS also offers potential for digital enhancement and rectification. This could provide a wider professional and public access to a map-based presentation of aerial photographic evidence.

Users say they would like to see more interpretive mapping by experienced personnel, while also having access to original material. This recognises that the interpretation and plotting of air photography are real skills. It also acknowledges that the subtleties of what can be seen on air photographs are such that their simplification into map form is always highly interpretive and therefore seldom completely definitive. Moreover, fieldwork (especially geophysics or excavation) can often lead to the discovery of additional evidence that modifies original interpretations.

[16] *http://heritagedata.ie/en/index.html*

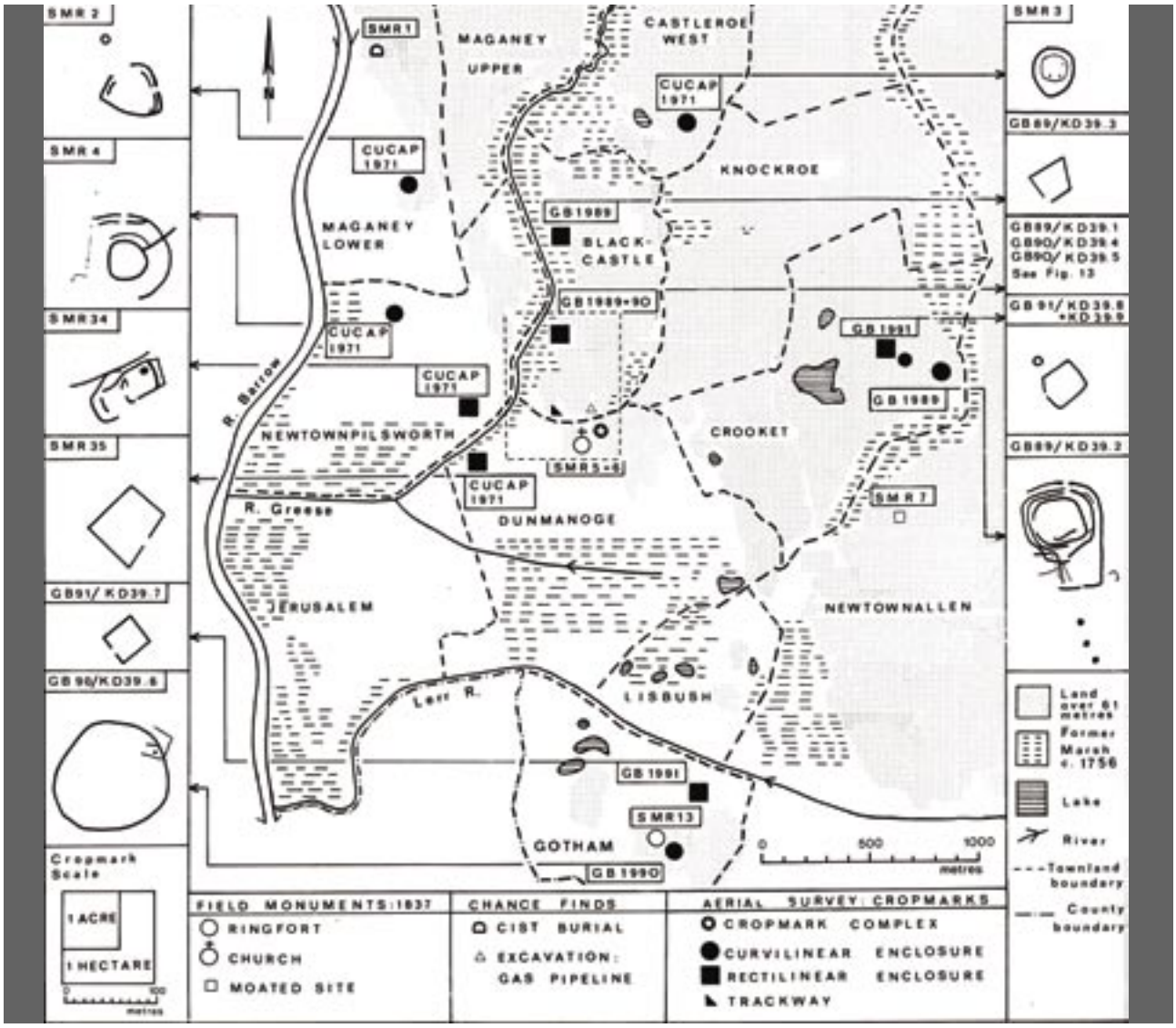


Figure 40: Gillian Barrett's (1995) mapping of topography, cropmarks and locations in the Barrow valley at Dunmanoge, Co. Kildare

While doing this on a national scale would be very time-consuming (with obvious complexities where multiple images are concerned), it is worth noting that a comprehensive approach to interpretative mapping has been adopted in England and elsewhere (Bewley 1995). So far, resources have not been available to make this feasible for general coverage of Ireland, but it is nevertheless particularly relevant for large areas earmarked (or generally suitable) for potential development such as urban expansion, roads, forestry or minerals. This will become increasingly important now that the EU Directive on Strategic Environmental Assessment (2001/42/EC) has come into force.

While such interpretative mapping is better established at a project-specific level (*e.g.* roads, pipelines, peat extraction and other major linear and site-specific developments), this needs to be developed further. Both strategic and project-specific application of the methods and outcomes warrant further review and development — and funding — by national development agencies and associations such as the National Roads Authority, Forest Service, Bord Gáis, Bord na Móna, local planning authorities and the Concrete Federation, all of which have established Codes of Practice for dealing with archaeology.

Within the research community, a range of approaches has been adopted for mapping results of aerial archaeology, both at a general level and more site-specific. Norman and St Joseph (1969) did not embark on this, but in the period since they first articulated the research potential of aerial archaeology in Ireland, several studies have been developing approaches to ways of converting photographic imagery into interpretive mapping or modelling (as outlined in Section 3.4). As discussed in the next section, such mapping has underpinned the use of aerial archaeology in a wide range of thematic and site-specific research projects.

4.2 Roles in Supporting Archaeological Research

Research Frameworks

The publication of archaeological research frameworks to guide new work is usually seen as a way of either reshaping ideas or giving them new impetus. This can be of value within a pure research context, as well as in projects carried out in response to development pressure. For example, the Irish urban surveys of the 1970s and 1980s were carried out in response to the need to address looming urban development pressures. Surveys such as these also acted as a wide review of the state of academic research in the subject.

The Discovery Programme and the Heritage Council have provided other avenues through which thematic reviews of the state of archaeological research and potential for future work on various themes have been developed. Aerial archaeology has been important in some of these, although this has been somewhat variable, depending on the theme concerned (see below).

Research Themes

In their book, *The early development of Irish society: the evidence of aerial photography,* Norman and St Joseph (1969) deliberately set out to indicate how aerial archaeology could contribute to a number of research themes. These were divided between four broad chapter headings: *Before the Celts*, *Iron Age Dwellings and Fields*, *Iron Age Defences*, and *Early Christian Sites*. They also illustrated several other aspects of aerial archaeology, including later medieval sites, and post-medieval and industrial remains. From the late 1970s onwards, aerial photography has figured in a range of important archaeological research projects. Although it is probably fair to say that aerial archaeology has not in general been regarded as a mainstream feature of archaeological research, it has been a key aspect of much work that fits well within all the broad themes highlighted by Norman and St Joseph. Indeed, it extends beyond them, as in the following:

- Multi-period ceremonial centres (Swan 1978; Condit 1993; Newman 1997; Hartwell 1991a, 1991b; Waddell 1983; Herity 1983, 1987, 1988; Burenhult 1980, Burenhult *et al.* 1984; Bergh 1995, 2002; Shell and Roughley 2004).
- Late prehistoric settlement patterns (Gowen 1988; Doody 1993c, 1995, 1996).
- Hillforts and settlement patterns (Condit *et al.* 1991; Condit and Gibbons 1991; Condit 1992; Condit 1995; Grogan 1993, 1996; Grogan *et al.* 1995).
- Early medieval settlements and the origin of early medieval ecclesiastical and urban centres (Swan 1983, 1985; Murphy 1993).
- Early medieval settlement and landscape change (Barrett 1980, 1982a and b, 1984, 1990, 1994, 1995a and b, 1997, 1999, 2002, and forthcoming a and b).
- Medieval rural settlement (O'Conor 1998).
- Field patterns and landscape change (Waddell 1983; Herity 1983, 1987, 1988; Kelleher 1995; Barrett 1995b, 1997, 1999; Shell and Roughley 2004).
- Methodological approaches (Doody 1993a, 1993c, 1995, 1996, 2001; Kelleher 1995; Redfern 1998, 2002; Shell and Roughley 2004).

It is inevitable that the effective use of aerial archaeology relies partly on an interactive process of enhancing interpretive approaches in the light of fieldwork results. Large projects in which aerial archaeology has played an important initial role tend

to provide the most useful feedback. These projects often trigger further initiatives, and methodological developments often help to spawn other projects or the long-term development of interest in an area that can last well over one or two decades. These include: Rathcrogan (Waddell 1983; Herity 1983, 1987, 1988; Redfern 1998, 2002; and a new Discovery Programme initiative, 2005); East Limerick (Gowen 1988; Doody 1993a, 1993b, 1993c, 1995, 1996, 2001); Tara (Norman and St Joseph 1969; Swan 1978; Newman 1997); and ceremonial landscapes in Sligo (Burenhult 1980, Burenhult *et al.* 1984; Bergh 1995, 2002).

The Discovery Programme has established a corporate policy of integrating aerial archaeology into its research programmes. As might be expected from earlier initiatives that demonstrated the potential, this has proved highly successful on ceremonial centres (Newman 1997) and late prehistoric settlement patterns and hillforts (Doody 1993c, 1995, 1996; Grogan 1993, 1996; Grogan *et al.* 1995). Further work using aerial photography and digital photogrammetry is now being done to produce 3D survey models and ortho-photos of monuments and archaeological landscapes. In 2004, the Discovery Programme carried out a 1:1,500 and 1:7,500 aerial survey of Mullaghfarna, Co. Sligo, in conjunction with Stefan Bergh (NUI Galway). In 2005, they carried out a large 1:7500 aerial survey of North Roscommon, including the area of Rathcroghan and the surrounding landscape.

Aerial archaeology has thus played an important role in developing and elucidating several core research themes of Irish archaeology – even if in many ways it is still not as universally used in landscape-based archaeology as it might be. It is also possible to point to a number of other themes where its potential has been clearly demonstrated but not yet fully developed. Three such themes – early medieval settlement, human exploitation of freshwater and maritime environments, and whole landscape approaches to long-term social and environmental change – are outlined below. In the first of these, aerial archaeological aspects have long been established but have not been backed up by relevant fieldwork until recently. In the second, some particularly important developments in approach have been demonstrated but are only beginning to be formulated into major research themes. And in the third, aerial archaeology can be seen as providing a key to unlocking the development of more sophisticated concepts and methods of analysing how the present-day historic environment reflects on long-term social and environmental change

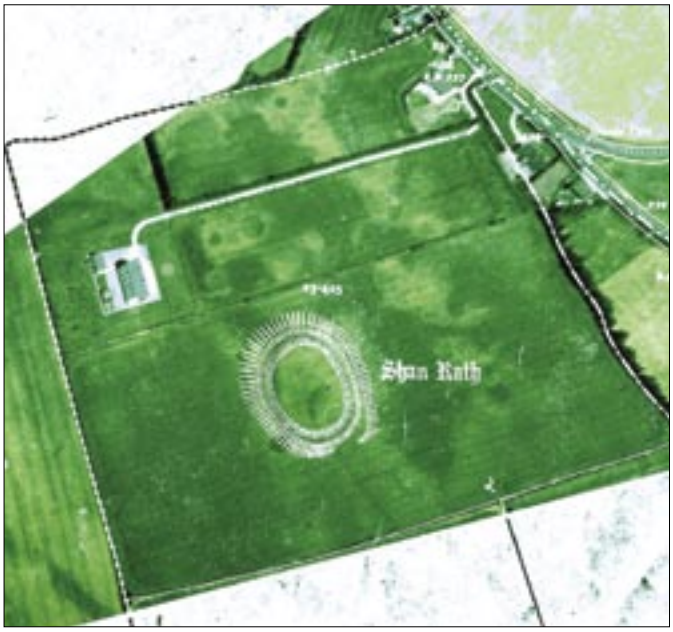
Early Medieval Settlement Studies

Woodman (1992) was able to show how aerial archaeology had helped to 'fill the spaces in Irish prehistory'. The fact that aerial archaeology has not made as notable an impact on early medieval research is perhaps because the interest of aerial archaeologists like Swan and Barrett at a landscape scale has not yet been taken up by others in research projects to test their ideas through fieldwork (as noted by Barrett 2002, 6). Yet their observations about distribution, form, pattern and sequence in early ecclesiastical centres and wider settlement patterns – which might have triggered a series of innovative fieldwork programmes – are no less valid than the similar issues that sprang from the impact of aerial archaeology on late prehistoric hillforts and settlements.

For example, there has already been much debate about the distribution and morphology of ringforts and what this means in relation to interpretations of settlement pattern and social hierarchy (Barrett 1980, 1982a, 1982b, 2002; Stout 1991, 1992, 2001). Stout (2001) has suggested that the relatively small proportion of ringforts identified from existing aerial photographic coverage (especially CUCAP, OSi and GSI material) in compiling the SMR makes it very unlikely that the distribution indicated by early Ordnance Survey maps is significantly wrong. It may very well be true that the early OS maps provide a reliable if not entirely complete indication of the distribution of these very common monuments. But as Barrett has highlighted, limitations in the timing, scale and clarity of vertical photography, and the coverage, frequency and recurrence of purposive reconnaissance (especially in tillage areas) are all factors that will have influenced the identification of low earthworks and flattened sites revealed by cropmarks and soilmarks that both the original OS surveyors and Archaeological Survey of Ireland may not have seen in their original mapping of monuments. It is also clear from cropmarks that partial clearance of some sites has left them looking like simple univallate ringforts, enclosures or graveyards, when in fact they once had much more complex morphologies (Figure 41).

Figures 41 a-b: Gillian Barrett's photography of enclosures and ringforts in tillage areas has shown that what remains visible above ground is only part of much more complicated sites, challenging over-simple classifications

a: The churchyard enclosure at Dunmanoge, Co. Kildare, is the only visible element of an extensive Anglo-Norman settlement complex (Gillian Barrett GB89/O/11, 13 July 1989)



b: A rectified aerial photograph of a plough-flattened ringfort at Shan Rath combined with the 1908 Ordnance Survey map showing the former earthworks. The banana-shaped cropmark in the interior is characteristic of a souterrain (Photography and compilation by Gillian Barrett)

This issue remains open to debate. Both Barrett and Stout accept that the distribution and survival of ringforts in pastoral areas is likely to be much more reliable than in tillage areas, and may therefore make a much better model for extrapolating meaningful settlement patterns. But even this may be open to some question, given new discoveries in well-surveyed areas based on high-resolution aerial imagery (*e.g.* Doody 2001; Shell and Roughley 2004) coupled with increasing knowledge of the recurrent pressures of agricultural change (including reorganisation of field systems).

These issues are important because the complexity and size of such sites are seen as evidence of social hierarchy, while their distribution raises further complex issues about chronology and survival of Gaelic settlement and culture within and beyond the Anglo-Norman Pale of eastern Ireland (O'Conor 1998). This is further complicated because the area of the Pale coincides (not accidentally) with the main area of tillage. There are thus significant challenges in disentangling land-use factors relating to the physical survival and detectability of evidence from real cultural reasons for differences in distribution, survival and destruction.

Until there is a programme of detailed review, additional reconnaissance, survey and excavation of a well-structured sample of ringforts, these issues concerning Ireland's most prolific monuments are likely to remain matters of debate rather than understanding. In the last few years, a significantly enhanced level of fieldwork has been undertaken through development-led archaeology and other initiatives. The rather arbitrary transects across the landscape that have been subject to intensive field survey, geophysics and excavation for the National Roads programme have resulted in an unprecedented opportunity to investigate ringforts and other early medieval sites (Figure 42). While the sample may be haphazard rather than 'well-structured', the results are already beginning to provide a much clearer basis for testing ideas generated from the aerial survey and geographical approaches developed by Barrett and Stout. The proposed collaboration of Dr Barrett in the Discovery Programme's research into the archaeology of the Barrow Valley may also assist in this area, even though it is not focussed specifically on this period.

Figure 42: A bivallate ringfort at Lissanisk, Co. Monaghan, overlooking a crannóg in Lissanisk Lough. The ringfort was excavated in advance of the construction of the N2 Carrickmacross Bypass (studiolab.ie, courtesy of the NRA)

The Archaeology of Lakes, Coast and Inshore Waters

The potential of aerial archaeology in exploring lake settlements and intertidal archaeology was noted long ago in Raftery's seminal paper on the value of aerial archaeology (Raftery 1944). With respect to lake settlements, aerial photography and other remote sensing techniques (infrared, radar and satellite imagery) were cited as important methodological techniques in the Discovery Programme's major review of the research potential of lake settlements (O'Sullivan 1998, 195). It is recommended as an important component in future integrated research strategies. The Discovery Programme's own work on the North Munster Project had shown the value of aerial imagery in understanding topographical and lakebed morphological context of the late Bronze Age lake settlement at Knocknalappa (O'Sullivan 1997a). The review also cited examples in Ireland (Norman and St Joseph 1969), Scotland (Morrison 1985, 85) and Switzerland (Arnold 1986).

The potential of aerial archaeology to contribute to investigations of intertidal and shallow coastal waters has been fully borne out by the invaluable mapping and analysis of the maritime cultural landscape archaeology of Strangford Lough (McErlean *et al.* 2002). This is a model example of an integrated approach to archaeological survey using aerial photography in conjunction with cartographic and documentary research, geophysics, field inspection, measured survey and selective excavation. The aerial archaeology component encompassed thorough archival search of air photography, recent complete cover of 1:10,000 vertical colour photography, 1:3,000 vertical colour and infrared digital imagery, and bespoke oblique photography through specially commissioned flights. These sources greatly amplified cartographic material, identified and provided clear basic locational data for numerous large features (notably stone walled fish traps – see Figure 43). It also enabled and facilitated ground fieldwork to check areas of potential and to clarify and/or amplify initial identifications from aerial imagery.

The following comment from the Strangford Lough report summarises the value of such integration:

> *'...while it is true that some stone features could be traced to a greater degree on the aerial photographs than on the ground, other features identified as potential artificial structures proved to be natural in origin... Wooden structures did not show up to any extent... On the other hand, stone landing stages, jetties and beach clearance slipways are highly visible on the photographs. Field boundary extensions and intertidal walls are also fairly prominent, but kelp grids require more detailed inspection. It is also worth pointing out that many natural features are easily traced on the photographs. The most important are former stream and tidal channels, the current channels which underwent changes over centuries. These palaeo-channels were examined on the ground, as they were the optimum locations for the siting of wooden fish traps in antiquity...'*
>
> *McErlean et al. 2002, 15-16*

The second phase of the Irish National Seabed Survey using airborne lidar has targeted key bays and priority areas for integrated survey work. Archaeological criteria were included in their selection, which could make an important contribution to enhancing baseline knowledge for more intensive research into coastal inshore and nautical archaeology. In the last three years, for example, 109 wreck sites have been accurately located (and in some cases newly discovered) off the coast of Donegal using multibeam echo sounding (Eibhlin Doyle pers. comm.). From a research point of view, there is a considerable advantage in the capability of lidar to enable seamless survey across terrestrial, intertidal and shallow water environments.

Taken together, these initiatives have clearly demonstrated how the use of both well-established and new aerial imaging techniques, integrated with other approaches, offer a major new opportunity for opening up research into Ireland's exceptionally rich archaeological heritage of freshwater lakes and rivers, coastal areas and inshore waters.

Figures 43 a-c: Air photography was one of several techniques used to explore the archaeology of Strangford Lough, Co. Down (Reproduced with the permission of the Environment and Heritage Service Northern Ireland, Crown copyright)

a: Vertical aerial photograph of the foreshore at Greyabbey Bay at low water showing 'V-shaped' stone fish traps (centre of picture) and crescent-shaped stone fish traps (bottom, right and left)

b: Ballyurnanellan stone fish trap near the middle of Greyabbey Bay

c: Greyabbey stone fish trap, Greyabbey Bay

Whole Landscape Approaches

Perhaps partly because of the relatively high survival of upstanding monuments in a predominantly pastoral landscape, Irish archaeology can be seen as being strongly rooted in the tradition of investigating visible field monuments defined within well-established types or classes. This remains a strong theme within landscape approaches to Irish archaeology, although much more effective use of aerial techniques has been developed and used in recent years. As outlined above, aerial archaeology provides a different perspective that in some ways challenges the traditional approach as reflected, for example, in the publication of County Inventories.

There is increasing recognition (*e.g.* Johnson 1999) that traditional site-based approaches cannot adequately capture the full richness of the historic environment, especially when settlement patterns and field or street patterns and other historic landscape features are taken into account (Figure 44); and this can apply both to townscape patterns (Swan 1983, 1985) and the rural landscape (Herity 1987, 1988; Barrett 1992, 1995a, 1997b, 1997/8, 1999; Kelleher 1995; Jones 1998; Cooney *et al.* 2000).

Figures 44 a-b: Archaeological monuments in their landscape context

a: A ringfort at Ballybaun townland, in the Burren, Co. Clare, is surrounded by a field system with which it seems to be integrated (CUCAP 16 July 1971)

b: Eochla stone fort, Inis Mór, Aran Islands, Co. Galway (Department of the Environment, Heritage and Local Government)

To get closer to the ways in which people and landscape really change means breaking out of some of the constraints of long-cherished categorisations of sites and chronologies. The complexity and seamlessness of landscape and social change — stretching from the distant past forwards into the future and operating at different rates and scales — has long been recognised, and aerial photography has had an important role in understanding landscape and presenting it to a wider audience (Figure 45; Norman and St Joseph 1969; Aalen *et al.* 1997). Historic landscape character is gradually becoming more widely recognised and better understood, assisted by being more readily articulated through GIS systems. As a result, traditional site-based systems for managing archaeological data look increasingly inadequate as a means of capturing such rich evidence of long-term social and environmental change.

Figure 45: Drumlin landscape near Ballinamore, Co. Leitrim. The field patterns clearly reflect and emphasise the characteristic 'basket of eggs' topography of low rounded hills and occasional lakes, helping to define the natural and historic character of the landscape (CUCAP 15 July 1967)

In England and Scotland, where characterisation approaches have been developing for some years, there is increasing recognition that information about the historic environment needs to be managed in more sophisticated ways – though this still has some way to go (Herring 1998; Fairclough 2002, Darlington 2002; Dixon and Hingley 2002). In Ireland, Cooney *et al.* (2000, 2002) have developed an approach based on a mixture of the Scottish and English methods. At the broad-brush level, their approach characterises whole townlands, representing a network of long-established historic territories as the basic framework for analysis. The much finer-grained approach of characterising individual land parcels is also being developed and partly underlies the broad picture (Cooney pers. comm.).

With all these approaches, it can be argued that there is still a missing level of linking site-based concepts to relict features and large-scale geographical approaches to present landscape character (Johnson 1999). The challenge lies in capturing the complexity of historic features and landscape or townscape character that is so richly reflected in aerial imagery. This is especially challenging where the complexity of some relict landscape features can be directly related to present-day landscape features and land use. This is extremely evident in much Irish aerial photography (*e.g.* Barrett 1997a, 1997b, 1997/8, 1999; Shell and Roughley 2004). Such complexity cannot be translated readily into simple map form, nor yet into broader characteristics at a townland scale. And yet it is fundamental to understanding the evolution of the landscape and its management. It is through these means that a better understanding can be gained of how modern landscape change, driven by agricultural improvement and other development, relates to longer term patterns of change, and development within different historical and social contexts, stretching far back in historical and archaeological time.

Aerial photography has an especially powerful role to play in revealing patterns of landscape change – and hence threats and pressures on the archaeological resource at a landscape scale. Linking aerial archaeology into the concept of the whole farm as an archaeological entity could be a rich seam of research, and a useful tool for landscape characterisation and management.

4.3 Reconnaissance and Assessment of Areas Earmarked for Development

Context of Economic Development

In relation to development, the use of aerial archaeology needs to be considered not just within the context of general archaeological responses to development pressure. This is very broadly reflected in the National Development Plan[17] which sets out the overall national programme and level of public investment in major new economic and social infrastructure. This has grown rapidly in the last 15 years:

National Development Plan	1989-1993	1994-1999	2000-2006
(Total Investment)	€12,275m	€16,800m	€57,111m

Within the figure for 2000-2006, €22.35 (44%) was allocated for investment in Economic and Social Infrastructure, averaging €3.19 billion per year. Within this programme, social housing accounts for 34%; national roads 27%; public transport 12%; health infrastructure 11%; sustainable energy 1%; with the remaining 14% allocated to employment services. Further public infrastructure investment is channelled through regional programmes.

Growth of public investment in infrastructure in the previous period is reflected in general and sectoral trends for construction industry output (DoEHLG 2001). Between 1994 and 1999, construction output grew from 13% to 20% of GNP. By 2000, Ireland had the highest level of construction expenditure per GNP in the EU, except for Portugal. By 2000, residential construction accounted for 54% of the value of construction output. Over the period from 1996 to 2001, the value of construction output by sector increased as follows:

- Residential: €3.2bn to €7.6bn
- Commercial non-residential: €1.4bn to €3.2bn
- Productive infrastructure: €1bn to €3.1bn (including roads €438m to €1.1bn; energy €222m to €779m)
- Social infrastructure: €467m to €1.4bn

Since the 1980s, aerial surveys have been used increasingly for major developments, principally roads and pipelines. Specially commissioned photography for these purposes tends to provide more detailed large-scale coverage than existing national vertical surveys. The value of this type of threat-related reconnaissance and mapping was demonstrated by pipeline projects in the early to mid 1980s (Cleary *et al.* 1987; Gowen 1988). Air photography has since become more widely recognised as a valuable means of ensuring fuller and earlier recognition of archaeological constraints. This is now included in a series of policy statements on archaeology in relation to various types of land-use change (*e.g.* Heritage Council 1998; DAHGI 1999a, 1999b; National Roads Authority undated; Bord Gáis undated; Irish Concrete Federation and DAHGI 2002; DoEHLG undated).

However, such guidance is not specific as to whether this means consulting existing sources, using general-purpose air photography taken for the scheme, or commissioning specialist archaeological aerial reconnaissance. In practice, the use of air photography for these purposes varies, from consulting those images taken for general engineering and planning purposes that are made available to archaeologists, to those specially commissioned as part of the archaeological assessment process.

[17] *http://www.ndp.ie*

Roads

The National Roads Authority's archaeological code of practice was drawn up in recognition of the major road construction programme outlined in the National Development Plan for 2001-2006. It outlines a basic framework of integrating archaeological assessment and mitigation of construction impacts for all stages of road development projects, from route selection to on-site construction. This includes the NRA's commitment to ensure that a project archaeologist is appointed by the local authority to oversee the archaeological process. One of the stages of work within this role is a requirement

'...to prepare the specification for the consultant archaeologist at EIA stage and ensure that all preparatory archaeological work (desk study/field walking, aerial photography and if necessary geophysical surveys etc.) for the EIA is of the highest standard...'

NRA undated, Appendix 1

While this allows for some flexibility of application, the NRA archaeologist reports that

'Currently we are requesting all potential new routes to be flown and photographed from an archaeological perspective. The time of the year that the aerial photography is carried out is crucial.'

Daire O'Rourke pers. comm.

The NRA itself, along with archaeological consultants and contractors, report a considerable increase in the use of aerial archaeology in the context of road schemes, having a role at several different stages from Environmental Impact Assessment to recording of sites (Figures 36, 42, 46, 47). Since individual schemes cross different geographical areas, the practical application of this policy varies. In general, more aerial photography is being carried out on road schemes due to requests by Project Archaeologists, but it appears from comments by practitioners that this can be tempered by various factors such as their own level of experience, the attitude of contracting engineers commissioned to design schemes, the nature of the scheme, and the terrain covered.

Figure 46: The Aghaboe ecclesiastical complex in Co. Laois, with possible associated earthworks. Photographed in February 2002 for the Environmental Impact Assessment of the M7 Portlaoise–Castletown/M8 Portlaoise–Cullahill motorway scheme (Margaret Gowen & Co. Ltd, courtesy of the NRA)

In some cases, purposive archaeological reconnaissance will be carried out at each stage of the route selection and design process. This will include general reconnaissance of a broad corridor, followed by more focussed photography of a preferred route, and occasionally specific photography of individual excavations if they are very extensive (D. O'Rourke, M. Casey, pers. comms.). This was the model pioneered on some gas pipelines (Gowen 1988) where it was found that a 1:5,000 scale vertical survey of the pipeline route itself in ideal conditions greatly clarified what had been observed from a 1:10,000 survey of the route corridor. In other cases, much more reliance is placed on general purpose vertical aerial photography carried out by the local authority or the design consultants. While these are often not flown in ideal conditions for archaeology, they may nevertheless provide valuable information.

The quality of reports on aerial surveys is said to be rather variable, as it does not always provide adequate interpretation, mapping and locational details to support further stages of investigation. Similarly, not all identified features are proved to be real following ground investigation. And although many features are identified that were not known before, this clearly does not entirely preclude the discovery of unforeseen archaeology (R. Swan pers. comm.). To put this into perspective, it appears that purposive aerial archaeological reconnaissance is now a much more standard procedure for Irish road schemes than is common in the UK.

Since 2002, when the views outlined above were originally canvassed and when the policy was quite new, several concerns have started to be addressed, and two schools of thought are beginning to emerge about the value of aerial archaeology. One states that it is a vital element of the process of identifying archaeological remains likely to be affected by new road schemes. The other says that intensive geophysics and trial trenching are so much more effective in practice that they make most of the aerial survey redundant. This, however, is a false distinction. Aerial archaeology may not be the best way of finding or defining the character and extent of every site. But it can certainly be crucial in initial identification. It is a vital part of the earlier stages of desk studies and reconnaissance, before a detailed road line has been fixed and when more expensive geophysics and trial trenching are not practicable. The key point, reflected in draft guidance for the conduct of archaeological assessment of road schemes (NRA 2005), is this: aerial archaeology is just one of an important range of desk study and reconnaissance methods that needs to be integrated into each stage of the identification and development of the route for any new road. It also has a valuable role to play in recording progress of construction, and as part of that can make an important contribution to presenting archaeological work within its landscape context (Figure 47).

Figures 47 a-b: In addition to reconnaissance, air photography has a role to play in monitoring the progress of road construction and providing valuable illustrative material to show excavations in context

a: Test trenching carried out as part of the archaeological testing of the M7 Portlaoise–Castletown/M8 Portlaoise–Cullahill motorway scheme (Narrowcast, courtesy of the NRA)

b: Three Early Neolithic houses uncovered at Monanny, Co. Monaghan, along the route of the N2 Carrickmacross Bypass. (studiolab.ie, courtesy of the NRA)

Figure 48: Quarrying immediately adjacent to the megalithic cemetery at Carrowmore, Co. Sligo. Apart from the impact on the setting of visible monuments, quarrying is liable to destroy subsoil remains that may only be detectable from aerial photography, geophysics or trial trenching (Gillian Barrett, June 1991)

Pipelines

The general principles that apply to roads were developed and continue, in principle, to apply to pipelines. The provisions of the archaeological code of practice for new pipelines, drawn up in recognition of the need for major new pipelines between Mayo, Galway, Limerick and Dublin, are almost identical to those for roads (Bord Gáis undated). However, respondents comment that because the scale and impact of pipelines are less than other major linear developments like roads, and the scope for minor diversions greater, there tends to be less emphasis on the use of aerial photographic reconnaissance as a standard procedure, at least on the smaller schemes.

Minerals

There are now similar guidelines for archaeological reconnaissance for minerals, issued with the Irish Concrete Federation in relation to aggregates (Irish Concrete Federation and DAHGI 2002). The purpose of this code is to provide a consistent framework within existing legislation and regulations to enable ICF members to maintain the supply of development materials while having appropriate regard for archaeology (Figures 48, 49).

The code also provides for the appointment of a Project Archaeologist to manage archaeology within the industry, and like others mentioned above, it refers to the value of aerial photography. In effect, the code represents the industry's recognition that it is in the interest of both the public and the industry to minimise the risks and unexpected costs that can arise from archaeology. Dr Charles Mount, the ICF archaeological officer, explains this as follows:

'Proposals for new quarries and new land acquisitions are vetted by the ICF for their members on a confidential basis, pre-purchase, to assess the likelihood of encountering archaeology. Members are encouraged to avoid acquisitions with known sites and monuments, and the attendant risks, planning difficulties and costs are outlined. Indicative surveys would be useful, but the ICF does not have a mechanism for funding work that is industry based, only member-based.'

Section 261 of the 2000 Planning Act established a Register of quarries, bringing all quarries into the planning process for the first time. In relation to quarries predating 1 October 1964, the local authorities have the option to require them to apply for planning consent with an Environmental Impact Assessment if they are over 5ha, are likely to have a significant environmental effect, or if they are located in an area subject to a European designation. Quarries in operation for less than seven years which have not received planning permission should be subject to the full planning process, including the preparation of an EIA. For quarries with planning permissions more than five years old, local authorities have the option to restate, modify or impose conditions. The GSI carries out geologically based Mineral Potential Mapping which assists industry and local authorities alike to plan for future quarrying of commercially valuable aggregates and other minerals.

As with other large-scale developments, EIAs for individual mineral extraction schemes may occasionally incorporate purposive archaeological aerial photography as part of the site assessment process, but this is by no means always the case. In any event, success may depend heavily on seasonality and weather conditions, especially in relation to soil- and cropmarks in arable areas subject to exploitation for aggregates (*e.g.* Figures 33, 34, 35, 49).

The archaeological potential of mineral-rich areas (whether for aggregates, hardrock or specialist minerals) is well established, as is the value of both low-level oblique photography and low/medium-level vertical photography for recording previously unknown earthworks and soil- or cropmarks (see above). Cropmark evidence is especially important for locating buried archaeological sites on river gravels and limestones that are both well-drained and fertile, and which have long attracted agricultural settlement. This can raise specific research opportunities. For example, Dr Mount notes that

'One promising area [involves] twelfth and thirteenth century manors which have been ploughed for arable for up to 800 years, especially in Leinster, so that practically all earlier archaeology has been removed by deep ploughing. With the changes in land ownership which accompanied the Act of Settlement (1653) and the Williamite confiscations (1690-1703), the medieval remains have been ploughed up as well. Often these are sited on exactly the aggregate deposits that the industry requires.'

The specific relationship between air photography of cropmark sites and extraction of minerals in Ireland was highlighted by St Joseph (Norman and St Joseph 1969). Since then, it has been demonstrated very clearly – and repeatedly – by Hartwell (1991a) in relation to the ricssance is dependent on annual variations in weather conditions and particular seasonal windows of opportunity (Figure 49). It cannot therefore be assumed that adequate coverage can be left to individual development proposals – even if they are of a size to warrant such an approach.

Figure 49: Clonmelsh, Co. Carlow, showing a cropmark sequence comprising a ring ditch, curvilinear enclosure and linear divisions adjacent to a quarry (Gillian Barrett, August 1995)

It is a matter for some concern that, until now, there has never been any official, systematic strategic archaeological reconnaissance and mapping of areas most subject to mineral extraction as was done from the 1970s onwards in the UK (*e.g.* Benson and Miles 1974), though this is not to say nothing has been done. Reconnaissance flying and recording of some of the tillage counties is being carried out regularly by Michael Moore of NMS, with direct input to the SMR, but this is only partly targeted at areas likely to be subject to aggregates exploitation. Dr Gillian Barrett's research-led reconnaissance has also covered significant areas of river gravels, and while some locational data has been incorporated into the Record, it appears that no systematic arrangements have been made to acquire copies of photographs in her collection, though the opportunity has been offered.

The much firmer application of planning legislation and EIA requirements to mineral extraction established in the last five years is likely to lead to a plethora of archaeological assessments. All these issues are further emphasised by the inevitable growth in the demand for aggregates resulting from the enormous expansion of the construction industry in the last ten to 15 years.[18] But as Dr Mount of the Irish Concrete Federation comments: '*indicative surveys would be useful, but we don't have a mechanism for funding work that is industry based, only member-based*'.

The GSI's Minerals Potential Mapping provides an impartial assessment of areas with geological potential for minerals. So far, the counties of Meath, Wicklow and Donegal have been assessed, as their local authorities have expressed an interest in this type of work. Given the requirements for mineral extraction to be covered by EIAs, there will now (since 2004) also be a requirement for national or local plans identifying preferred areas for mineral exploration and extraction to be subject to Strategic Environmental Assessment (SEA), both in its own right and as an indirect effect of other development. The archaeological heritage is one of the topics that must be covered by SEAs. Logically, this should at least entail an archaeological review, synthesis and mapping of all available existing aerial imagery to provide an up-to-date baseline of archaeological constraints. Like Minerals Potential Mapping, this is clearly in the interest of both the public (in this case, to protect the heritage) and the industry (to avoid unexpected environmental risks and costs of mitigation). Where the responsibility for compiling such surveys will lie is not clear, but it would be logical for it to be undertaken in parallel, or even integrated, with the Minerals Potential Mapping process.

[18] *DoEHLG 2001; http://www.ndp.ie*

General Development

Where there is extensive development pressure, some local authorities commission vertical photography or other surveys when updating their local plans. Such surveys are seldom, if ever, commissioned with a view to maximising their archaeological value and are not automatically reviewed for archaeological content, although some may be highly informative where they happen to have been taken in favourable conditions. The Heritage Council's (2000) guidance on Heritage Appraisal of Development Plans expects authorities to check the implications of proposed areas of development against the Record of Monuments and Places, as well as other environmental records. It does not, however, provide guidance on any need for enhancement (or later stages of assessment) using aerial archaeology. This is a further area in which the EU Directive requiring strategic Environmental Impact Assessment of development plans is highly relevant.

Inspection of existing air photographic archives (albeit normally on a very selective basis) is much more part of the routine process of desk-based assessments. Occasionally, some archaeological consultants will undertake aerial reconnaissance of large-scale development sites as part of an EIA process (Margaret Gowen pers comm.), but the responses of those interviewed indicated that this is very much the exception rather than the rule.

The general absence of either general reconnaissance or systematic review of all the main new or existing archival sources of aerial photography at a strategic level thus means that very large-scale suburban development can proceed with remarkably little use of aerial archaeology to enhance the archaeological record prior to development. In view of the combined scale of the residential, commercial and social infrastructure sectors of the construction industry, as outlined above,[19] this must be a matter of some concern.

Peat Extraction

Guidelines agreed between NMS and Bord na Móna are not specific about the use of aerial archaeology,[20] although aerial imaging does play at least some part in the practical assessment and surveying of extraction areas by the Wetland Archaeological Unit (WAU). This has demonstrated the value of aerial survey in defining the geological and topographical extent of bogs as well as identifying observable features. The WAU reports are among the very few in Ireland to use satellite imagery, albeit only as a general illustrative tool (*e.g.* Moloney 1993). Several respondents consider that aerial archaeology and remote sensing may have greater potential roles to play in relation to the archaeology of raised bogs and other wetland landscapes. To some extent, this relates to topographical features, but also, for example, to the emergence of ancient field walls which may become visible from the air before they are readily seen from ground-level monitoring.

While there are clearly limits to what may be detectable beneath thick undisturbed peat, there is merit in assessing more fully the potential value of modern infrared, thermal and possibly radar imaging techniques for detecting archaeological remains in undisturbed or recently exposed peat.

4.4 Rural Development and Land-Use Change

The vast majority of Ireland is farmland. All aspects of the historic environment are subject to the ongoing pressures of change in farming methods and the continuance of traditional methods, both of which may or may not be beneficial for conservation. In very general terms, the pressures for improvement exerted by market forces and government subsidies over many decades have tended to be destructive (Figures 22, 52). It is only in recent years that the pendulum has swung in favour of clearer recognition of, and greater support for, the role that farmers and landowners have in conserving the heritage of rural Ireland. For the period 2000 to 2006 (NDP and DEFARD u.d), the CAP Rural Development Plan set an overall budget of €687.9m for forestry, and €2,039.9m for the Rural Environment Protection Scheme (REPS). Coastal erosion and fisheries represent further pressures on the historic environment.

[19] *DoEHLG 2001; http://www.ndp.ie*
[20] *http://www.bmn.ie/group/conservation_and_afteruse/archaeology_code.htm*

Forestry

The Forest Service (*An tSeirbhís Foraoise*) of the Department of Agriculture and Food is the national forest authority in Ireland. It is charged with the development and regulation of forestry and forestry activities within Ireland in a manner and to a scale that maximises its contribution to national socio-economic well-being on a sustainable basis that is compatible with the protection of the environment.

Coillte Teoranta was established in 1989 under the Forestry Act 1988 as the State-owned commercial forestry company which legally owns and manages the country's public forest estate. However, since the mid 1990s, Coillte has not been involved in the afforestation of new land in any significant way. Currently, their contribution to planting new land accounts for less than 1% of the annual total. Private landowners do the remaining 99% of planting, of which over 90% are farmers.

Commissioned by the Heritage Council, Johnson (1998) undertook a thorough study of the implications of forestry for archaeology. She recommended that

'Where large areas of land are likely to be afforested, aerial photographs and reconnaissance may be an invaluable surveying tool, particularly in remote areas which are difficult to survey at ground level. Medium and low-level photographs are available for some regions, but in many it will be necessary to commission new surveys. While aerial photography can be expensive, the costs could be kept to a minimum especially where large areas are likely to be afforested by forestry companies, co-operatives etc. Previous studies demonstrate how an area can be covered relatively quickly, thereby keeping costs to a minimum.'

The Heritage Council's (1999a) policy paper on *Forestry and the National Heritage* (Section 4.4 on the Archaeological Heritage) recommended that an archaeological study should be made to investigate areas targeted for afforestation in co-operation with the Forest Service. It also stressed the following:

'Over-reliance on the Record of Monuments must be avoided and its preliminary status must be emphasised. To view the Record as a definitive list of archaeological sites in Ireland is to misinterpret its function. The Record is based on the Sites and Monuments Records which were compiled as the first stage in an on-going attempt to identify and ultimately protect sites. They collate the sites known at the time of publication and must be updated frequently to include newly identified sites. They are distributed to the Forest Service, the larger forestry companies, and those with control over agricultural/forestry activities in the different regions. It is essential, therefore, that before any large-scale development in a relatively unexplored landscape takes place, the area should be assessed by suitably experienced archaeologists for its archaeological potential.'

Since the publication of the Heritage Council's report, there have been some significant policy and practical advances. There are now three permanent archaeologists working across the NMS (DoEHLG), the Forest Service and Coillte Teoranta. Mr Emmet Byrnes, archaeologist for the Forest Service, has provided the following observations.

The 'Forest Consent' system, established under the terms of the European Communities (EIA) (Amendment) Regulations 2001 (97/11/EC), has brought the procedures much closer to fulfilling the more realistic recommendations in relation to afforestation from Johnson's 1998 report. The threshold for EIA has been reduced from 200ha (in 1989), to 70ha (in 1999), to 50ha (by 2001).

All referred applications (all within 200m of a recorded monument) are now examined in the first instance by the Forest Service Archaeologist who does a desk-based assessment. This includes checks against the Record of Monuments and Places, the published Inventory and Survey entries, and other known published descriptions and photographs. As reported in a paper to the Institute of Archaeologist of Ireland (IAI) Annual Conference in Dublin in 2004, this now includes for every case a close examination of all anomalous features identifiable in both sets of the orthographically-rectified digital aerial photographs on the Department of Agriculture and Food's IMAP GIS system: OSi Black and White 1995 and Colour 2000. Mr Emmet Byrnes makes an important observation in noting that this is resulting in the identification of

'...numerous sites in pasture marked as "de-listed" on the Record of Monuments and Places which can still be seen as crop marks in the more recent aerial Ordnance Survey high-level vertical aerial photographic coverage (Black and White 1995; Colour 2000)...'

The NMS note that the records for all monuments are under review, including the de-listed monuments in the context of a reissue of the Record of Monuments and Places.

In 2004, 374 applications were dealt with through this procedure, among which 25 definite new archaeological sites or monuments were identified largely as a result of the aerial photography. As a result, 8.6% of these cases had areas permanently excluded; another 3% were made subject, either in part or total, to an 'archaeological impact assessment' (AIA); 5% were subject to archaeological monitoring; and just under 2% were refused outright. In addition to the desk-based assessment procedure, 46 (12.3%) of the applications in 2004 referred to the Forest Service Archaeologist were also inspected in person in the field.

The inter-visibility of sites and landscape relationships are now being taken into account for archaeological complexes and areas, with outright refusals or requirements for the maintenance of linkages or whole areas to be left open and unplanted. Often, this can be achieved at least partly through targeted application of a 15% biodiversity/open space provision with the afforestation grant/premium scheme. This can be used to protect individual sites and allow for the maintenance of linkages or whole areas to be left open and unplanted (Figure 50).

Figure 50: A relatively recent forestry plantation adjacent to a moated site on the southern slope of Brandonhill, Co. Kilkenny (Ian Doyle, 26 July 2005)

In addition to the 2001 regulations, new and additional assessment procedures were put in place in November 2003. These apply to all initial afforestation applications identified through the 'Environmental Considerations' criteria which include areas that have a definite or potential archaeological concern. This has made archaeology a standard issue to be assessed for any forestry proposal. In the last two years, 16 individual consultant archaeologists or companies have been working for farmers/forestry companies involved in the preparation of archaeological assessments, monitoring or inspection reports, either in advance of or in conjunction with afforestation proposals.

While aerial archaeology now plays a significant and effective role in the procedures for individual forestry proposals, less progress has been made in terms of a more strategic Afforestable Land Survey (ALS) of the type that the Scottish Royal Commission undertook in the 1990s, and which was part of the Heritage Council's recommendations. To some extent, the Scottish model of an afforestable land survey is now outdated, as it dealt with large stretches of unimproved uplands that were once considered the prime target for afforestation. Mr Emmet Byrnes points out that in the last 15 years, the yearly planting rate in Ireland has almost halved and the average block of land proposed for afforestation is now only 10ha in size. Planting now occurs in a more fragmentary way, and on average only 50% of those farmers who make an application to the Forest Service for 'consent to afforest' end up planting their land in any given year. Furthermore, the recent designation of over 80,000 acres of land in the

south-west under the Birds Directive and of other blanket bog areas under the Habitats Directive is also likely to reduce the number of archaeologically sensitive upland areas that might be vulnerable to afforestation.

But as Mr Emmet Byrnes acknowledges, this does not mean that the basic principle of more strategic archaeological assessment which makes good use of archival aerial photography and new surveys is not still valid. He has commented that such an approach would be very useful in terms of the future production of Indicative Forest Strategies. He suggests that this should be seen as the ultimate responsibility of the DoEHLG, conducted 'primarily by the NMS Archaeological Survey Unit, but obviously with assistance from and in conjunction with the Forest Service'.

The principle of more strategic assessment is thus clearly acknowledged. Whether the responsibility should lie with the DoEHLG is more debateable. Given the application of the EIA regulations to quite small forestry proposals, any overall programme of support for forestry or any strategic targeting of where it should apply will now (since 2004) require a strategic environmental assessment under the European Commission's SEA Directive (2001/42/EC).

With the additional requirements for SEAs since Johnson's (1998) analysis and the Heritage Council's statement, it is now even more arguable that the Forest Service itself should – and might actually be obliged to – commission a strategic programme of aerial reconnaissance. This should be combined with the thorough review of archival air photography as a cost-effective means of establishing an enhanced baseline of archaeological information to underpin SEAs for any Indicative Forest Strategies.

Agriculture and the Rural Environmental Protection Scheme

Agricultural improvements – specifically the increasing cultivation and reseeding of grassland, reorganisation of field boundaries, and other aspects of intensification – have led to the loss of upstanding archaeology. This was particularly the case during the 1970s when land improvements received strong government support (Figures 22, 52). Although there was a system for consultation about the possible archaeological impact of such work at the time, examination of a selection of site files in the SMR suggest that, in many cases, the then Office of Public Works did little to stop destructive improvement works on sites originally identified from air photography. It appears that subsoil sites known only from cropmarks were often assumed to have been 'destroyed' already. In at least one case, remnant earthworks as well as subsoil features survived, but these too were dismissed as non-archaeological because they were no longer easily recognisable as standard forms of earthwork – yet were later proven to be archaeological through excavation. Little or no consideration was given to wider issues of the historic landscape character embedded in field systems and unimproved pastureland.

Following Ireland's accession to the EU, such grants have ceased, but destructive agricultural improvements continued to occur, encouraged by CAP production subsidies. However, in the 1990s, prior to the Agenda 2000 reforms of the CAP, Ireland had introduced the Rural Environmental Protection Scheme (REPS). This is intended to provide incentives to farmers to safeguard the environment, including as an aim 'the upkeep of the landscape and historical features on agricultural land'. Under the REPS scheme, participants must carry out their farming in accordance with a farm-specific agri-environmental plan which must be drawn up by a planning agency approved by the Department of Agriculture. On the basis of the plan, they must comply with eleven basic measures, which include objectives to:

- Maintain farm and field boundaries.
- Protect features of historical and/or archaeological interest.

The Heritage Council's (1999b) policy statement on Agriculture and the National Heritage does not deal with the historic environment, concentrating instead on wildlife and landscape. But the Heritage Council's Archaeological Features At Risk (AFAR) survey and subsequent studies of damage to archaeological sites indicated a serious problem in the rate of loss of monuments in rural areas. The AFAR report (O'Sullivan *et al.* 2001) concluded that:

- *The destruction of known archaeological monuments in the Republic of Ireland has not slowed in recent years. On the contrary, it has accelerated dramatically.*

- *Earthen monuments are coming under increasing pressure.*
- *Archaeological monuments set in pasture are most vulnerable.*
- *In general, the destruction of archaeological monuments can be linked directly to land improvements, which are associated with more intensive farming.*
- *In some respects, and especially for the purpose of monitoring the destruction of archaeological monuments, the information contained in the County Archaeological Inventories and Surveys is considerably out of date.*

Commenting on measures available to protect rural sites, O'Sullivan *et al.* (2001) observed:

'By including Measure 7 in REPS, however, the Department of Agriculture, Food and Forestry has begun to address the problem, stipulating that monuments of historical or archaeological interest must be preserved. The advantage of REPS is that it requires the participating farmer to manage the landscape, including the archaeological landscape, in a way that meets the requirements laid down by the Department of Agriculture, Food and Forestry. Each participant in the scheme farms according to a five-year agri-environment plan prepared in consultation with an agri-environment advisor. In return, the farmer is given an annual grant to subsidise the measures needed to meet the requirements of the plan.

At the time of writing, approximately 40% of all farmers in the country now participate in REPS, so in theory, the archaeological monuments on their land are protected. The difficulty is that, in general, they appear to represent the agricultural sector which is least threatening to archaeological monuments.'

This report has been criticised for various aspects of its methodology and the assumptions underlying its statistics, which have been challenged in subsequent survey work commissioned by NMS. One of the shortcomings of the AFAR survey was that it did not itself use aerial archaeology, or address issues relating to its use and its potential contribution to understanding the archaeological resource. This raises a number of issues:

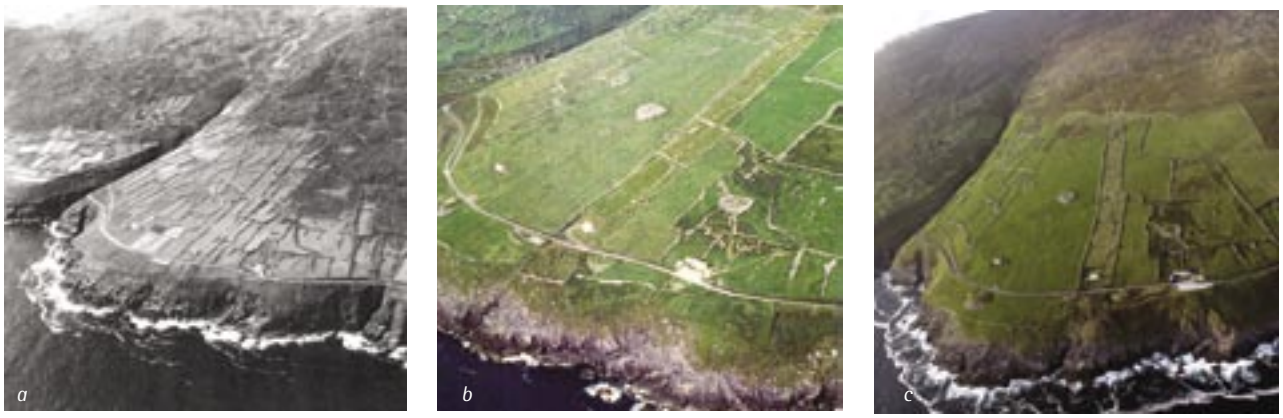
- The status of cropmark sites is not clear in the AFAR report or, apparently, in many RMP entries. In terms of agricultural improvement to upstanding earthworks, they might be regarded as damaged or even 'destroyed' in terms of their visibility from the ground. The subsoil remains, however, could still be of very substantial importance and would certainly not be regarded as 'destroyed' in relation to quarrying or other truly destructive agencies.
- Consideration of the contribution that can be made by aerial archaeology as discussed earlier in Chapter 3 suggests that the Record of Monuments and Places and the County Inventories are only starting points for assessing the whole historic environment of a land holding. In addition to known sites, it can be anticipated that thorough examination of existing aerial photography and/or new reconnaissance of an area are likely to reveal significantly more sites.
- Aerial archaeology can also result in a much richer, more holistic perspective on the historic character of the landscape in terms of both extant and relict features, including field patterns (Barrett 1997b, 1997/8).
- The quality of low-level aerial photography used to illustrate the County Inventories and research projects like Tara (Newman 1997) and High Island (Marshall and Rourke 2000) indicates the potential for monitoring the condition of archaeological sites from the air (Figures 19 and 51).

Figure 51: A ringfort at Cush, Co. Limerick, showing heavy encroachment of scrub (Department of the Environment, Heritage and Local Government)

Despite its possible shortcomings, the AFAR study did highlight concerns about the rapid rate of decay of rural archaeology in Ireland. Even if its detailed results can be questioned, the need to address the issues raised has, if anything, been reinforced by subsequent surveys by NMS. Other studies (Barrett 1997b, 1997/8; Dunford 2002, 2003; ERA-Maptec *et al.* 2005) have begun to highlight different aspects of pressures on historic landscape character.

Taken together with broader trends in the economics of farming (ICSTI 1999), these issues suggest that significantly more attention needs to be paid to the conservation of the rural historic environment. This need is all the greater now, as current problems with the economic viability of farming mean that there is increasing pressure to intensify production in the more productive areas, while at the same time precipitating a withdrawal from farming in less productive areas, with the subsequent development of unmanaged scrub vegetation on monuments. As noted above (Figure 37), this effect is already discernible in the Burren (Dunford 2002, 2003; ERA-Maptec *et al.* 2005).

Aerial archaeology has very clear potential to play an0 important, and probably very cost-effective, role both in enhancing understanding and in monitoring these trends and their effects on the historic environment (Figure 52). But its use for these purposes is insufficiently developed.



Figures 52 a-c: Successive air photographs of Glanfahan, Co. Kerry by (a) St Joseph (1964), (b) Gillian Barrett (1990), and (c) Markus Casey (c.2000) show the impact of modern clearance and land improvement on well-preserved ancient countryside (the latest image shows there has been little change since 1990)

Designed Landscapes and Conservation Plans

While aerial archaeology is not the principal means by which parkland and other designed landscapes can best be understood, it can play a valuable role in their interpretation and the identification of lost features that may show up from pasture marks or other indications. This can be a valuable source of information in the development of restoration or management plans. A good example of this is the Conservation Plan for Russborough, Co. Wicklow (Integrated Conservation Group 2005) where use of both vertical and low-level oblique aerial photography was integrated with historic map evidence to identify previously unrecorded lost aspects of the landscape design (Figure 53). This enabled the position and remains of features such as terraces and paths which had been largely obliterated by later improvements to be identified, accurately located, and taken into account in developing the Conservation Plan for the park.

Figure 53: Aerial photography has considerable potential in locating designed landscape features as seen here at Russborough Park, Co. Wicklow. The pond and associated terracing (a, b, c, d, e and f) were mapped by Rocque in 1760 and were clearly visible in low spring light in 2001. (The survey by M. Gowen & Co. Ltd was carried out as part of a Conservation Plan commissioned by the Heritage Council)

Coastal Erosion and Management

Although the Marine Institute does not have a specific archaeological programme, it has undertaken infrared aerial photography of the whole of the Irish coast(available on CD-Rom[21]). This is in addition to vertical coverage held by the Geological Survey, OSi and Air Corps, all excellent sources for investigating rates of coastal erosion – a subject of research at the Geography Department of Cork University, among others. In the context of intertidal environments, aerial archaeology has a clear role to play in defining more clearly the extent and character of the archaeological resource and the threat to it, both in terms of more intensive review of existing and new reconnaissance of areas under particular threat of erosion or development. The role of aerial archaeology in the interdisciplinary archaeological survey of Strangford Lough is an excellent example of establishing a thorough basis for research and informed decision-making (O'Sullivan *et al.* 1997; McErlean *et al.* 2002 Figure 81)

[21] *http://www.marine.ie/publicationsandlibrary*

The Heritage Council has grant-aided Markus Casey to carry out specific aerial reconnaissance of coastal promontory forts as one of the types of major archaeological site most at threat from coastal erosion (Figures 2, 37, 54). Between 2001 and 2003, this survey covered the coast in the following areas: Donegal, Antrim, Wicklow, Wexford, Waterford; East Cork (in Casey 2001); West Cork and Kerry (Casey 2002); Dublin, Iveragh. and Cork (Casey 2003).

Figures 54 a-b: Detailed aerial photography of costal promontory forts has recorded their surviving condition in relation to natural erosion (Markus Casey)

a: A promontory fort at Lisheencankeragh in Meenogahane, Co. Kerry, has suffered from severe coastal erosion, with only a small part of the interior remaining

b: An eroding ringfort at Doon West, Co. Kerry, backs on to steep cliffs to the north of Ballybunion

Together with other initiatives such as the Discovery Programme's work (O'Sullivan 2002) and the inshore lidar survey being commissioned by the GSI and the Marine Institute (Sections 2.2 and 3.4), along with the increasing coverage of relatively high resolution satellite imagery provided by Google Earth, these resources and projects offer a significant body of material from which to develop the beginnings of a coastal archaeological strategy.

4.5 Potential for Inter-disciplinary Integration

In Irish archaeology as in Britain, there is a long tradition of close collaboration between archaeologists and aerial photography carried out by other specialists – first the military, then OSi, and then State heritage services. Recently, the potential of making better use of more specialist forms of remote sensing has begun to be recognised. Archaeologists have become more aware of the potential application of techniques such as lidar, and of the resources already being developed for other purposes by bodies such as the OSi, GSI and the Marine Institute.

There is a long tradition of archaeologists using vertical photography which was taken for other purposes. This continues to be a valuable way of checking current land use (and hence the potential condition) of known sites and of identifying previously unknown ones. However, it tends to be somewhat hit-and-miss whether vertical photography is taken in ideal conditions for archaeological purposes, except where specially commissioned by archaeologists (*e.g.* Gowen 1988 1:5,000 cover; Doody 1993c). There is not always much scope for integrating all archaeological requirements with other needs. Because archaeology tends to require high quality in resolution of detail, especially in respect of low-to-medium-level vertical stereoscopic coverage, a strong argument suggests that timing of surveys to achieve high-quality imagery for archaeology will also maximise utility for other purposes. In purely practical terms, this is often hard to achieve as these considerations are seldom critical to the paying client.

Where vertical photography is commissioned, there is an increasing case for archaeology to be considered which serves a number of purposes, including environmental protection, as with road schemes, strategic development planning and agri-environment planning and monitoring. Most respondents recognised the value of this and considered that more integration should be developed. Several, however, pointed to a number of practical and institutional hurdles that would need to be overcome by

showing the clear benefits of integration to the commissioning body. Requirements for Strategic Environmental Assessment could become a catalyst for encouraging better strategic integration of multi-purpose survey.

Phase 2 of the Irish National Seabed Survey being undertaken by the GSI and the Marine Institute is a good recent example of the integration of archaeology into other surveys. Building on collaborations already explored in Phase 1, the survey will be targeting key bays and priority areas around Ireland as selected after intensive consultation through the various stakeholders, including the Underwater Archaeology Unit of DoEHLG. Within the priority bays are areas that have high archaeological potential (*i.e.* piers, harbours, fish traps and wreck sites). Airborne lidar has been selected as the preferable tool for mapping these inshore areas.

Although there is widespread recognition of the inter-disciplinary values of aerial photography and remote sensing, it appears that archaeology and heritage practitioners have had rather little involvement in the work of the Irish Society of Surveying, Photogrammetry and Remote Sensing.[22] Founded in 1968, the ISSPRS is a learned society established to further the development of surveying and mapping related disciplines in Ireland, and acting as a key body to promote, facilitate and encourage inter-disciplinary interest in these areas.

4.6 Access and Publications

Access to Aerial Photography

It is clear that accessibility is a key factor influencing the use of aerial photography. The small scale of the GSI vertical coverage is widely quoted as a serious limitation on its archaeological value. Reported in several publications that have clearly demonstrated this limitation (Gowen 1988; Doody 1993a, 2001), this collection is most frequently quoted as the key source, and archaeologists are by far the most numerous users. It seems almost certain that if the more extensive and varied collections held by the OSi (much of which is also held as copies within NMS) were as easily accessible, the GSI collection would hardly be used at all. This issue is not unique to the GSI and OSi collections, as indicated in the comments on accessibility of aerial archaeology collections outlined in Section 2.

This shows that accessibility is very often a more critical factor in determining what aerial imagery is used, rather than the general quality and usefulness of images held in different collections. The issue of accessibility is thus fundamental to determining whether, beyond the limits of specialist research projects, the value of aerial imagery is likely to be fully appreciated or used, especially in relation to the time and cost constraints that often apply to development-led archaeology.

Publications

The use of air photography as a means of analysing and conveying the results of research, particularly in academic papers and monographs, is clearly dependent on how far it was used as part of the research methodology. Numerous works referred to in this study can be examined to appreciate such usage.

Norman and St Joseph (1969) noted, with some disappointment, that Raftery (1951) included only four aerial photographs in his *Prehistoric Ireland*, and Ó'Ríordáin (1964) included only eight in the 4th edition of *Antiquities of the Irish Countryside*. One might expect that, since then, the impact of the work of St Joseph and others would have made a difference. But the use of aerial photography in textbooks and other monographs providing an overview of research is quite variable. For example, while Mytum (1992) included nine aerial photographs in *The Origins of Early Medieval Ireland* and thematic research reviews by the Discovery Programme make copious use of them (O'Conor 1998; O'Sullivan 1998), Waddell (1998) includes only one air photograph in *The Prehistoric Archaeology of Ireland*. Cooney (2000) includes only three in his *Landscapes of Neolithic Ireland*. Yet these authors clearly not only appreciate, but also make much use of, what aerial archaeology has contributed to the understanding of prehistoric archaeology at a landscape scale, as is evident from these works and other research publications (*e.g.* Waddell

[22] *http://www.surveyireland.ie/about.html*

1983). The issue is thus not whether the results of aerial archaeology are used in such textbooks and overviews, but how the role of aerial archaeology is conveyed in such overviews. A preference for using maps and diagrams rather than aerial imagery for this type of work makes sense when synthesising the combined results of aerial survey and other data. This is especially true when trying to highlight features of form and topographical and spatial relationships which, on any single photograph, may be unclear or obscured by later landscape features. But the need to synthesise still needs to be balanced with the power of good aerial imagery to convey what such places are like on the ground, not just in the minds of archaeologists.

Air photographs figure much more in publications aimed at the general reader and in publications covering particular sites. Since the 1980s, a programme of aerial photography of key sites and areas has formed a standard part of photographic work undertaken by the NMS (principally Con Brogan). This has provided very high-quality illustrative material for a wide variety of the NMS's own publications, including the County Inventories and guidebooks (*e.g.* Manning 1994), as well as external publications, such as Marshall and Rourke's (2000) study of High Island, or the Discovery Programme's research at Tara (Newman 1997). In addition, the photographic archive provides a collection of high-quality images of significant localities available for general publicity, exhibitions and reproduction on a commercial basis.

The value of aerial archaeology for reconnaissance, interpretation and illustration has been very usefully conveyed both to archaeologists and a wider audience through numerous editions of *Archaeology Ireland* (see Bibliography for several examples), and in several of the card guides to key sites and monuments issued as regular supplements to the magazine. Condit (1997) has provided a very useful introduction to the subject for the general reader (available in the National Museum of Ireland shop in Dublin as well as other bookshops).

Air photography of sites and monuments is also used commonly in more general books on the landscape and history of Ireland. For example, out of the 188 photographs and diagrams included in the second edition of Mitchell and Ryan's *Reading the Irish Landscape* (1990), 46 are aerial photographs from 13 different sources (predominantly CUCAP and NMS). This includes 16 of the 52 colour plates. Significant use is made of archaeological and other aerial photography in Aalen, Whelan and Stout's *Atlas of the Irish Rural Landscape* (1997). As a technique, it is obviously the basis for two publications entitled *Ireland from the Air* (Pochin Mould 1972; Somerville-Large and Hawkes 1997) and *Northern Ireland from the Air* (Common 1964). Dr Pochin Mould's *Discovering Cork* (1991) is an example of a similar approach at a county level, while Billy Colfer's (2007) use of aerial photography in his study of the Hook Peninsula illustrates the value of aerial photography in local studies.

Overall, therefore, aerial archaeology figures quite well in many publications for different audiences. However, it is probably fair to say that in many general works, it is used mainly for its purely illustrative value, rather than reflecting its application as a core tool for research and analysis. The relative paucity of its use in textbooks may reflect the continued predominance of object- and site-based approaches to academic research, even for geographical and landscape-based studies — though this is not to deny important exceptions as outlined above.

4.7 Public Exhibitions and Outreach

Air photography is commonly used in archaeological exhibitions, displays at sites open to the public, and in guidebooks (Figure 55). It is clearly seen as a particularly powerful way of conveying a strong visual perception of what places are like from a perspective that is different than the normal ground-level view of everyday life. It appears that there have been relatively few cases where aerial archaeology has been the principal means of explaining archaeology to the public; most of those spoken to considered that it could be used much more as a means of informing the public about the historic environment and its conservation and management. Two instructive cases were cited as examples of what can be done.

Figure 55: Aerial photograph of Clonmacnoise, Co. Offaly. Such images bring immediate clarity and understanding to the topographical setting of this well-visited monastic complex (Department of the Environment, Heritage and Local Government)

Cork Archaeological Survey

During the course of fieldwork carried out by the Cork Archaeological Survey, it was important to make contact with local communities to win support for the work, gather information and convey results (Ursula Egan pers. comm.). Approximately 40 temporary exhibitions were mounted, lasting anything from a day to about a week or more in a wide range of local venues (local museums and libraries, banks, agricultural shows, local archaeological and historical societies). In all of these, aerial photography was a core element in explaining the archaeological interest of areas, with several 10x8" images per panel, including cropmark sites that were often a striking new phenomenon to people not previously aware of their existence. The strong emphasis on using aerial photography to explain the work of the Survey also applied to numerous lectures – both separately and accompanying some of the exhibitions – and it was also used in publicity leaflets.

Both as an awareness-raising exercise and in terms of making links with the community and conveying information back to local people, the exhibitions and other forms of outreach received extremely positive feedback. The aerial photography was often the centre of attracting people's interest.

Disappearing Landscapes

In 1993, Dr Gillian Barrett mounted a travelling exhibition of her work entitled *Disappearing Landscapes – Archaeology and the Irish Landscape – An Aerial View*. This was a substantial travelling exhibition consisting of 36 thematic panels and about 350 photographs with explanatory text (Figure 56). It was first displayed in Dublin (at ENFO – The Environmental Information Service) and subsequently in ten other venues in Ireland and in Europe. In Ireland, these included Dundalk, Clonmel, Kilkenny

and Letterkenny. In Europe, the exhibition was mounted in Potsdam (Germany), Rostock (Germany, in association with the University of Rostock), the National Museum, Ljubljana (Slovenia), and Split in Croatia (the latter two in association with the University of Ljubljana).

The purpose of the exhibition was two-fold. First, it sought to establish interest and research contacts among Irish archaeologists — which unfortunately did not materialise. Secondly, it sought to generate a broader interest and awareness of the nature of the historic landscape in Ireland, the processes of change, and the role of aerial photography as a technique of discovery and of monitoring change. This attracted significant public interest.

The Irish Times described the showing at ENFO as 'Ireland as you have never seen it before', and as 'one of the best and certainly one of the most original exhibitions mounted at this excellent centre' (*The Irish Times* 24 May 1993). *Geonews* described it as 'by far their best exhibition to date' and praised the 'quite breathtaking photographs with excellent commentary'.

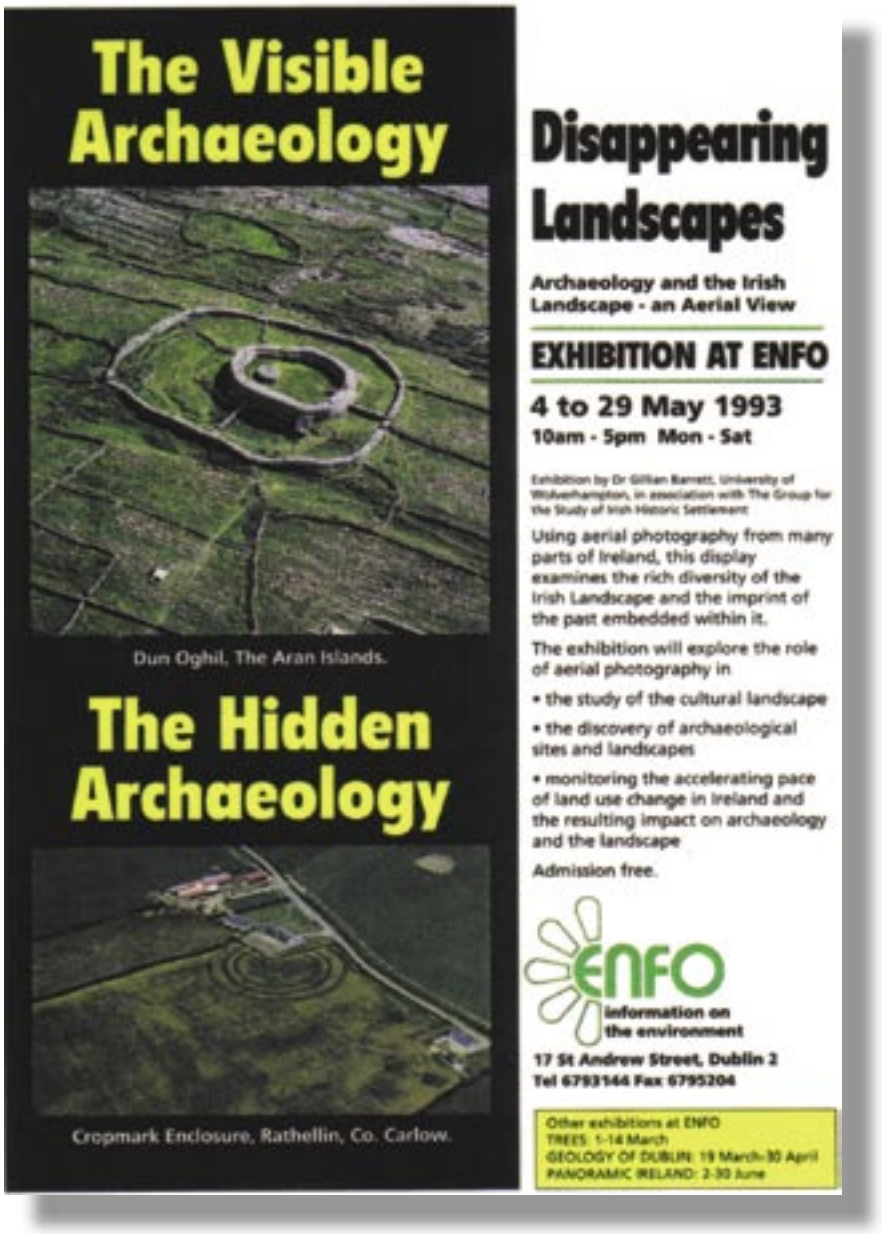


Figure 56: Gillian Barrett's exhibition Disappearing Landscapes at the ENFO Centre, Dublin 1993, communicated the potential of aerial photography and survey to a wide audience.

5 QUALITY, RESOURCES AND ORGANISATION OF AERIAL ARCHAEOLOGY

5.1 Quality of Outcomes

This study has not sought to be a systematic review of the standards adopted in undertaking, reporting or archiving aerial photography in Ireland. Nevertheless, a number of observations may be made from views expressed by respondents and from the literature reviewed. In general, respondents point to the widely admired high standards adopted in some work, such as that of the Discovery Programme. They also voiced their concerns that, in other instances, work is very variable and not always to the standard that might be expected. Various respondents and organisations consulted felt that there was a need for a good practice handbook for the conduct of aerial archaeology.

Reconnaissance

A number of respondents stated that the growing use of aerial archaeology for a wide range of projects (especially road schemes, for example) has led to more work being undertaken by relatively inexperienced practitioners. Some concern was voiced that this may, in a few cases, be compromising legal and safety standards. This view was not supported by actual evidence of specific instances of poor practice, but seemed to be based on observation. Equally, it was noted by some of the contracting companies that they take their legal and safety responsibilities extremely seriously.

Reporting

The practice of undertaking and reporting the results of aerial survey as part of Environmental Impact Assessments has only recently become significant in terms of the number of reports produced and outcomes monitored. A review such as that carried out for testing and monitoring (Lambrick and Doyle 2000) may now be appropriate. From comments by a number of respondents, it is clear that reporting standards may not be very consistent, and in some cases, not entirely fit for purpose in terms of guiding further investigations. Now that the new arrangements for dealing with roads schemes in particular have been in place for some time, it would be appropriate to review both the quality and stages of reconnaissance, along with the reporting of results.

Some of the issues which need be examined here arise from points that can be noted from some of the reports and papers using aerial archaeology referred to in this study. Authors differ quite considerably in how thoroughly they report their methods. For example, the sources used and, in the case of the Record of Monuments and Places and County Inventories, the direct references to particular photographs used tend to be backed up by only the vaguest statement of what searches were carried out to find them. Thus the Wicklow Inventory (Grogan and Kilfeather 1997) simply states that 'An examination of available aerial photography was also conducted.'

Barrett (*e.g.* 1995b) is unusual in how far she describes not only flight paths, lighting and weather conditions, but also in quoting soil moisture deficits derived from the local meteorological monitoring service used by farmers and others. She is also exceptional in mapping cropmark locations in relation to soil types.

Presentation

Numerous useful formats have been used in publications of projects involving aerial photography (*e.g.* Walsh 1983; Herity 1983; Swan 1985; Hartwell 1991a; Doody 1993c; Barrett 1995b; Newman 1997; Redfern 2002; Shell and Roughley 2004). These include a variety of means of plotting the distributions of sites, rectified plotting, comparisons of aerial and geophysical surveys, and incorporation of topographical surveys etc. None of these necessarily provides an ideal or best model, since all are adapted

to suit their purposes. Most examples contain both distribution maps and/or interpretive plots, as well as reproductions of the photographs themselves, at least on a selective basis.

An area that has received less attention (at least until recently) is the consideration and analysis of the whole historic environment – and the history of landscape change – rather than just picking out relict features. For example, in a report for Teagasc, Kavanagh (2002) reviewed the effectiveness of the REPS scheme in relation to the survival and discovery of individual monuments and more general landscape 'quality', but not the wider historic character of the landscape. Where the wider historic landscape character has been addressed effectively, it is often the richness of the photographs themselves that most clearly illustrates the detailed complexity of the rural historic environment and the insidiousness of pressure of change (*e.g.* Barrett 1997b; 1997/8; Dunford 2002, 2003).

Archiving

The practice of duplicating sets of aerial photographic material (*e.g.* NMS copies of photos from CUCAP, OSi, Air Corps, GSI and other sources; National Museum set of CUCAP photos and some other sources) means that much relevant photography is not reliant on its survival for a single source – at least in terms of prints. Moreover, public archives with original material have good storage conditions on the whole.

More problems arise with valuable private collections which are available for consultation but not yet fully assessed for their content. There would clearly be merit in duplicate sets of prints being available (subject to copyright restrictions and rights), both for the security of the information they contain and for easier consultation.

The growing use of digital imagery and remote sensing techniques poses particular challenges for long-term archiving. The Archaeology Data Service in Britain has published a guide to good practice (Bewley *et al.* 1998).[23]

5.2 Cost-effectiveness, Resources and Co-ordination

In very general terms, the cost-effectiveness of aerial archaeology is widely recognised (*e.g.* Wilson 2001; British Academy 2002). It is not easy to estimate the totality of aerial archaeology carried out in Ireland – not least because a considerable amount of reviewing and plotting of existing photography is done on a case-by-case basis. In any case, this is not the best measure of whether it is used effectively.

Johnson (1998) has noted the value of analysing existing photographic archives, observing:

'Kelleher (1995) reported a high success rate in identifying previously unrecorded sites through the use of computer enhancement and mapping programmes to analyse aerial photographs. The results were particularly impressive in identifying field systems and associated enclosures in marginal areas.'

In terms of reconnaissance for oblique photography, the cost-effectiveness of the technique can be gauged on the basis of 'yield' of results per flying time or the approximate cost per new discovery. In the exceptional year of 1989, Barrett (1995b) recorded 137 sites in six hours' flying along the Barrow Valley between Monasterevin and Bagnelstown. Power (1993) records that over 200 previously unrecorded sites were discovered in just six hours' flying in the area between Fermoy and Mallow along the Blackwater Valley (c. 20 miles x 5 miles). However, Power also notes that this was highly exceptional. Otherwise, over ten years, the Cork Archaeological Survey undertook 40 hours' flying, recording previously unknown sites at around one or two per hour. Power observed that

'...this discovery rate compares very unfavourably with the returns from actual fieldwork – especially in the less intensively farmed parts of the county. The return is even less productive when one considers that those sites not revealed by cropmarks still have to be visited on the ground...'

[23] *http://ads.ahds.ac.uk/project/goodguides/adandrs/*

Estimates of costs per site or target are also variable. These can be expected to vary considerably, depending on how much previous work has been done, weather conditions etc. In the drought year of 1989, with a grant of Stg£2,000, Dr Gillian Barrett recorded 106 new sites (Barrett 1995; pers comm.), giving a figure of *c.* Stg£19 (€29) per site. Markus Casey (pers. comm.) suggests a rough estimate of *c.* €50 per new site for his recent work on coastal promontory forts. These figures do not allow for repeat photography/monitoring of known sites within the same sortie. Unfortunately, Doody (2001) does not give figures for the costs of the Bruff survey where comparative medium and low-altitude vertical and oblique reconnaissance was compared with high-level vertical coverage. Estimates for the UK for aircraft costs per 'target' (*i.e.* for both new and known sites) was *c.* Stg£20 (€31) in 1996-8 (British Academy 2001).

A few years ago, the DoE Heritage Service in Northern Ireland (N. Brannon pers. comm.) examined the pros and cons of using video cameras to monitor the condition of nature reserves and other sites.

Pros include:

- *Large savings in person-days and subsistence costs. Staff shortages are acute so using programme monies can be the best way to manage financial resources.*
- *Video record of condition of entire site at the time of the survey. This also allows basis for comparisons.*
- *Copies of videos can be supplied to HQ and other organisations who would find the information useful.*
- *Photographs can be taken from the air which are useful for condition monitoring work, slide shows and publications.*
- *More sites can be covered in good conditions, suitable for covering significant areas.*

Cons are that:

- *Flights are expensive: e.g. for Lough Neagh area, a flight is roughly 50% more expensive than ground-based vehicle costs.*
- *The helicopter method is more dependent on good weather conditions than ground-based survey.*
- *There is less scope for detailed examination of sites.*
- *Contact with landowners is lost.*
- *If hire of a photographer and video equipment is involved, extra costs can also include larger helicopter (c. Stg£100/hr extra).*

In the example modelled, it was reckoned that a single helicopter flight costing *c.* Stg£1,340 in travel costs could achieve a saving of about Stg£5,000 on fieldwork that otherwise would take two people *c.* 35 days to complete on the ground. However, this was for continuous filming of large areas of nature reserve rather than more isolated sites.

The Discovery Programme's recent experience has been that the basic costs of commissioning a vertical photogrammetry survey is approximately €150-175 per km^2, excluding software licences and processing costs. Lidar costs are in the order of €800-1,200 per km but this may be broadly comparable with photogrammetry when processing costs are taken into account. Satellite imagery (true colour at 60cm resolution and minimum of $25km^2$) is much cheaper (€13.5-15 per km^2 for archive images; €17-25 for new images, with an extra 25-50% to obtain near cloudless or cloudless conditions) but is significantly more limited in terms of resolution and potential metrical data.

Photogrammetry, lidar, satellite imagery and other remote sensing techniques are becoming increasingly cost-effective options, with relative costs being reduced through technical improvements and increasing economies of scale fuelled by demand for more strategic coverage. So far, the use of these techniques has mainly been within the domain of special pilot studies and research projects, but this is changing. Cost-effectiveness is ultimately dependent not on the relative cost of different techniques, but on the quality of the data required and the uses to which it is put – including potentially large savings in replacing other ground-based methods. Understanding the different techniques which can be achieved and choosing the best way to meet specified needs are thus critical and will vary greatly with the nature of the type of work being done.

Archaeological use of some of the more expensive techniques is most likely to become routine if these trends are also accompanied by cost-sharing based on close inter-disciplinary co-ordination with other user groups, as already exemplified by the Phase 2 Irish National Seabed Survey.

5.3 Resources Available for Aerial Archaeology in Ireland

Because of the way in which aerial archaeology is integrated with other kinds of archaeological and non-archaeological work – and the varied organisational academic, conservation and development contexts in which it is carried out – it is not possible to give a realistic estimate of the overall resources available for carrying out aerial archaeology in Ireland. In terms of sorties flown by State heritage agencies in Britain and Ireland, NMS fly about 10-20 reconnaissance hours per year (E. Cody pers. comm.), together with a significant additional amount of flying for illustrative photography; DoE NI Environment and Heritage Service fly between 3 and 7½ hours; the Welsh Royal Commission fly *c.* 11-40 hours for both reconnaissance and monitoring. The Scottish Royal Commission fly *c.* 101 to 120 hours, and English Heritage 236-296 hours. All these bodies (and the Heritage Council in Ireland) grant-aid some freelance flying. In England, very substantial resources are devoted to mapping the results of reconnaissance, but this does not apply in Ireland, either north or south of the border. None of this takes account of the work done through development-led archaeology, or university or private research.

Because of the additional work being commissioned for road schemes, the number of 'practitioners', in the sense of archaeologists who have taken air photographs, is probably now increasing, but a number of more experienced practitioners are now less involved. Respondents suggested that there is now rather less provision for mentoring and training, especially in the context of competitive tendering for development-led work than in the context of survey or research-led work. Nevertheless, companies undertaking development-led work do in some cases try to ensure that experience is more widely spread through mentoring by more experienced personnel.

Overall, it appears that no individuals work in aerial archaeology full time, and there is no obvious problem of capacity for doing more aerial archaeology in terms of personnel – including experienced flyers. Current capacity appears to be limited by the priorities, and hence budgets are devoted to aerial archaeology, rather than the availability of expertise.

In particular, there appears to be a particular shortage of resources devoted to strategic reconnaissance, and data management, mapping and enhancement. Yet the general amount of aerial photography and other remote sensing for other purposes, many of which are related to development and land-use issues of considerable relevance to archaeology, appears to be burgeoning.

5.4 Organisational Context and Support Needed to Sustain Roles

As the foregoing sections indicate, a wide range of individuals and archaeological and other organisations spanning the State, academic, commercial and private sectors contribute in a variety of ways to the pursuit of aerial archaeology in Ireland. And as noted above, nobody is engaged in aerial archaeology as their sole occupation. This strongly reflects the way in which it is rightly viewed as just one element of the archaeological process, not a stand-alone technique. But this highly integrated approach also has a downside: in another sense, it is highly fragmented. Compared with Britain, there appears to be less overall co-ordination to share experiences, discuss methods and develop new approaches or maximise the value of lessons learned. The absence of support for experienced practitioners to contribute to a strategic programme of regional flying, such as existed some years

ago in England, may have meant that there was no catalyst for such collaboration, although individual efforts have made very important contributions, as in the Cork Survey.

This is not to say that there is no discussion or interaction – especially at the cutting edge of aerial archaeology in Ireland. But most respondents commented on the lack of any formal or semi-formal public sharing of views and experiences rather than simply informal private contact, which clearly does occur in clusters of people with similar thematic or geographical interests. This lack of broader awareness of some of the developments and issues for aerial archaeology in Ireland is arguably apparent in some of the patterns of literature citation. There also appears to be rather little awareness (or membership) of bodies such as the Aerial Archaeology Research Group (AARG), which provides a forum for discussing issues and approaches to the technique. AARG's useful website[24] provides many useful references to literature and links to other relevant internet sites. It describes their role as follows:

'The Aerial Archaeology Research Group (AARG) provides a forum for the exchange of ideas and information for all those actively involved in aerial photography, photo interpretation, field archaeology and landscape history. This also includes the use of aerial photography in defining preservation policies for archaeological sites and landscapes.

The Aerial Archaeology Research Group (AARG) began life in 1981 as a small seminar called to discuss ideas raised by Paul Ashbee (then of the University of East Anglia) and David Wilson (of CUCAP).

The critical issue was to examine ways of obtaining archaeological information from existing aerial photographs – problems that now tend to fall within "post-reconnaissance" work. Meetings of that group then continued to be held at least once a year – and those were exciting times.

Computer rectification had become available and allowed, for the first time, rapid mapping of complex features and large areas. This was used by a small number of research students to study different areas of Britain, and many of the early AARG meetings were spent discussing ways of illustrating different kinds of features (see Aerial Archaeology 11) and of methods of classification of the mapped features and their results. The latter is a never-ending quest and recurs at intervals and as new areas (each of which has its own specific problems) are studied or new methods applied (see, for example, papers by Duncan and Redfern in AARGnews 14).

More recently, the annual AARG meetings have become slightly more formal presentations of finished, or ongoing, projects, although our present chairman intends to reintroduce some more open discussion. Presentations have included some of the results from the National Mapping Programme for England (RCHME), and integration of different survey methods (such as comparing results from AP interpretation with geophysics, or adding field-walked data to AP-derived maps). Use of satellite images has been pursued as the special interest of one member but, with the increasing resolution now publicly available, this media is becoming a useful source of archaeological information (see Fowler in AARGnews 9-15, Comfort in AARGnews 14).

As AARG enlarged in size, so it attracted aerial photographers as members and topics have arisen which pursue their interests. The merits of different types of hardware (cameras, films, filters, etc) have been discussed (see Crawshaw AARGnews 8-10; Jones in AARGnews 16) and our meetings tend to include an informal session at which members can show a selection of their latest photographs. Current interest, raised as an important post-reconnaissance question, asks whether the traditional archaeological oblique photographs provide reliable data on which to base archaeological survey. This continues to form part of discussions at the annual conferences...

[24] *http://aarg.univie.ac.at/*

Membership

Membership of AARG is open to those interested in aerial archaeology as well as its active participants. All applications for membership, subscriptions and changes of address should be sent to the Secretary, Cinzia Bacilieri. You can download also the membership form.

Membership entitles you to receive AARG news for each membership year (from 1st January) as well as regular mailings about the Annual Conference and other events. Subscription rates are: Individual, €10; Students/concessions €5; Institutional €15.'

Apart from a day seminar held as a result of this study in December 2005, it appears no conferences on aerial archaeology in Ireland have been held in recent years, despite the considerable advances and interest in the subject demonstrated by several different projects indicated here. It may also be noted that Dr Gillian Barrett comments that one of the least successful aspects of her *Disappearing Landscape*s exhibition was that it did little to build more linkages with other archaeologists interested in aerial archaeology, although it was highly successful for non-archaeologists. As noted above, archaeology and heritage do not appear to be covered much by the Irish Society of Surveying, Photogrammetry and Remote Sensing.

Thus there seems to be an unfortunate lack of collective communication and networking, both among archaeologists and between them, and those with cognate interests in aerial photography and remote sensing in other disciplines. This does not, of course, mean that there has not been much valuable individual contact and exchange of views. It may, however, help to account for the subject not having been given the recognition and resources it deserves, despite some excellent individual programmes of research and development.

6 TEACHING AND TRAINING

6.1 Coverage of Aerial Archaeology in University Teaching

Most undergraduate courses in archaeology and some in other disciplines cover the broad principles and applications of aerial archaeology. At the post-graduate level, there are ample opportunities for individual and group MA/MSc/PhD projects, though how far these are taken up depends greatly on the extent to which they fit within departmental and personal research priorities of senior academics. The provision of taught courses specifically focused on aerial archaeology is more limited.

University of Glasgow

The only specific post-graduate university course with a special focus on aerial archaeology is an MLitt and Postgraduate Diploma in Aerial Photography with Geophysical Survey run by Professor Hanson at University of Glasgow Department of Archaeology. It is described as follows:[25]

This degree programme is unique – no other University in Europe offers a course on aerial photography for archaeology. The course focuses on the principles, methods and applications of aerial photography and geophysical survey in archaeology. It combines expertise in aerial photography, geophysical survey and computing within the Department of Archaeology with that in photogrammetry in the Department of Geographical and Earth Sciences, and the practical and professional aerial photographic skills of the staff of the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS). The strong practical content and work placement provides a highly focused vocational course and offers very marketable specialist skills for any student wishing to pursue a career in archaeology.

Entry requirements

An upper-second class Honours degree in Archaeology or other relevant discipline (e.g. Geography, Geology, History, Environmental Science, Physics); or equivalent qualification; or suitable practical experience.

Programme structure

The taught part of the course in the first two terms concentrates on the basic theory, principles and methods of aerial photography and geophysical survey. A period of 9 weeks during the third term is spent on placement with the RCAHMS in Edinburgh in order to gain practical experience of professional aerial photographic work. All elements are compulsory.

- *Interpretation and application of aerial data, including interpretation and classification; transcription methods and data handling; applications of aerial photography.*
- *The principles and practice of aerial archaeology, including the nature of aerial phenomena; methods of data acquisition; and the principles of photogrammetry.*
- *Geophysical survey: interpretation and applications, including data manipulation; interpretation; applications and case studies.*
- *Geophysical survey: theory and practice, focusing on the theory and practice of magnetometry, resistivity, and other survey methods.*

[25] *http://www.gla.ac.uk/departments/archaeology/prospectivestudents/ postgraduate/taughtmasters/aerialphotographyandgeophysicalsurvey*

- *Work Placement, in RCAHMS to experience the major aspects of their practical work, including data acquisition, classification and cataloguing, and curation.*

The MLitt Dissertation is a sustained piece of scholarly work on a topic to be agreed between the convenor and the student and is undertaken between June and September.

Assessment

Assessment is entirely on the basis of course work (essays, practicals etc.) and a portfolio of practical work. Progression to the MLitt dissertation will require performance at MLitt level across the coursework elements.

There are no training courses as such for aerial archaeology in Ireland. But most undergraduate and MA courses in archaeology in Irish universities do include aerial archaeology as a standard technique, as follows.

University College Dublin

The undergraduate course in archaeology includes 'Practice and context of archaeology in Ireland' which includes remote sensing. Their MA in Landscape Archaeology includes 'Looking at sources in landscapes studies' which includes aerial archaeology. In 2005, the Discovery Programme was invited to spend a day introducing the MA class to the range of GIS and survey techniques used in archaeology. After a classroom session showing the methods and technologies involved, from GPS ground survey through to aerial photogrammetry and GIS data manipulation, the group experienced some of the practical aspects of survey.

University College Cork

The undergraduate course in archaeology includes a module on 'Archaeological Fieldwork and Excavation' which includes aerial archaeology. The MA in Archaeology includes a module on 'Archaeological Cultural Resource and Project Management', but this does not explicitly cover aerial archaeology.

National University of Ireland, Galway

The undergraduate course in archaeology includes 'Introduction to fieldwork' which covers aerial archaeology. Their MA in Landscape Archaeology includes a module on 'Investigating Landscapes' which includes aerial archaeology.

Queen's University Belfast

The undergraduate course in archaeology has a module on 'Archaeological sites' that includes aerial archaeology. Their Postgraduate Diploma and MA in Archaeology included the same module on 'Archaeological sites', and after a break in 2006-07, Masters courses are to be reinstated for 2007-08.

Other University and Practical Courses

Not all teaching and training need be within formal archaeological courses (or departments). For example, at the Geography School at Wolverhampton in the UK, Dr Gillian Barrett used her extensive collection of Irish aerial photographs in undergraduate courses to illustrate the potential and problems of aerial reconnaissance and post-reconnaissance mapping and evaluation in Year 2 as part of a 'Reading the Landscape' module, and in Year 3 in a module exploring the links between Geography and Archaeology. English Heritage hold a regular annual workshop, and another short course training session is provided in the professional archaeology programme at the Department for Continuing Education at Oxford University. There seems no reason why similar initiatives should not be developed in Ireland.

6.2 Other Provisions for Training and Mentoring

With the growth in archaeological aerial survey of road corridors, a number of archaeological contracting companies are encouraging more staff members to assist in taking air photographs. The extent to which this can be regarded as training or even mentoring depends on the experience of those who accompany such new or inexperienced recruits – and it is apparent that this varies. Even though such initiatives may only occasionally involve practitioners with a long and varied track record of experience, there must be at least some benefit in encouraging more archaeologists to have the practical experience of seeing archaeology from the air.

In the longer run, this may prove to be the basis for further development of aerial archaeology in Ireland if there is rapid expansion of demand for these services. But in the shorter term, there is some concern that competition for work means that relatively inexperienced archaeologists are being used with little real training or instruction from experienced practitioners – who might otherwise do the work themselves anyway.

Although universities and others do provide a basic introduction to aerial archaeology, these courses are mostly fairly introductory, unless students go on to develop their interests through dissertations, placements or much more detailed mentoring. A number of courses have enabled students and others to develop their skills in this way.

Figure 57: A pre-flight briefing at an Aerial Archaeology Research Group/EU Culture 2000 training course in Cirencester 2006. Three Irish archaeologists received training in aerial survey as part of this initiative

A number of respondents suggested that there would be value in developing more training and mentoring for the development of new talent, including practical legal and safety issues (including suitability of aircraft and airfields) as well as in issues concerning timing, ground and weather conditions, lighting and photographic technique. More training in standards of reporting, interpretation and presentation is also needed (Figure 57). The results of the EU Culture 2000 project – European Landscapes Past, Present and Future – have illustrated graphically the value of close collaboration and training in aerial archaeology and related techniques (Musson and Horne 2007).

Appendix 1: Bibliography

Aalen, F H A (ed), 1985. *The Future of the Irish Rural Landscape*, Department of Geography, Trinity College Dublin.

Aalen, F H A, Whelan, K and Stout, M (eds), 1997. *Atlas of the Irish Rural Landscape*. Cork University Press, Cork.

Alcock, O, de hÓra, K, and Gosling, P, 1999. *Archaeological Inventory of Galway 2: North Galway*. Stationery Office, Dublin.

Barclay, A, Gray, M and Lambrick, G, 1995. *Excavations at the Devil's Quoits Stanton Harcourt Oxfordshire, 1972-3 and 1988*. Oxford Archaeology Thames Valley Landscapes: The Windrush Valley 3.

Barrett, G, 1980. 'Aerial photography and the study of early settlement structures in Ireland'. *Aerial Archaeol* **6**, 27-38.

Barrett, G, 1982a. 'Problems of spatial and temporal continuity of rural settlement in Ireland, AD 400 to 1169'. *J Hist Geogr* **8**, 245-60.

Barrett, G, 1982b. 'Ring-fort settlement in County Louth: sources, pattern and landscapes'. *J Co. Louth Archaeol Hist Soc* **20**, 77-95.

Barrett, G, 1984. 'The reconstruction of protohistoric landscapes using air photographs: case studies in County Louth'. *J Co Louth Archaeol Hist Soc* **20**(3), 215-36.

Barrett, G, 1990. 'The hidden landscape – the evidence of aerial reconnaissance, July 1989'. *Archaeology Ireland* **4**(3), 26-8.

Barrett, G, 1992. 'Landscapes at Risk?' *Archaeology Ireland* **6**(2) 16-18.

Barrett, G, 1993. 'Bird's eye view'. *Brit Archaeol News* **5** 12.

Barrett, G, 1995a. 'Disappearing landscapes: archaeology and the Irish landscape – an aerial view'. *Group for the Study of Irish Historic Settlement Newsletter* **4**, 8–10.

Barrett, G, 1995b. 'Recovering the hidden archaeology of Ireland. The impact of aerial survey in the River Barrow valley, 1989-91', in Konnow, J (ed) *Luftbildarchäologie in Ost- und Mitteleuropa*. [Aerial Archaeology in Eastern and Central Europe] *Internationales Symposium 26-30 September 1994. Kleinmachnow Land Brandenburg*, Forsch. Arch. Land Brandenburg, **3**, 45-60.

Barrett, G, 1997a. 'Recovering the Hidden Landscape' in Aalen, F H A, Wheelan, K and Stout, M (eds) 1997. *Atlas of the Irish Rural Landscape*. Cork University Press, Cork, 64-66.

Barrett, G, 1997b. 'The Destruction of Antiquities – an Aerial View' in Aalen, F H A, Wheelan, K and Stout, M (eds) 1997. *Atlas of the Irish Rural Landscape*. Cork University Press, Cork, 250-253.

Barrett, G, 1999. 'Relèvement aérien d'árcheologie en Irlande (1989-1991)'. *Rev. Arch. Picardie*, **17**, 245-252.

Barrett, G, 2000. 'Lufterkundung und-bilder als Forshungsmethode bei Untersuchungen und Management von Kulturlandschaften: ein irisches Beispel' [Aerial survey and photography as a research technique in the study and management of the cultural landscape: an Irish perspective] in H. Behm (ed.) *Kulturelles Erbe – Landschaften im Spannungsfeld zwischen Zerstörung und Bewahrung*, Wittenburg, Germany: Pro Art Verlag, 87-106.

Barrett, G, 2002. 'Flights of Discovery Archaeological Air Survey in Ireland 1989-2000'. *Journal of Irish Archaeology* **11**, 1-29

Barrett, G, forthcoming a. 'Early Landscapes in County Carlow: an Aerial Perspective' for *County Carlow: History and Society*.

Barrett, G, forthcoming b. 'Discovering Kildare's 'hidden' landscapes: archaeological air survey 1989-2000' for *County Kildare: History and Society*.

Benson, D and Miles, D 1974. *The Upper Thames Valley: An Archaeological Survey of the River Gravels*. Oxford Archaeological Unit.

Bergh, S, 1995. *Landscape of the Monuments A study of the Passage Tombs in the Cúil Irra Region Co. Sligo, Ireland*. Riksantikvarieämbetet Arkeologiska Undersökningar Skrifter Nr 6.

Bergh, S, 2002. 'Knocknarea — the Ultimate Monument: Megaliths and Monuments in Neolithic Cuil Irra, Northwest Ireland', in Scarre, C (ed). *Monuments and Landscapes in Atlantic Europe*. Routledge, London, 135-51.

Bewley, R, 1995. 'A National Mapping Programme for England' in Kunow, J (ed), *Luftbildarchäologie in Ost- und Mitteleuropa*. [Aerial Archaeology in Eastern and Central Europe] *Internationales Symposium 26-30 September 1994 Kleinmachnow Land Brandenburg*, Forsch. Arch. Land Brandenburg, 3, 83-92.

Bewley, R, Donoghue, D, Gaffney, V, van Leusen, M and Wise, A, 1998. *Archiving Aerial Photography and Remote Sensing Data: A Guide to Good Practice*. http://ads.ahds.ac.uk/project/goodguides/apandrs/

Bewley, R and R—czkowski, W (eds), 2002. *Aerial Archaeology: Developing Future Practice*. NATO Science Series 337, IOS Press, Amsterdam.

Bewley, R and Musson, C, 2002. *Culture 2000 Project (Agreement No 2000 - 0836/001-001 Clt Ca1a) Conservation Through Aerial Archaeology (CAA) Final report* http://rs6000.univie.ac.at/AARG/aerarch/papers/cult2000report.pdf.

Bord Gáis u.d. *Code of Practice Between Bord Gáis Éireann and the Minister for Arts, Heritage, Gaeltacht and the Islands*. Bord Gáis, NMS and DAHGI, Dublin.

Brindley, A and Kilfeather, A, 1993. *An Archaeological Inventory of County Carlow*. The Stationery Office, Dublin.

British Academy, 2001. *Aerial Survey for Archaeology: Report of a British Academy Working Party, 1999*. British Academy, London.

Buckley, V M, 1986. *Archaeological Inventory of County Louth*. The Stationery Office, Dublin.

Buckley, V M and Sweetman, P D, 1991. *Archaeological Survey of County Louth*. The Stationery Office, Dublin.

Burenhult, G, 1980. 'The archaeological excavation at Carrowmore, Co. Sligo, Ireland: excavation seasons 1977-9'. *Theses Pap N European Archaeol* **9** Stockholm.

Burenhult, G, *et al*. 1984. 'The archaeology of Carrowmore. Environmental archaeology and the megalithic tradition at Carrowmore, Co Sligo, Ireland'. *Theses Pap N European Archaeol* **14** Stockholm.

Casey, M, 2001. *The Coastal Promontory Forts of Ireland* [1]. Unpublished Project Report for the Heritage Council.

Casey, M, 2002. *The Coastal Promontory Forts of Ireland* [2]. Unpublished Project Report for the Heritage Council.

Casey, M, 2003. *The Coastal Promontory Forts of Ireland* [3]. Unpublished Project Report for the Heritage Council.

Chart, D A, 1930. 'Air Photography in Northern Ireland'. *Antiquity* **4**, 453-459.

Cleary, R M, Hurley, M F, and Twohig, E, 1987. *Archaeological Excavations on the Cork-Dublin Gas Pipeline (1981–1982)*. Cork Archaeological Studies 1, University College Cork.

Colfer, B, 2004. *The Hook Peninsula*, Cork University Press.

Common R (ed) 1964. *Northern Ireland from the Air*. Queen's University Belfast

Condit, T, 1992. 'Ireland's Hillfort Capital'. *Archaeology Ireland* **6**(3) 16-20.

Condit, T, 1993. 'Ritual enclosures near Boyle, Co Roscommon'. *Archaeology Ireland* **7**(1), 14–16.

Condit, T, 1995. 'Hillfort Discoveries near Killaloe, Co. Clare'. *Archaeology Ireland* **9**(1) 34-37.

Condit, T, 1997. *Ireland's Archaeology from the Air*. Town House, Dublin.

Condit, T and Gibbons, M, 1991. 'A glimpse of Sligo's prehistory'. *Archaeology Ireland* **5**(3), 1991, 7-10

Condit, T, Gibbons, M and Timoney, M, 1991. 'Hillforts in Sligo and Leitrim'. *Emania* **9**, 1991, 59-62.

Cooney, G, 2000. *Landscapes of Neolithic Ireland*. Routledge.

Cooney, G, Condit, T and Byrnes, E, 2000. 'Timescapes: Understanding and Managing Archaeological Landscapes' in *Ireland Policies and Priorities for Ireland's Landscape*. Heritage Council, Kilkenny.

Cooney, G, Condit, T and Byrnes, E, 2002. 'The Archaeological Landscapes Project: an approach to cultural landscapes in Ireland' in Fairclough, G and Rippon, S (eds), *Europe's Cultural Landscapes: Archaeologists and the Management of Change*. Europae Archaeologiae Consilium Occasional Paper **2**, Brussels 39-48.

Crawshaw, A, 2001a. 'Some history of the captured German WWII photography'. *AARGnews* **22**, 45-50.

Crawshaw, A, 2001b. 'Verticals/obliques: seventh note'. *AARGnews* **23**, 6-7.

Darlington, J, 2002. 'Mapping Lancashire's Historic Landscape: the Lancashire Historic Landscape Characterisation Programme' in Fairclough, G and Rippon, S (eds), *Europe's Cultural Landscapes: Archaeologists and the Management of Change*. Europae Archaeologiae Consilium Occasional Paper **2**, Brussels, 97-105.

Department of Agriculture, Food and Rural Development (DAFRD), undated. *Ireland CAP Rural Development Plan 2000-2006 Summary*. The Stationery Office, Dublin.

Department of Arts, Heritage, Gaeltacht and the Islands 1999a. *Framework and Principles for the Protection of the Archaeological Heritage*. Dublin.

Department of Arts, Heritage, Gaeltacht and the Islands, 1999b. *Policy and Guidelines on Archaeological Excavation*. Dublin.

Department of the Environment, Heritage and Local Government (DoEHLG) 2001. *Construction Industry Review 2000, Outlook 2001-2003*. The Stationery Office, Dublin.

Department of the Environment, Heritage and Local Government (DoEHLG) undated. *Code of Practice between Coillte and the Minister for the Environment and Local Government*. The Stationery Office, Dublin.

Dixon, P and Hingley, R, 2002 'Historic Land-use Assessment in Scotland' in Fairclough, G and Rippon, S (eds), *Europe's Cultural Landscapes: Archaeologists and the Management of Change*. Europae Archaeologiae Consilium Occasional Paper **2**. Brussels, 85-8.

Doody, M G, 1993a. 'The Bruff aerial photographic survey'. *Tipperary Hist J* **10**, 173–80.

Doneus, M, 2000. 'Vertical and oblique photographs'. *AARGnews* **20**, 35-41.

Donoghue, D N M, Galiatsatos, N, Philip, G and Beck, A R, 2002. 'Satellite Imagery for Archaeological Applications: A Case Study from Orontes Valley, Syria' in Bewley R and R¹czkowski, W (eds), *Aerial Archaeology: Developing Future Practic*e, 211-223.

Doody, M G, 1993b. 'Bronze Age Settlement' in Shee Twohig, E and Ronayne, M (eds) *Past Perceptions: The Prehistoric Archaeology of South-West Ireland*. Cork University Press, Cork.

Doody, M G, 1993c. 'Ballyhoura Hills Project' in *Discovery Programme Reports* **1**, 20-30.

Doody, M G, 1995. 'Ballyhoura Hills Project' in *Discovery Programme Reports* **2**, 12-26.

Doody, M G, 1996. 'Ballyhoura Hills Project' in *Discovery Programme Reports* **4**, 15-25.

Doody, M G, 2001. 'Medium Altitude Aerial Photographic Survey in E Limerick and W Tipperary'. *Jn Irish Archaeol* **10**, 13-24.

Driver, T, 2002a. 'Recording industrial buildings from the air – the case of the Brynmawr Rubber Factory'. *AARGnews* **24**, 26-31.

Driver, T, 2002b. 'Approaches to Aerial Survey and Heritage Management in Wales' in Bewley R and R¹czkowski, W (eds), *Aerial Archaeology: Developing Future Practic*e, 247-255.

Dunford, B, 2002. 'Land Use Change in the Burren Uplands, Co. Clare – Causes and Consequences' in *Farm & Food*, Spring 2002. Teagasc Publications, 44-47.

Dunford, B, 2003. *Farming and the Burren*. Teagasc Publications.

Edis, J, McCloed, D and Bewley, R, 1989. 'An Archaeologist's Guide to the Classification of Crop Marks and Soil Marks'. *Antiquity* **63**, 112-126.

ERA-Maptec Ltd, Wilworks Ltd, Parr, S and Grant, C, 2005. *Assessment of Landscape Change and Effects on Archaeology and an Assessment of Habitat Survey in the Burren, Co. Clare*. Unpublished report for the Heritage Council.

Fairclough, G, 2002. 'Europe's Landscape: Archaeology Sustainability and Agriculture' in Fairclough, G and Rippon, S (eds), *Europe's Cultural Landscapes: Archaeologists and the Management of Change*. Europae Archaeologiae Consilium Occasional Paper **2**. Brussels, 1-12.

Fairclough, G and Rippon, S, 2002. *Europe's Cultural Landscapes: Archaeologists and the Management of Change*. Europae Archaeologiae Consilium Occasional Paper 2, Brussels.

Fenner, V E P and Dyer, C A, 1994. *The Thames Valley Project. A Report for the National Mapping Programme*. RCHME Internal Report.

Forte, M, 2002. 'GIS, Aerial Photographs and Microtopography in Archaeology: Methods and Applications' in Bewley R and R¹czkowski, W (eds), *Aerial Archaeology: Developing Future Practic*e, 196-210.

Fowler, M J F, 1996. 'High-resolution satellite imagery in archaeological application: a Russian satellite photograph of the Stonehenge region'. *Antiquity* **70**, 667-71.

Fowler, M J F and Darling, P, 1998. 'Archaeological applications of imaging radar'. *AARGnews* **17**, 19-25.

Fowler M J F, 2002. 'Sub-Metre Resolution Satellite Imagery'. *AARGnews* **24**, 11-13.

Geological Survey of Ireland, 1983. *Aerial Photography – Information on the 1:30,000 Aerial Photographic Survey of Ireland*. Geological Survey of Ireland Information Circular 81/1, Dublin.

Going, C J, 2002. 'A Neglected Asset. German Aerial Photography of the Second World War Period' in Bewley R and R¹czkowski, W (eds), 2002, *Aerial Archaeology: Developing Future Practic*e, 23-30.

Gosling, P, 1993. *Archaeological Inventory of Galway 1: West Galway*. Stationery Office, Dublin.

Grogan, E, 1993. 'North Munster Project' in *Discovery Programme Reports* 1, 32-5.

Grogan, E, 1996. 'North Munster Project' in *Discovery Programme Reports* **4**, 26-72.

Grogan, E, Condit, T, O'Carroll, F and O'Sullivan, A, 1995. 'Preliminary Assessment of the Prehistoric Landscape of the Mooghaun

Study Area', in *Discovery Programme Reports 2: Project Results 1993*. Royal Irish Academy, Dublin, 47–56.

Grogan, E and Kilfeather, A, 1997. *Archaeological Inventory of County Wicklow*. The Stationery Office, Dublin.

Gowen, M, 1988. *Three Irish Gas Pipelines: New Archaeological Evidence in Munster*. Wordwell.

Haigh, J G B, 1996. 'Another member of the AERIAL software family'. *AARGnews* **12**, 26-33.

Hartwell, B, 1987. [aerial survey using OS verticals] *Emania* **2**.

Hartwell, B, 1991a. 'Recent air survey results from Navan'. *Emania* **8**, 5-9.

Hartwell, B, 1991b. 'Ballynahatty a Prehistoric Ceremonial Centre'. *Archaeology Ireland* **5**(4), 12-15.

Heritage Council, 1999a. *Forestry and the National Heritage*. Kilkenny.

Heritage Council, 1999b. *Agriculture and the National Heritage*. Kilkenny.

Heritage Council 2000. *Heritage Appraisal of Development Plans*. Kilkenny.

Herity, M, 1983. 'A Survey of the Royal Site of Cruachain in Connaght'. *JRSAI* **113**, 121-42.

Herity, M, 1987 'A Survey of the Royal Site of Cruachain in Connacht: III'. *JRSAI* **117**, 125-141.

Herity, M, 1988. 'A Survey of the Royal Site of Cruachain in Connacht: IV'. *JRSAI* **118**, 67 - 84.

Herring, P, 1998. *Cornwall's Historic Landscape*. Cornwall Archaeology Unit, English Heritage and Cornwall County Council.

Holden, N, Horne, P and Bewley R 2002. 'High-Resolution Digital Airborne Mapping and Archaeology' in Bewley R and R¹czkowski, W (eds). *Aerial Archaeology: Developing Future Practice*, 173-180.

Horne, P D, 2002 'The Use of Aerial Photographs for the Survey of Archaeological Earthworks' in Bewley R and R¹czkowski, W (eds). *Aerial Archaeology: Developing Future Practice*, 262-268.

Integrated Conservation Group, 2005. *Russborough, County Wicklow*. Heritage Conservation Plan **7**, The Heritage Council, Kilkenny.

Irish Concrete Federation and DAHGI 2002. *Code of Practice between the Irish Concrete Federation and the Minister for Arts, Heritage, Gaeltacht and the Islands*.

Irish Council for Science, Technology & Innovation, 1999. *Technology Foresight Report on Natural Resources* (http://www.forfas.ie/icsti/statements/tforesight/natural/execsumm.htm)

Johnson, G, 1998. *Archaeology and Forestry in Ireland*. The Heritage Council, Kilkenny.

Johnson, N, 1999. 'Context, Meaning and Consequences: Using the Map in Cornwall' in Fairclough G (ed), *Landscape Characterisation Papers, Presented at an English Heritage Seminar ... 11 December 1998*. English Heritage, London.

Jones, C, 1998. 'The Discovery and Dating of the Prehistoric Landscape of Roughan Hill in Co. Clare'. *Journal Irish Archaeology* **9**, 27-44.

Kavanagh, B, 2002. *Approaches to Evaluating Some REPS Measures* (http://www.teagasc.ie/publications/reps1999/paper3.htm)

Kelleher, M G, 1995. *An Investigation of Field Systems and Enclosures in Counties Limerick and Clare using Analytical Aerial Photography*. MA Thesis (unpublished) Department of Archaeology, University College Cork.

Kirwan, S, 1993. 'The Limerick Sites and Monuments Record: A Means for Reviewing the Current State of Research' in E. Shee

Twohig and M. Ronayne (eds) *Past Perceptions: The Prehistoric Archaeology of South-West Ireland*. Cork University Press, Cork, 140–146.

Knisely-Marpole R, 2001. 'Kite Aerial Photography in Egypt's Western Desert'. *AARGnews* **23**, 33-37.

Lambrick, G H and Doyle, I W, 2000. *Review of Archaeological Assessment and Monitoring Procedures in Ireland*. The Heritage Council, Kilkenny.

Lambrick, G H and Spandl, K, 2000. *Archaeological Practice in Ireland: A Review of Urban Archaeology*. The Heritage Council, Kilkenny.

Manning, C, 1994. *Clonmacnoise*. Office of Public Works, The Stationery Office, Dublin.

Marshall, J W and Rourke, G D, 2000. *High Island*. Town House and Country House, Dublin.

McErlean, T, McConkey, R, and Forsythe, W, 2002. *Strangford Lough An Archaeological Survey of the Maritime Cultural Landscape*. The Blackstaff Press and Environment and Heritage Service.

Mitchell, F and Ryan, M, 1990. *Reading the Irish Landscape* (2nd ed). Town House, Dublin.

Moloney, A, (ed) 1993. 'Survey of the Raised Bogs of County Longford'. *Irish Archaeological Wetland Unit Transactions* **1**.

Monk, M, 1989. 'Archaeological Prospection Part 2: Ground and Aerial Survey'. *Archaeology Ireland* **3**, 64-7.

Monk, M 1998. 'Early medieval secular and ecclesiastical settlement in Munster' in Monk, M and Sheehan, J (eds) *Early Medieval Munster: Archaeology, History and Society*. Cork University Press.

Monk, M and Sheehan, J (eds) 1998. *Early Medieval Munster: Archaeology, History and Society*. Cork University Press.

Murphy, D 1993. 'Monasterboice: Secrets from the Air'. *Archaeology Ireland* **7**(3), 15–17.

Musson, C and Horne, P, 2007. *European Landscapes Past, Present and Future*. Culture 2000 Project Ref. No. CH-A2-UK-2077. Final Report, Culture 2000 and English Heritage.

Mytum, H 1992. *The Origins of Early Christian Ireland*. Routledge.

NAPLIB, 2001. *Directory of Aerial Photographic Collections in the United Kingdom* (2nd ed). National Association of Aerial Photographic Libraries, ISBN 0 9530436 1 4.

National Development Plan and Department of Food Agriculture and Rural Development undated. *Ireland CAP Rural Development Plan 2000-2006 Summary*. Stationery Office, Dublin

National Roads Authority u.d. *Code of Practice Between the National Roads Authority and The Minister for Arts, Heritage, Gaeltacht and the Islands*. NRA and DAHGI, Dublin.

National Roads Authority, 2005. *Guidelines for the Assessment of Archaeological Heritage Impact of National Road Schemes [Draft]*. NRA, Dublin.

Newman, C, 1997. *Tara: an Archaeological Survey*. Discovery Programme Monograph **2**.

Norman, E R and St Joseph, J K S, 1969. *The early development of Irish society: the evidence of aerial photography*. Cambridge University Press, Cambridge.

O'Conor, K D, 1998. *The Archaeology of Medieval Rural Settlement in Ireland*. Discovery Programme Monographs 3.

O'Donovan, E and O'Neil, J 2003. 'Chapelstown'. *Excavations Ireland* 2001.

O'Leary, T, McCormack, A, Hutchinson, G, Campbell, D, Scarpa, R and Riordan, B, 2004. 'Putting a Value on the Farm Landscape' (http://www.teagasc.ie/publications/2004/20041103/paper02.htm)

Oltean, I A, 2002. 'The Use of Satellite Imagery for the Transcription of Oblique Aerial Photographs' in Bewley R and R¹czkowski, W (eds), *Aerial Archaeology: Developing Future Practice*, 224-232.

Ó'Ríordáin, S P, 1964. *Antiquities of the Irish Countryside* (4th Edition).

Ó'Ríordáin, S P and Hunt, J, 1942 'Medieval Dwellings at Caherguillamore, Co. Limerick'. *JRSAI* **72**(pt II), 37-63.

O'Sullivan, A, 1998. *The Archaeology of Lake Settlement in Ireland*. Discovery Programme Monographs **4**.

O'Sullivan, A, 2002. *Farmers, Foragers and Fishers in a Coastal Landscape — An Intertidal Archaeological Survey of the Shannon Estuary*. Discovery Programme Monographs **5**.

O'Sullivan, A and Sheehan, J, 1993. 'The South West Kerry Archaeological Field Survey' in Shee Twohig, E and Ronayne, M (eds). *Past Perceptions: The Prehistoric Archaeology of South-West Ireland*. Cork University Press, Cork, 147–8.

O'Sullivan, A and Sheehan, J, 1996. *The Iveragh Peninsula — An Archaeological Survey of South Kerry*. Cork University Press, Cork.

O'Sullivan, A, McEvlean, T, McConkey, R and McCooey, P, 1997. 'Fish Traps in Strangford Lough'. *Archaeology Ireland* **11**(1), 36-38.

O'Sullivan, M, O'Conor, D J and Kennedy, L, 2001. *Archaeological Features at Risk: A Survey Measuring The Recent Destruction of Ireland's Archaeological Heritage*. The Heritage Council, Kilkenny.

Palmer R, 2002. 'Air Photo Interpretation and Mapping to Guide Fieldwork in Commercial Archaeology in England' in Bewley R and R¹czkowski, W (eds). *Aerial Archaeology: Developing Future Practice*, 299-308.

Patrick, J 1974. 'Simple Photogrammetric Techniques Suitable for Use in Archaeological Work and Some Recent Discoveries in the Boyne Valley' in Scott, B G (ed). *Perspectives in Archaeology*. Association of Young Irish Archaeologists.

Pochin Mould, D D C, 1972. *Ireland from the Air*. David and Charles, Newton Abbot.

Pochin Mould, D D C, 1981: 'The Monastery of Cill Ruán'. *Journal of the Cork Historical and Archaeological Society* **85**, 107-8.

Pochin Mould, D D C, 1991. **Discovering Cork**. Brandon Books, Dingle.

Power, D, 1988. 'Aerial Photography and Regional Survey'. *Organisation of Irish Archaeologists' Newsletter* **7**, 16–17.

Power, D, 1993. 'Archaeological Survey in the Republic of Ireland and the Cork Experience' in Shee Twohig E and Ronayne M (eds). *Past Perceptions: The Prehistoric Archaeology of South-West Ireland*. Cork University Press, Cork, 137–9.

Power, D, 1994. *Archaeological Inventory of County Cork — Volume 2: East and South Cork*. The Office of Public Works, Dublin.

Power, D, 1997. *Archaeological Inventory of County Cork — Volume 3: Mid Cork*. The Office of Public Works, Dublin.

Power, D, Lane, S, Byrne, E, Egan, U and Sleeman, M, 2000. *Archaeological Inventory of County Cork 4: North Cork*. Stationery Office, Dublin.

Raftery, J, 1944. 'Air Photography and Archaeology'. *JRSAI* **24**, 119-23.

Raftery, J, 1951. *Prehistoric Ireland*.

Redfern S, 1998. 'A Framework for Digital Survey from Aerial Photographs'. *Journal Irish Archaeology* **9**.

Redfern, S, 2002. 'An approach to automated morphological-topographical classification' in Bewley R and R¹czkowski, W (eds), 2002. *Aerial Archaeology: Developing Future Practice*, 31-37.

Reeves-Smith, T and Hammond, F (eds) 1983. *Landscape Archaeology in Ireland*. BAR (British Series) **116**, Oxford.

Roe, H M, 1981. *Monasterboice and its Monuments*. Dundalk.

Schönherr, M, 2001. 'Aerial Archaeology by Remote Controlled Micro Aircraft'. *AARGnews* **23**, 39.

Scollar, I, 2002 'Making things look vertical' in Bewley R and R¹czkowski, W (eds), 2002. Aerial Archaeology: Developing Future Practice, 166-172.

Shee Twohig, E and Ronayne, M (eds), 1993. *Past Perceptions: The Prehistoric Archaeology of South-West Ireland*. Cork University Press, Cork.

Shell, C, 2002. 'Airborne High-Resolution Digital, Visible, Infra-Red and Thermal Sensing for Archaeology' in Bewley R and R¹czkowski, W (eds). *Aerial Archaeology: Developing Future Practice*, 181-195.

Shell, C, Roughley, R and Shee Twohig, E, 2004. *Understanding the Landscapes of Loughcrew Through Airborne LIDAR Survey and Digital Spatial Analysis*. Unpublished Report to the Heritage Council.

Shell, C and Roughley, R, 2004. 'Exploring the Loughcrew Landscape: a New Airborne Approach'. *Archaeology Ireland* **18**(2), 22-5.

Sommerville-Large, P and Hawkes, J 1997. *Ireland from the Air*. Weidenfeld & Nicolson.

Stout, M, 1991. 'Ringforts in the South-West Midlands of Ireland'. *Proc Royal Irish Academy* **91C**, 201-43.

Stout, M, 1992. 'Plans from Plans: An Analysis of the 1:25,000 OS Series as a Source for Ringfort Morphology'. *Proc Royal Irish Academy* **92C**, 37-53.

Stout, M, 2001. *The Irish Ringfort*. Irish Settlement Studies 5. Four Courts Press, Dublin.

Swan, DL, 1978. 'The Hill of Tara Co, Meath: the Evidence of Aerial Photography'. *JRSAI* **108**, 51-66.

Swan, DL, 1983. 'Enclosed Ecclesiastical Sites and their Relevance to Settlement Patterns in the First Millennium AD' in Reeves-Smyth, T and Hammond, F, (eds). *Landscape Archaeology in Ireland*. BAR Brit Ser **116** Oxford, 269-294.

Swan, DL, 1985. 'Monastic Prototowns in Early Medieval Ireland: the Evidence of Aerial Photography, Plan Analysis and Survey' in Clarke, H B and Simms, A (eds), *The Comparative History of Urban Origins in Non-Roman Europe: Ireland, Wales, Denmark, Germany, Poland and Russia from the 9th to the 13th century*. BAR Int Ser **S255** Oxford, 77-102.

Waddell, J, 1983. 'Rathcrogan — a Royal Site in Connaght'. *Journal of Irish Archaeology* **1**, 21-46.

Waddell, J, 1998. *The Prehistoric Archaeology of Ireland*. Galway University Press.

Williams, B, 1996 'Intertidal Archaeology in Strangford Lough'. *Archaeology Ireland* **10**(3), 14-16.

Wilson, DR, 2000. *Air Photo Interpretation for Archaeologists*. Tempus.

Woodman, PC, 1992 'Filling in the spaces in Irish Prehistory'. *Antiquity* **66**, 295-314

Appendix 2: Individuals Consulted and Responses Received

The Heritage Council and the author are grateful to the following individuals who have contributed much fruitful information and views about aerial archaeology in Ireland.

Sean Kirwan	(formerly) Department of the Arts, Heritage, Gaeltacht and the Islands; NMS
Tom Condit	National Monuments Section, DoEHLG
Con Manning	National Monuments Section, DoEHLG
Gerry Browner	National Monuments Section, DoEHLG
Eamon Cody	National Monuments Section, DoEHLG
John Scarry	National Monuments Section, DoEHLG
Tony Roche	National Monuments Section, DoEHLG
Mauris de Buitler	GIS Unit, Heritage Service DoEHLG
Ian Doyle	Heritage Council
Charles Mount	(formerly) Heritage Council; Irish Concrete Federation
Felicity Devlin	National Museum of Ireland
Nick Brannon	DoE Northern Ireland Environment and Heritage Service
Brian Williams	DoE Northern Ireland Environment and Heritage Service
Hugh Mangan	Ordnance Survey Ireland
Desmond Shorten	Ordnance Survey Ireland
Colin Bray	OSi; Irish Society of Surveying, Photogrammetry and Remote Sensing
Morgan Sharpe	Ordnance Survey Ireland
Matthew Parkes	Geological Survey of Ireland; Mining Heritage Trust
Eibhlín Doyle	Geological Survey of Ireland
Fiona Fitzpatrick	Marine Institute
Brendan O'Grady	Photographic Department, Air Corps
Daire O'Rourke	National Roads Authority
Ronan Swan	Project Archaeologist for roads, West Meath
Emmet Byrnes	Forest Service
Christine O'Brian	Forest Service
John McCloughlin	Coillte Teoranta
Declan Mullins	Area Aid Unit, Department of Agriculture
Michael Walsh	Teagasc Research Centre
Brian Lacey	Discovery Programme
Anthony Corns	Discovery Programme

Colin Shell	Cambridge University
Gillian Barrett	Wolverhampton University
Göran Burenhult	Gotland University College, Visby, Sweden
Ursula Egan	Cork University Cork and Kerry Archaeological Survey
Margaret Gowen	Margaret Gowen & Co. Ltd
Beth Cassidy	Archaeological Development Services Ltd
Jorg Schmit	Vallerie J Keeley Ltd
Dermot Nellis	Archaeological consultant
Markus Casey	Archaeological consultant
Chris Mawson	Aerofilms Ltd
Sam Barr	BKS Coleraine
Aideen Ireland	President, The Royal Society of Antiquaries of Ireland
Edward Bourke	Secretary, Royal Irish Academy Committee for Archaeology
Terry Barry	Trinity College Dublin