Herefordshire Archaeology
Conservation and Environmental Planning
Planning Services
Environment Directorate
Herefordshire Council

Lower Lugg Archaeology And Aggregates Resource Assessment

Volume 1

Herefordshire Archaeology Report 226

Prepared for English Heritage with funding from the Aggregates Levy Sustainability Fund as administered by English Heritage for the historic environment (in accordance with English Heritage ALSF Project Design PN 3336)

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Dr Eric Johnstone (University of Wales, Aberystwyth)

Section 1: Introduction
Section 2: Aggregate Extraction Context
Section 3: Geological, Geomorphological and Palaeoenvironmental Resource

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Herefordshire Archaeology is Herefordshire Council's county archaeology service. It advises upon the conservation of archaeological and historic landscapes, maintains the county Sites and Monument Record, and carries out conservation and investigative field projects. The County Archaeologist is Dr Keith Ray MBE.

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1.1 About the Lower Lugg Archaeology and Aggregates Resource Assessment

1.1.1 *The Lower Lugg Archaeology and Aggregates Resource Assessment*

This document sets out an archaeological resource assessment for the Lower Lugg Valley, Herefordshire. The assessment includes specific consideration of the process of past and present sand and gravel quarrying in the Lower Lugg Valley, and the future threat this poses to the archaeology of the area. The assessment concludes by defining a research framework for future archaeological investigation in the Lower Lugg area.

In addition to the preparation of this report, the project also involved the collation and preparation of a GIS database combining archaeological, geological, geomorphological and palaeoenvironmental information relating to the Lower Lugg Valley. The GIS database was intended to facilitate the preliminary analysis of the identified resource which is presented in this report, and to create a practical tool to assist future archaeological management and research activity in the Lower Lugg locality.

1.1.2 *Project organisation*

The assessment has been managed and executed for English Heritage by Herefordshire Archaeology (the archaeology service of Herefordshire Council) with funding from the Aggregates Levy Sustainability Fund as administered by English Heritage for the historic environment (in accordance with English Heritage ALSF Project Design PN 3336).

The work was undertaken between April 2006 and February 2007 by a project partnership including Herefordshire Archaeology, Worcestershire County Council Historic Environment and Archaeology Service (WHEAS), The Institute of Geography and Earth Sciences, University of Wales, Aberystwyth, and Air Photo Services. Each of these organisations was responsible for particular components of the collation, analysis and report preparation work (see below). The process of integrating those different elements within the final assessment was achieved by a series of project team meetings at key stages of the project.

The project team members were:

Dr Keith Ray MBE, FSA, MIFA (County Archaeologist, Herefordshire Archaeology).
<u>Role</u>: Initial project design and overall project management for Herefordshire Archaeology including editorial contributions.

Ian Bapty (Senior Project Archaeologist, Herefordshire Archaeology)
<u>Role</u>: From August 2006, general project coordination, preparation of quarry context collation and analysis component, preparation of archaeological collation, summary, and analysis component, preparation of research framework, preparation of overall report.

Robin Jackson MIFA (Senior Archaeologist, Worcester Historic Environment and Archaeology Service)
<u>Role</u>: Preparation of past WHEAS Lower Lugg archaeological work summary component, general liaison on quarry related archaeological issues in the Lower Lugg.

Chris Cox MIFA (Consultant, Air Photo Services)
<u>Role</u>: Preparation of air photography digital mapping and analysis component.

Dr Eric Johnstone (Lecturer, Institute of Geography and Earth Sciences, University of Wales, Aberystwyth)
Role: Preparation of geological, geomorphological, and palaeoenvironmental collation, summary and analysis component, GIS database design and creation.

Dr Paul Brewer (Senior Lecturer, Institute of Geography and Earth Sciences, University of Wales, Aberystwyth)
Role: GIS database design and creation, GIS based spatial analysis.

Melissa Seddon (Herefordshire Archaeology SMR Officer) and **Lucie Dingwall** (Herefordshire Archaeology SMR Officer) also assisted with the Herefordshire Archaeology data collation and GIS data preparation elements of the project.

Progress of the assessment was monitored for English Heritage by Helen Keeley (English Heritage Project Officer). Lisa Moffett (English Heritage Regional Archaeology Science Adviser) also provided specialist advice and input during the course of the project.

1.1.3 *Background and rationale*

The 14 km long Lower Lugg river valley is located in central Herefordshire, and extends to the north and east of Hereford city. The valley, with its broad river flood plain, gently undulating surrounding landscape, and good agricultural land, has long been a focus of human settlement. In addition, the Lower Lugg corridor has an established strategic importance as part of the main north/south transport corridor through the Marches geographical zone. The area is also underlain by extensive reserves of sand and gravel which are of local and regional economic significance.

This archaeological resource assessment stems from the late 20th century development of large scale sand and gravel extraction in the Lower Lugg valley. Since 1986, the progressive expansion of the quarry at Wellington has been associated with the discovery of highly important and exceptionally well preserved multi-period archaeological deposits buried within the flood plain alluvium (which overlays the valley bottom sand and gravel beds). These finds have emphasised the currently poor archaeological understanding of the Lower Lugg beyond Wellington Quarry, and the very limited context which exists to establish the local significance and meaning of the Wellington archaeological material. The Wellington discoveries have also fundamentally illuminated the problem of managing an undefined yet high potential archaeological resource in a zone of apparently increasing quarrying activity.

The work at Wellington (which has been principally carried out by Worcestershire Historic Environment Archaeology Service/WHEAS) and the nearby quarry at Lugg Bridge has also focussed attention on the particular technical and interpretative challenges of undertaking effective archaeological fieldwork in deeply buried alluvial contexts. In this sense, the development of the archaeological process at Wellington has sat alongside evolving programmes of archaeological engagement with river valleys across Britain in the last 20 years. An important practical aspect of the Wellington work has been the problem of coping with the complex geomorphological and site formation processes of the alluvial zone. This is fundamental both to realising proper contextual analysis of archaeological sequences and to understanding the differential impact of site formation processes on the character of the archaeological resource.

The major strategic archaeological resource management issue in the Lower Lugg Valley is the problem of facilitating in situ preservation of poorly defined archaeological remains in proposed quarry areas. At the point where a nationally important but unexpected archaeological find is made during permitted aggregate extraction – and the possibility of such a find is clearly demonstrated by previous discoveries in the waterlogged alluvium at Wellington – then there would currently be no archaeological mitigation option available other than preservation by record. There is an urgent to need to overcome this fundamental archaeological management weakness, and to create better conditions for pro-active archaeological engagement with the process of quarrying in the Lower Lugg Valley. The core aim of this resource assessment is to begin the process of addressing this situation.

1.1.4 *Objectives and outputs of the assessment*

The core objective of the English Heritage ALSF scheme is to reduce the impact of aggregate extraction on the historic environment. The stated objectives of the scheme are to:

- Develop capacity to manage aggregate extraction landscapes in the future.
- Deliver to public and professional audiences the full benefits of knowledge gained through past work in advance of aggregate extraction.
- Promote understanding of the conservation issues arising from the impacts of aggregate extraction on the historic environment.

Against these objectives and the particular archaeological resource management circumstances of the Lower Lugg Valley, this assessment provides:

- An overall assessment of the known archaeological resource of the Lower Lugg (including archaeological excavation evidence, the wider record of archaeological sites and finds, and the air photo record of archaeological features). This assessment component is a key starting point for setting the discoveries from Wellington in a wider local context, and specifying the archaeological significance and potential of the Lower Lugg as a whole.
- A careful assessment of the known geological, geomorphological and palaeoenvironmental resource of the Lower Lugg. This assessment component is a fundamental part of evaluating and understanding local archaeological site formation processes, and defining the context for the development of human settlement in the area.
- A considered assessment of the effectiveness of archaeological management and fieldwork strategies in the Lower Lugg. This assessment component is a key starting point for gauging the success of current fieldwork and development mitigation approaches, and evaluating the potential to improve future strategic and practical engagement with the Lower Lugg archaeological resource.
- A full assessment of patterns of past, current and probable future quarrying in the Lower Lugg. This assessment component is crucial to understanding and strategically managing the principal threat to the archaeological deposits of the area, and to defining the value of past quarrying as an integral part of the archaeological resource of the area. In addition it will contribute to the conservation planning agenda with respect to future aggregate extraction in the Lower Lugg Valley.
- A research framework defining an integrated approach to future archaeological and ‘geoarchaeological’ investigation in the Lower Lugg Valley. This assessment component is fundamental to facilitating better future understanding of the Lower Lugg Valley archaeological resource, and to contributing in the short to medium term to wider conservation and mitigation agendas.

- A Lower Lugg Valley Resource Assessment document and a GIS database which will be used to make information about the archaeological resource of the Lower Lugg Valley more widely available, and will accordingly contribute to local awareness of the importance and fragility of that resource.

1.1.5 *Structure and content of the report*

Section 1: Introduction (Ian Bapty, Herefordshire Archaeology). This section defines the aims of the assessment, summarises the characteristics of the Lower Lugg Valley geographical and settlement context, and outlines the structure and content of the Lower Lugg Valley archaeological resource GIS database.

Section 2: Aggregate Extraction Context (Ian Bapty, Herefordshire Archaeology). This section reviews the history of quarrying activity in the Lower Lugg area (including collation of map and archaeological data relating to quarrying), outlines and analyses the current minerals planning framework relevant to the Lower Lugg Valley, and presents an analysis of current quarrying patterns and the likely future development of quarrying in the locality

Section 3: Geological, Geomorphological and Palaeoenvironmental Resource (Dr Eric Johnstone, University of Wales). This section outlines the geological, geomorphological and paleaoenvironmental resource of the Lower Lugg Valley, and presents a critical analysis of this information.

Section 4: Archaeological Resource (Ian Bapty, Herefordshire Archaeology; Robin Jackson, WHEAS; Chris Cox, Air Photo Services). This section summarises the results of WHEAS work in the Lower Lugg Valley (Robin Jackson, WHEAS), collates and summarises known information relating to the wider archaeology of the Lower Lugg Valley area (Ian Bapty, Herefordshire Archaeology) and collates and summarises the results of the mapping of all Lower Lugg Valley archaeological features known from aerial photograhy (Chris Cox, Air Photo Services).

These data sources are collectively analysed in a critical review of the combined archaeological information (Ian Bapty, Herefordshire Archaeology). By comparing the Lower Lugg data with national and regional archaeological sequences, this critical review aims to establish the significance of the existing resource, to reveal the gaps in current archaeological knowledge of the Lower Lugg Valley, and to suggest the potential for future archaeological discovery in the area. The critical review also includes evaluation of the archaeological fieldwork and mitigation methodologies currently employed in the Lower Lugg Valley.

Finally, a demonstration GIS spatial analysis utilising data for the wider Lugg Valley area exemplifies the potential use of this tool to develop future ‘geoarchaeological’ understanding of the Lower Lugg context.

Section 5. Conclusions (Ian Bapty, Herefordshire Archaeology). This section presents the overall conclusions of the resource assessment, and proposes a combined research framework for future archaeological, geomorphological and palaeoenvironmental investigation in the Lower Lugg Valley.

Section 6. Bibliography (all contributors). A full bibiliography for archaeological, geological, geomorphological and palaeoenvironmental information relating to the Lower Lugg area.

Section 7. Supporting Information. A hard copy of the database resources prepared and collated by the assessment including the quarries database, the air photo database, and the SMR database.

1.1.6 *Constraints*

Sources, methodology and constraints are set out at the beginning of each section of the assessment. However in general terms it should be noted that:

- This initial resource assessment has not extended beyond the data which were readily available via existing secondary sources. Although the project involved critical assessment of those data (and collation and transcription of that material to give new insights and understanding), it should in no way be read as going beyond the fundamental limitations of the source material. In this sense, it would be inappropriate for the conclusions about the significance and potential of the archaeology of the Lower Lugg Valley to be taken as anything more than provisional indications intended to clarify future research directions.
- The analysis throughout has essentially been undertaken as a discursive exercise, and does not involve significant statistical manipulation or projection of data. This approach fundamentally reflects the poor quality of the existing archaeological and wider data coverage for the Lower Lugg Valley which would render 'hard' analysis a largely meaningless exercise at the present time. An indication of the potential in the future to use the GIS to facilitate more specific analytical engagement (subject to further research and data recovery) is included in **Section 4.5**.
- As indicated above, the assessment has been produced through collaboration with a number of different specialists/contributors. Although the objective through this process has been to separate out different collation and critical analysis elements, and to ensure that material is presented in a common format which contributes intelligibly to the overall assessment, it is inevitable that there are some differences in presentational style, and some overlaps in the information summaries. For example, discussion of Palaeolithic archaeology (**Section 4.4**) or the history of quarrying (**Section 2.2**) was not possible without reference to the geological and geomorphological background which is dealt with in full detail in **Section 3.1**. It is hoped that these repetitions do not undermine the overall coherence of the document, and cross references to other relevant sections are provided throughout.

1.1.7 *Key findings of the Lower Lugg Archaeology and Aggregates Resource Assessment*

- The known archaeological resource of the Lower Lugg is heavily focused on a few excavated sites (Wellington/Moreton Quarry in particular). There is very limited data and poor spatial coverage for all periods before the Medieval. Nevertheless, it is possible provisionally to recognise a locally distinctive archaeological sequence in the Lower Lugg Valley including regionally and nationally significant elements.
- Major quarrying activity will continue (and quite possibly expand) over the next 25 years. This will be focussed in just those areas of the flood plain area where the archaeological deposits are least known, least understood in terms of geomorphological and site formation processes, and yet are also likely to be of high value and to include features of national importance.
- The current minerals planning framework (as defined by national legislation and guidance and the pending Herefordshire Unitary Development Plan) only offers opportunity for rejection of a minerals planning permission to protect archaeological remains where those remains are already properly known and described, and of defined national or regional significance.

1.2 The Lower Lugg Valley Context

1.2.1 *Definition of the project area*

The Lower Lugg Valley is located in central Herefordshire, and extends north and east of Hereford city (Figures 1 and 2). The defined project area for this assessment is bounded in the north by the bridge at Bodenham (SO 535 512) and in the south by the confluence of the Lugg with the River Wye at Mordiford (SO 565 372).

In the west and the east the lines of roads fringing the valley have been used as convenient study area boundaries (Figures 1 and 2)). Although these may seem an arbitrary choice, the use of roads does mean that the edges of the study area make sense in terms of established patterns of human settlement, and therefore delineate a logical unit of historic landscape study. The choice of the western and eastern boundaries also ensured that the study area included both the modern valley area and the surrounding landscape of palaeo-river terraces. The terraces are fundamental to the character and geomorphological origins of the valley (**Section 3.1**), and are closely associated with the evolved pattern of human settlement (**Section 4.2**).

The defined project area measures 13km from north to south and is approximately 5 km wide from east to west.

1.2.2 *Physical characteristics*

The River Lugg drains 883 km2 of North West Herefordshire and the adjoining uplands of Powys (Terra Nova 2002). Its catchment area is bounded by Llangunllo and Pool Hill in the north, and Glascwm and Newchurch in the south. Its major tributaries are the River Arrow, the River Frome and the Little Lugg, and it is itself a tributary of the Wye which it flows into at Mordiford (**Section 3.1**).

The northern edge of the Lower Lugg basin is defined by the geological transition between the harder sandstones of the St Maughans formation and the softer Raglan mudstone formation (**Section 3.1**). This shift also very visibly informs the topography of the area, with the elongated ridge of Dinmore Hill (comprising hard sandstones of the St Maughans formation) forming a well defined landscape feature which clearly separates the middle and lower reaches of the Lugg. Adjacent to the confluence with the Wye, the Woolhope Dome - an upstanding massif comprising Wenlock limestone and shale, Bringewood beds and Woolhope limestone - also forms a very prominent southern backdrop to the Lower Lugg Valley (Brandon 1989).

The eastern and western flanks of the valley are less clearly marked in topographic terms, and comprise low and gently rolling hills made up of Silurian rocks which overlie the Old Red Sandstone (**Section 3.1**). These hills are capped with glacial drift and associated river palaeo-terrace deposits. The remains of four river terraces are recognised in the Lugg valley (**Section 3.1**), and the evolution of these fluvio-glacial landforms over the last 500,000 years has had a major impact on the appearance of the valley, and on the creation of the landscape niches which structure patterns of human settlement.

The river floodplain area alternates between the geologically constricted areas west of Bodenham (SO 535 512), west of Marden (SO 512 471), and east of Shelwick Green (SO 532 430) and the intervening basins where the floodplain can be up to 1.5 km wide (Figure 5, **Section 3.1**). In the constrictions, the river is straight and fast flowing, while in the basins it follows a sinuous and meandering course. Local river patterns are also affected by the confluences with the Wellington Brook (east of Wellington), the Little Lugg (at Lugg Bridge) and the River Frome (north of Mordiford).

Overall, the Lower Lugg Valley appears 'too big' for the river which now occupies it, and this may suggest that the River Lugg was a more major regional drainage feature before the Devensian glaciation (Brandon 1989, **Section 3.1**). The present valley is also in part the creation of glacial outflow activity following the last glaciation (Brandon 1989), and this process laid down the undulating sand and gravel beds which underlie the flood plain area. The sand and gravel deposits are now sealed beneath up to 3 metres of Holocene alluvium.

1.2.3 *Current settlement patterns*

Settlements in the Lower Lugg Valley are principally situated on the terraces above, but immediately adjacent to, the river flood plain (Figures 2, 3, 4 and 5). The area retains a rural feel, and what appears to be a well established settlement pattern is characterised by a series of nucleated settlements principally made up of 17th to early 20th century buildings, and some post war infill housing and estates (**Section 4.2**). The principal villages in the project area are Wellington, Stony Cross/Marden, Moreton-on-Lugg, Sutton St Nicholas, Withington, Bartestree, Lugwardine and Hampton Bishop. Between the villages are more dispersed patterns of hamlets and farmsteads (e.g areas such as Shelwick, Frankland's Gate and Litmarsh), and it is evident that some of these derive from Post Medieval decline of what were once more significant settlement sites (see **Section 4.2**). The south western segment of the project area also incorporates part of the 20th century housing estates on the eastern edge of modern Hereford.

The Lower Lugg Valley is served by a well developed infrastructure of roads and lanes (Figure 2). The principal valley bottom route is the A49 trunk road (running north from Hereford towards Ludlow). The A49 has seen considerable upgrade in the later 20th century, but other roads and lanes are little altered from their historic form (**Section 4.2**). Parallel with the A49 is the Cardiff-Manchester railway line, which runs within the River Lugg flood plain area.

The area retains many of its established field boundaries, which typically consist of mixed hedgerows. The contrasting field shapes in different parts of the landscape evidently represent a complex process of enclosure development (Figures 3 and 4, **Sections 4.2, 4.3, 4.4,** Ray and White forthcoming) Today, the flood plain is typically used for enclosed sheep and cattle pasture, while the terraces show a greater focus on arable agriculture, although small areas of woodland and orchard are also retained. An important survival in the south of the project area is the Lugg Meadows, a Site of Special Scientific Interest owned by the Herefordshire Nature Trust. The Lugg Meadows remain in unenclosed state, and are still managed using the traditional 'Lammas' water meadow system (**Section 4.2**, Brian and Thompson 2005).

The most obvious signs of Late 20th/Early 21st century development are the sand and gravel quarries in the vicinities of Wellington and Lugg Bridge (**Section 2.6**), and an industrial estate complex at Wellington which utilises part of the area of the former Moreton-on-Lugg military camp.

Figure 1: Location of the project area

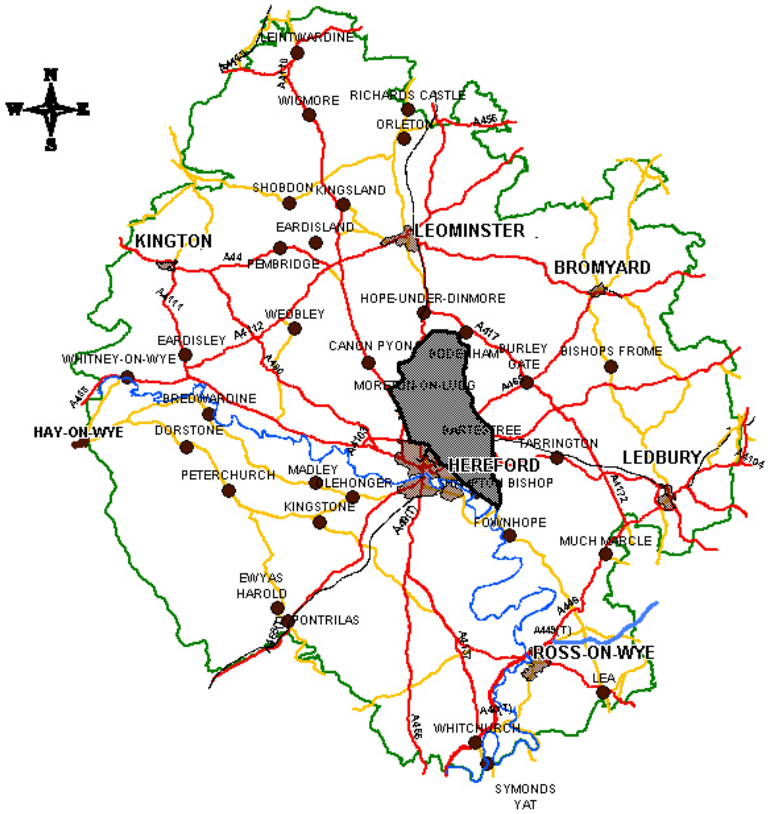
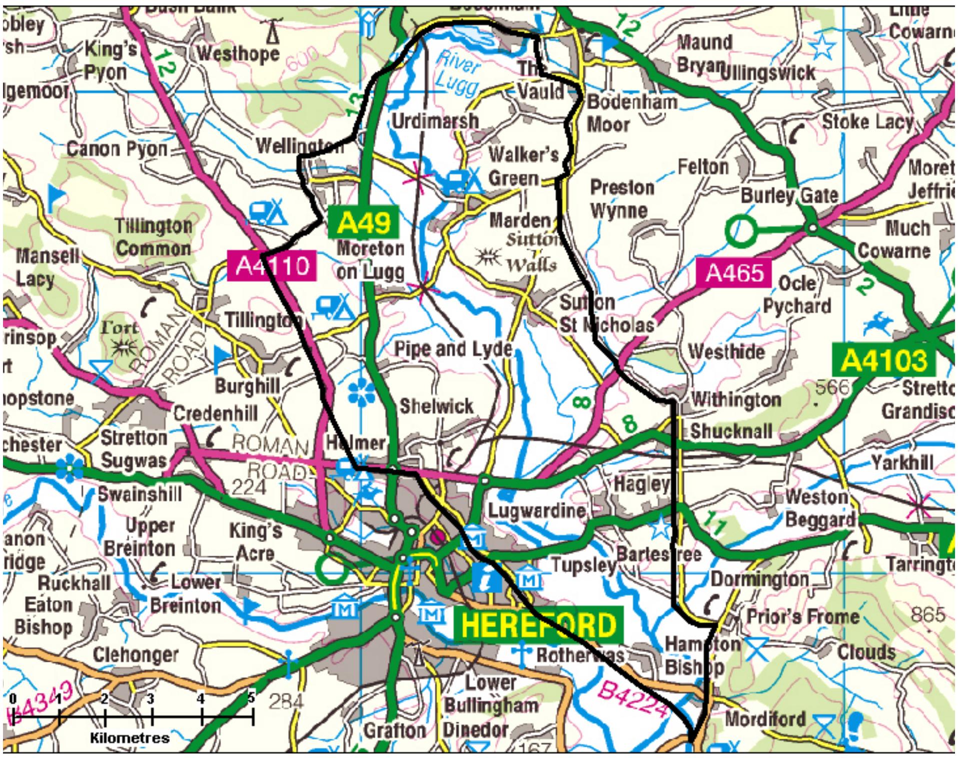


Figure 2: Boundaries of the project area



1.2 The Lower Lugg Valley Context

Ian Bapty (Herefordshire Archaeology)

Figure 3: Aerial photography overview

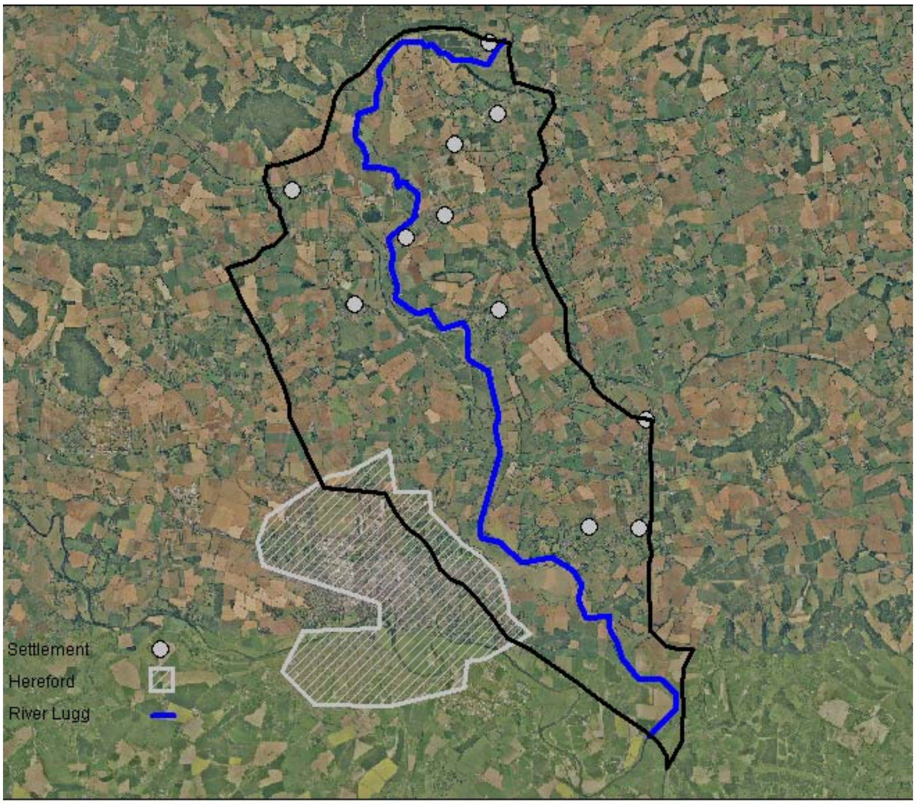


Figure 4: Boundaries, field systems and woodland overview

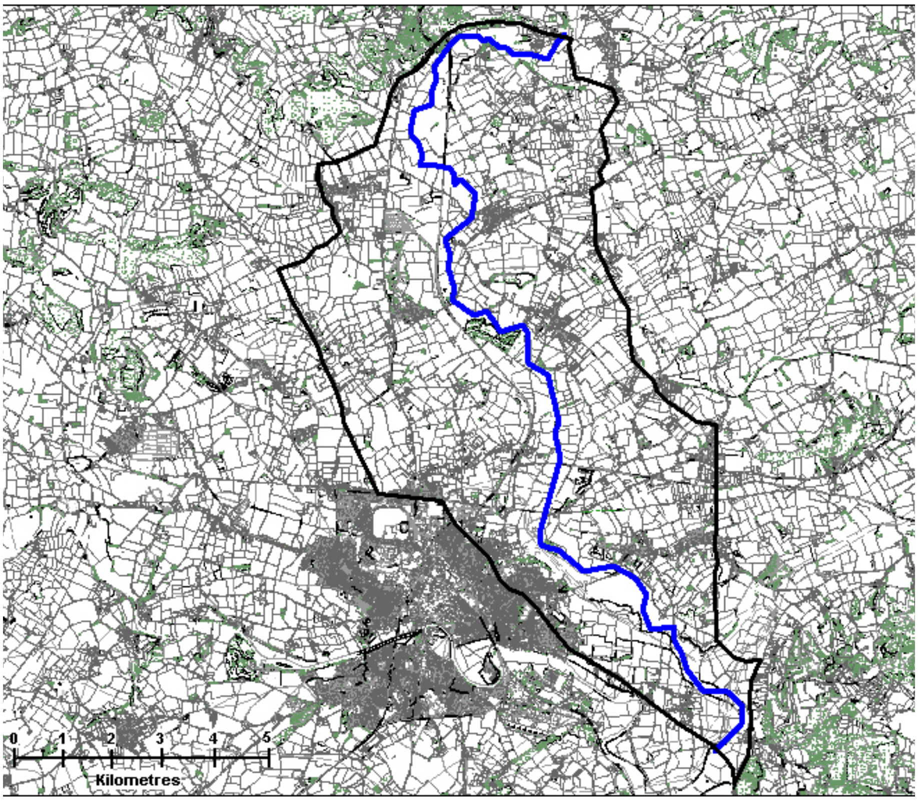
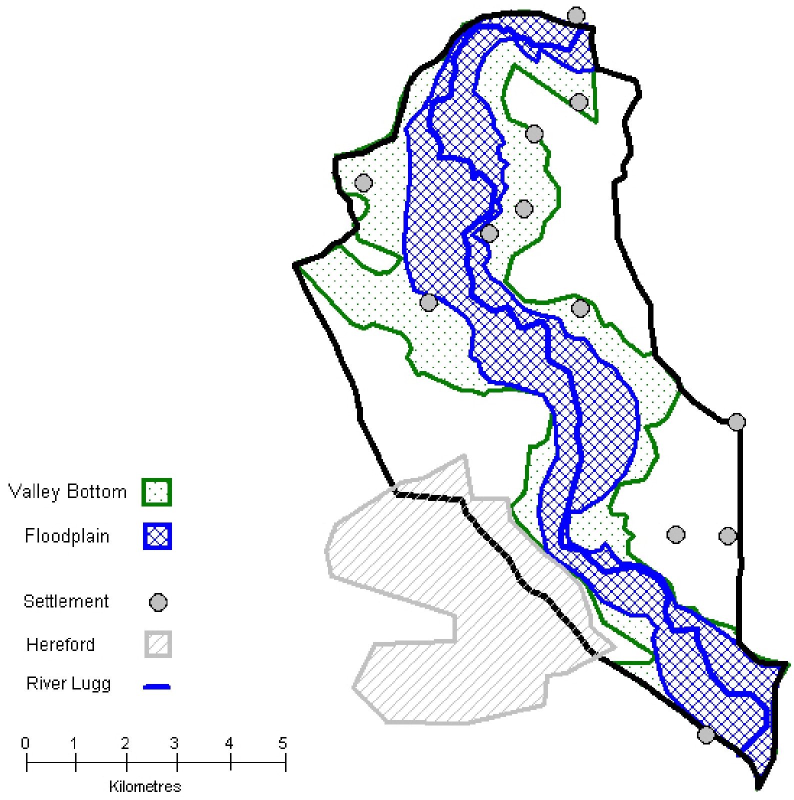


Figure 5: Flood plain and valley bottom zones



1.3 The Lower Lugg GIS Database

1.3.1 *Introduction*

The GIS database constructed for the Lower Lugg Valley Archaeology and Aggregates Project is a resource that can be used to view and analyse digital data records collated for the Lower Lugg study area. The ability of the GIS to be used as a tool for analysis makes it a valuable resource as it allows spatial relationships between archaeological data sources and physical landscape variables to be investigated in a level of detail that has not previously been possible in the Lower Lugg study area.

This section outlines how the Lower Lugg Valley GIS Database was constructed and provides details about the data that have been incorporated in the GIS.

1.3.2 *Construction of the Lower Lugg Valley GIS Database*

The completed Lower Lugg Valley GIS Database has been finalised and submitted to Herefordshire Archaeology on DVD in both ArcMap and MapInfo formats. The GIS is composed of three major layer groupings (baseline layers, landscape layers and cultural layers), which consist of digital data sources that have been classified according to the type of data they contain. The data layers as they appear in the Lower Lugg GIS are listed in Table 1 (under GIS Layer) along with information concerning the nature of the data and their original source.

Each of the GIS layers can be looked at individually or multiple GIS layers can be activated and overlaid so that spatial relationships between GIS layers can be viewed. At this basic level of operation, the GIS serves as a useful resource that allows a wide range of digital data sources from the Lower Lugg study area to be readily accessed and examined. At a more advanced level, the GIS can also be used to interrogate the digital data layers and, in particular, to conduct sophisticated analyses of spatial relationships between data layers within the GIS.

Construction of the Lower Lugg GIS was initially carried out using ArcMap software. In the case of sources such as LiDAR elevation data and the geomorphological mapping data, a significant amount of data processing was required before they could be incorporated within the GIS. More details concerning the manipulation and processing of raw data sources are provided in Sections 2.1, 2.2 and 2.3 of this report. On completion of the Lower Lugg GIS in Arc Map, the ESRI shape files were converted to MapInfo tab files to allow the GIS to be opened in a MapInfo Workspace.

1.3.3 *Baseline Layers*

The Ordnance Survey (OS) baseline layers have been clipped so that they only cover the Lower Lugg study area. OS Land-Line tiles provide a large-scale, vector-format digital base map for the GIS, depicting man-made and natural features, including details such as administrative boundaries. Each discrete item within the Land-Line base map has a feature code (e.g. FC1010 describes water features) which allows it to be distinguished from other types of feature in the Land-Line base layer. The OS Land-Line base map is supplemented by OS contour data, with contours at 5 m intervals, which provide first-order topographical information. The historical map tiles (OS 1st and 2nd edition maps) are in a raster format and

Table 1: Data layers included in the Lower Lugg Valley GIS Database

Layer Group	Layer Type	GIS Layer	Information
Baseline layers	Ordnance Survey Layers	OS 5 m contour	
		OS 1st edition maps	Grouped to act as one continuous layer
		OS 2nd edition maps	Grouped to act as one continuous layer
		OS Land-Line	Lines only (excludes labelling), grouped to act as one continuous layer
	British Geological Survey (BGS) Layers	BGS Bedrock Geology	Bedrock (or solid) geology. Mostly consolidated natural rocks >1.8 million years old.
		BGS Superficial Deposits	Superficial (or drift) deposits. Unconsolidated natural *in situ* superficial or surficial deposits <1.8 million years old.
		BGS Artificial Geology	Recent man-made deposits, mineral workings, re-modelling or altered ground.
		BGS Fault Geology Line	E.g. normal, thrust, reverse; observed or inferred.
		BGS Landform Geology Line	E.g. buried channel margin, glacial drainage channel margin.
		BGS Rock Line	E.g. coal seam, gypsum or ironstone bed; observed or inferred
		BGS Mass Movement Geology	Primarily landslips or foundered ground moved down slope under gravity.
	Dudley Stamp Land Use maps	Dudley Stamp Land Use maps	Not georeferenced for use with ESRI ArcMap
	ALSF	ALSF Study Area	From air photo archaeological analysis conducted by Christine Cox, Air Photo Services
Landscape layers	LiDAR layers	Unfiltered LiDAR (m)	Incomplete Lugg coverage. 2 m horizontal and 25 cm vertical resolution (from the Environment Agency)
		Filtered LiDAR (m)	Incomplete Lugg coverage. 2 m horizontal and 25 cm vertical resolution (from the Environment Agency)
	Herefordshire Air Photos	Herefordshire Air Photos	From Herefordshire Archaeology
	NextMap Digital Elevation Model (DEM)	NextMap DEM	Interpolated from OS surveyed contours. 5 m resolution. Obtained from Herefordshire Archaeology
	BGS borehole data	BGS borehole	From BGS archive data
	Geomorphological mapping	Valley edge	Mapped by RBDH Research Group
		Terrace edge	Mapped by RBDH Research Group
		Palaeochannels	Mapped by RBDH Research Group
		Marsh	Mapped by RBDH Research Group
		Pond	Mapped by RBDH Research Group
		Alluvial fan edge	Mapped by RBDH Research Group
		Alluvial fan arrows	Mapped by RBDH Research Group
		Alluvial fan edge (dissected)	Mapped by RBDH Research Group
		Alluvial fan arrows (dissected)	Mapped by RBDH Research Group
		Industrial area	Mapped by RBDH Research Group
		Urban area	Mapped by RBDH Research Group
		Settlements (small)	From OS Land-Line
		Levee	Mapped by RBDH Research Group
		River channel	From OS Land-Line
		Water features	From OS Land-Line
Cultural Layers	Quarry data layer	2007 Current Quarries	Constructed by Ian Bapty, Herefordshire Archaeology
		Post 1982 Defunct Quarries	Constructed by Ian Bapty, Herefordshire Archaeology
		Post 1982 Failed Quarried	Constructed by Ian Bapty, Herefordshire Archaeology
		Pre 1982 Quarries	Constructed by Ian Bapty, Herefordshire Archaeology
		Pre 20th Century Quarries	Constructed by Ian Bapty, Herefordshire Archaeology
		Tithe map quarries	Constructed by Ian Bapty, Herefordshire Archaeology
	Archaeology AP Analysis	Bank	AP Analysis by Christine Cox, Air Photo Services
		Ditch	AP Analysis by Christine Cox, Air Photo Services
		Fills	AP Analysis by Christine Cox, Air Photo Services
		Modern boundaries	AP Analysis by Christine Cox, Air Photo Services
		Non archaeological lines	AP Analysis by Christine Cox, Air Photo Services
		Palaeochannels (from air photos)	AP Analysis by Christine Cox, Air Photo Services
		Possible Archaeology (point)	AP Analysis by Christine Cox, Air Photo Services
		Possible Archaeology (line)	AP Analysis by Christine Cox, Air Photo Services

		Quarry	AP Analysis by Christine Cox, Air Photo Services
		Ridge and Furrow (following National Mapping Programme convention)	AP Analysis by Christine Cox, Air Photo Services
		Ridge and Furrow	AP Analysis by Christine Cox, Air Photo Services
		Archaeological site boundaries	AP Analysis by Christine Cox, Air Photo Services
		Archaeological site information (points)	Contains database information by Christine Cox, Air Photo Services
		Archaeological site numbers	AP Analysis by Christine Cox, Air Photo Services
		Archaeological site text	AP Analysis by Christine Cox, Air Photo Services
		Water Management Features	AP Analysis by Christine Cox, Air Photo Services
	Site and Monument Record (SMR)	Unfiltered SMR	Edited by Herefordshire Archaeology
		Filtered SMR	Edited by Herefordshire Archaeology

have been grouped together so that they act as seamless layers in the GIS, rather than numerous individual tiles.

The Ludlow and Hereford map sheets from the digital geology data (Digital Geological Map of Great Britain, DiGMapGB) were merged to create a single layer covering the Lower Lugg study area. The principal layers of geological interest are the bedrock geology and superficial deposit layers. These are polygon datasets, at a scale of 1:50,000, which incorporate a large amount of attribute data compiled by the British Geological Survey (BGS). The bedrock geology (or solid geology) layer consists of data pertaining to consolidated natural rocks of pre-Quaternary age (> 1.8 million years old) whilst the superficial deposits (or drift geology) layer contains information relating to unconsolidated, natural surficial deposits that date from the Quaternary (< 1.8 million years old). The three attributes of chief interest in both these data layers are LEX_D, ROCK_D and LEX_ROCK. LEX_D is a description of the Lexicon Code of the geological unit, as listed in the BGS Lexicon of Named Rock Units, which describes the rock or deposit unit (e.g. River Terrace Deposits 1). ROCK_D is a description of the Rock Code, representing the type of rock or lithology (e.g. Sand and Gravel). Using this format a unit may be described by type or composition, and with the combination of these two, LEX_ROCK gives a unique identifier to each unit (BGS, 2006).

Dudley Stamp Land Use maps, dating from the 1930s, have also been inserted as a baseline layer. They appear as they were received from Herefordshire Archaeology.

1.3.4 *Landscape Layers*

To create the LiDAR layers, the individual raw data ASCII files were converted to raster grid files. The LiDAR data coverage in the Lower Lugg study area is incomplete with data being held for a small reach around Bodenham and a more substantial section of the valley floor between Shelwick Green and the River Wye confluence at Mordiford. The raster grid tiles in each of these two areas have been merged so that they open as seamless layers. The LiDAR elevation data are available as two discrete GIS layers: Unfiltered LiDAR and Filtered LiDAR. Unfiltered LiDAR incorporates all the elevation points recorded during data collection and means that man-made features such as hedgerows, roads and buildings are included in the final output. The Filtered LiDAR uses an algorithm (developed and applied by the Environment Agency) to remove man-made features so that only elevation data relating to the ground surface are provided in the final output. From previous experience of using LiDAR data, the RBDH Research Group recommends that the unfiltered data layer is used for visual analytical purposes, as filtered datasets often contain errors due to the algorithm that is applied. With a vertical resolution of 25 cm, LiDAR data are useful for identifying valley floor features such as terraces and palaeochannels. The elevation categories employed in the GIS can be altered by the user to optimise the scale at which different valley floor landscape features are viewed.

Herefordshire vertical aerial photography and NextMap DEM data have been incorporated in the Lower Lugg GIS as landscape layers but appear as they were received from Herefordshire Archaeology and have not been subject to any processing by RBDH. BGS borehole data were obtained from the British Geological Survey borehole database. In all, 13 borehole records were purchased from BGS to obtain information on sub-surface sediments in the Lower Lugg study area. The quality of the borehole records, however, is relatively poor. Nevertheless, the point dataset has been incorporated in the GIS and has been created along with attribute tables which provide information on borehole locations and details of the recorded sedimentary logs.

The geomorphological mapping layer was created by the RBDH Research Group from a range of data sources. Geomorphological details were compiled from OS data sources, historical maps, geological maps, aerial photographs and LiDAR elevation data. The mapping was restricted to the valley floor environment and focused principally on fluvial features such as terraces and palaeochannels. The use of desk-top sources means that the geomorphological map is preliminary in nature and would require significant ground-truthing to be verified.

1.3.5 *Cultural Layers*

The Herefordshire Sites and Monuments Record (SMR) is a record of all known archaeological sites in the county. It appears in the GIS as a point dataset with associated attribute data, which provides information on the nature and age of each archaeological record. The SMR has been clipped to cover only the area of the Lugg Valley and appears as filtered and unfiltered layers. The unfiltered dataset contains every record of archaeology in the Lugg Valley (2514 records in total), whilst the filtered SMR has had selected records such as Post Medieval buildings removed (1499 records in total). Editing of the SMR datasets was carried out by Herefordshire Archaeology.

The layer containing data relating to the archaeological analysis of aerial photography was created by Christine Cox of Air Photo Services. The data received by RBDH included a separate Access database containing information about each of the archaeological sites identified from the aerial photography analysis. To incorporate this information within the GIS, the database was converted to a point file so that it could be accessed through an attribute table associated with each archaeological site.

The quarry data layer included in the GIS contains polygon data and an attached database relating to past and present quarrying activity in the Lower Lugg study area. The layer was created by Ian Bapty of Herefordshire Archaeology.

1.3.6 *Conclusion*

The Lower Lugg Valley GIS database is a valuable resource that can be used to aid planning and development decisions in the Lower Lugg study area. It has been constructed in such a way that it can be used as a simple visualisation tool to view the distribution of features such as archaeological sites, but it can also be used as a powerful analytical tool to investigate, at a range of levels, spatial relationships between landscape and cultural variables. A wide range of data are contained within the GIS and, as it exists at present, it constitutes a valuable resource for Herefordshire Archaeology but it can also be expanded in the future to incorporate additional information concerning landscape or cultural variables in the study area. Any digital data sources that are added to the GIS, however, should be carefully examined and assessed as the value of the GIS as a resource for aiding planning and development decisions is heavily dependent on the quality of the data that it contains.

2.1 Introduction

2.1.1 *Objective*

This section of the assessment details the historical and current patterns of mineral extraction in the Lower Lugg Valley, sets out the current planning framework relating to existing and future mineral extraction, and presents an analysis of the likely future patterns of quarrying in the area.

2.1.2 *Background*

The process of aggregate quarrying in the Lower Lugg Valley has, since at least the 19th century, been one of the main means of discovery (and destruction) of the archaeological remains of the area. It is no coincidence that the principal archaeological excavations in the Lower Lugg at Sutton Walls (mid 20th century, see **Section 4.2**) and Wellington (1985 to present, see **Section 4.1**) have taken place in association with two of the major 20th century quarry sites. Indeed, the exceptional archaeological sequence from Wellington in particular, with preservation within the valley bottom alluvium of a multi-period complex of important archaeological features, has transformed understanding of the archaeological potential of the locality.

It is this scenario which sets the core agenda for this resource assessment. Continuing large scale sand and gravel quarrying in the Lower Lugg constitutes the most obvious and immediate threat to the archaeological resource of the area. Understanding the nature, geographical focus and likely future course of that activity is therefore a central component of the present exercise. This requires analytical engagement with past, present and projected future patterns of quarrying in the Lower Lugg, as well as an understanding of the complex frameworks of statutory planning legislation and guidance which determine the modern minerals planning process.

It is also important to recognise that quarries and their remains are in themselves a major and distinctive part of the archaeological resource of the area. The presence of significant aggregate reserves in the Lower Lugg area has been a key influence on the later Post-Medieval development of the locality, although the archaeology of that process has been little explored. Understanding the development of Lower Lugg quarrying is therefore in itself a key component of this section of the resource assessment.

2.1.3 *Analytical process and sources*

The analysis presented here is based on a two stage process. Firstly, data relating to aggregate permissions and to the geological deposits exploited by aggregates extraction has been researched and collated. Secondly, that information has been subject to critical analysis in terms both of assessing the historical development of quarrying patterns, and of predicting the likely future development of quarrying in the area.

Sources consulted have included:

- Historic mapping, including OS mapping (1st Edition and later) data and Mid 19th century Tithe Maps

- Information specifically relating to the planning process, including Post 1947 minerals planning records (held by Herefordshire Council), and national, regional and local minerals planning frameworks

- Information relating to the superficial geology, including British Geological Survey minerals data and material derived from survey of the wider literature. Quarry companies were also approached for additional information about the geological character of their holdings.

2.1.4 *Constraints*

It should be noted that it did not prove possible to access data from the quarry companies concerning the precise make up of the geological deposits within permitted or proposed quarry areas. This reflects the commercial sensitivity of that information. Some relevant material was identified in planning applications (including borehole data), but it was not possible to analyse that data in detail in the time constraints of this project. It may be that additional work could be undertaken to this end as part of future archaeological research programmes in the Lower Lugg.

It is therefore not possible at the present time to offer a detailed description of the specific geological deposits at particular operating, permitted or proposed quarry sites. Nevertheless, the more generalised analysis of the nature of the Lower Lugg sand and gravel resource presented below is judged to inform adequately an understanding of past, present and future quarrying patterns in the area. This analysis is incorporated into Sections 2.2 and 2.3 below.

2.1.5 *Outputs: GIS*

Past and present quarrying information has been mapped and incorporated in the following GIS layers/database:

- Tithe Map quarries
- Pre 20th century quarries
- Pre 1982 quarries
- Post 1982 defunct quarries
- Post 1982 failed quarries
- 2007 current quarries

In each layer, quarry areas are mapped as polygons, with an attached database incorporating a field structure compatible with established Herefordshire SMR practice. The database presents additional information on the chronology, ownership and application history (where known) of each quarry or potential quarry area. For post 1947 applications, this includes the current status of quarries as abandoned, active, dormant, preferred area or landbank sites (see Section 2.4 below for definition and relevance of these terms).

2.1.6 *Outputs: data summary and critical review*

The data summary and analysis is presented below in 5 sections:

- Section 2.2 presents an overview of the sand and gravel deposits of the Lower Lugg (see also **Section 3.1** for a more detailed treatment of this topic)

- Section 2.3 summarises and analyses the development of quarrying in the Lower Lugg up to 1990.

- Section 2.4 summarises the current minerals planning legislative and local guidance framework.

- Section 2.5 presents a critical analysis of the minerals planning framework with respect to the Lower Lugg.

- Section 2.6 summarises and analyses current quarrying in the Lower Lugg, including the likely future development of quarrying in the area.

2.2 Commercial Sand and Gravel Deposits in the Lower Lugg Valley

2.2.1 *What is sand and gravel?*

Natural sand and gravel originates from weathering and re-deposition of rock to produce reduced deposits of granular aggregate (Tarbuck and Lutyens 1998). The principal sand and gravel deposits in Britain were formed during the Pleistocene period in association with patterns of glacial advance and retreat, and associated river action (British Geological Survey undated).

The character of sand and gravel derives in part from the resistance of the parent material to weathering processes, and in part from the precise patterns of fluvio-glacial action which formed a particular deposit (Tarbuck and Lutyens 1998). Sand and gravels which were laid down without prolonged water action before deposition (typically in the context of glacial till formation or violent glacial outwash/flood events) are described as 'immature'. Such deposits show only limited natural sorting of the aggregate, with considerable intermixing in a given horizon of particles of different size. 'Mature' sand and gravels accumulate as a result of river action over longer periods. They therefore show more developed natural grading and contain defined beds of regular granular size (sand, gravel etc) with marked boundaries between lenses of different sand and gravel type.

Fine grained clays, produced and sorted by the same processes, are often also found in association with sand and gravel beds.

2.2.2 *The commercial uses of sand and gravel*

The uses of sand and gravel are primarily linked to construction (Tarmac undated). Coarser aggregates are extensively used for sub base construction associated with roads, buildings and drainage features. Fine and coarse aggregates are also used in many secondary products such as concrete, asphalt, mortar, and breeze blocks. Gravels are also widely used for decorative finish of outdoor surfaces such as domestic paths and driveways.

Because transport of aggregate is expensive, finished products are typically produced at the extraction site. Modern computer controlled washing plants allow highly efficient separation of 'raw' sand and gravel to produce specific grades of aggregate product according to commercial demands.

2.2.3 *The distribution and nature of sand and gravel in the Lower Lugg*

The Lower Lugg Valley area contains extensive resources of sand, gravel and clay (see also **Section 3.1** for more detailed discussion of the superficial geology of the Lower Lugg). These deposits were laid down by a complex sequence of fluvio-glacial activity over the last 500,000 years, and have also been subject to secondary erosion and reworking over that time to create much of the superficial landform of the Lower Lugg Valley (Brandon 1989, **Section 3.1**, Figures 13 and 14). In terms of understanding patterns of commercial exploitation of this resource, the sands and gravels of the Lower Lugg can be separated into two main groups, the older drift/river terraces and the younger valley bottom sand and gravels.

2.2.4 *The older drift and river terraces.*

These deposits (including sand, gravel and clay) are distributed around the margins of the present day valley, essentially forming the upper horizons of the landscape of terraces and low hills which overlook the river itself (Brandon 1989, **Section 3.1,** Figures 13 and 14). The 'older drift', which principally occurs in the vicinity of Lyde, Portway and Frankland's Gate, is not certainly dated, but may be associated with the period of the Anglian glaciation around 470,000 years ago (Brandon 1989). The deposits comprise glacial tills and fluvio-glacial terraces, and are associated with the advance and retreat of the pre-Devensian ice, and with glacial outwash episodes. The thickness of the deposits is variable, but can locally be up to 20 metres. The gravels are generally 'immature' in geological terms with considerable variation and mixing of particle sizes and materials consistent with rapid deposition (though elements of the fluvio-glacial deposits in particular - notably those at Frankland's Gate - show a greater degree of maturity/sorting).

The four terraces of the River Lugg are generally held to date between the period of the older drift and the time of the final Devensian glaciation, with the fourth terrace perhaps only a little younger than the older drift (Brandon 1989, Maddy 1999, see also **Section 3.1** for more detailed review of the geology of the terraces and dating evidence). These deposits are again of variable thickness and are widespread through the margins of the Lower Lugg valley. They were laid down by the gradual fluvial deposition of the proto-Lugg during earlier phases of development of the valley. As a result of this formation process, they are, on the whole, 'mature' in character, and show a high degree of natural sorting into different grades of material, with clearly defined sand/gravel lenses of different particle size.

It is also important to note that because of their considerable age, both the older drift and river terrace deposits have been subject to extensive subsequent erosion and geomorphological processes, and survive now in a context and form much altered from that of their original formation (indeed, they survive at all only because the Lower Lugg remained beyond the maximum southern extent of all post Anglian glacial episodes). What were once continuous blanket deposits extending over broad river plain areas have been dissected by later erosion to leave only smaller isolated blocks of surviving material (Brandon 1989).

In tandem with this spatial fragmentation, eustatic recovery following periods of glacial retreat has combined with the downward incision of later generations of the River Lugg to effectively 'lift' the ancient flood plain remnants as terraces well above the present valley floor. The result is that the oldest sand and gravel deposits now typically cap the prominent hills and ridges fringing the modern flood plain, with the fourth terrace remnant forming the hilltop of Sutton Walls perhaps the most obvious feature of this kind. Importantly, the raised situation of these terraces and the longstanding action of surface erosion processes upon them, has also meant that the sands and gravels are mostly free of later alluvial or glacial 'overburden' material, and form the immediate geology beneath the subsoil (Brandon 1989).

2.2.5 *The valley bottom sand and gravels*

The principal sand and gravel resource of the Lower Lugg is spatially associated with the present day valley bottom/flood plain area (**Section 3.1**, Figures 13 and 14). These deposits were laid down during a period of vigorous river activity in the aftermath of the final Devensian glaciation between about 18000 and 10000 years ago. Because they are geologically young, they have not been dissected and fragmented by later erosion, and therefore extend continuously throughout the valley bottom corridor. The deposits are of variable thickness, but seem to thin slightly to the south; they are generally between 4 and 7.5 metres deep at Bodenham reducing to between 3.6 and 5.3 metres at Lugg Bridge (Brandon 1989).

Given the formation process, the mineral is generally of 'immature' character, showing considerable mixing of particle size, and less natural definition of sorted sand and gravel elements. The valley bottom context also means the gravels have been overlain by Holocene fluvial deposition, principally comprising up to 3 metres of alluvium. The gravels themselves typically lie below the water table.

2.3 Quarrying in the Lower Lugg Valley up to 1990

2.3.1 *Early quarrying*

There is no known information on early quarrying activity in the Lower Lugg. However, the incidence of easily accessible sand and gravel deposits in the Lower Lugg, and the presence in the immediate vicinity of major settlements such as Hereford in the Medieval period and Kenchester in the Roman period, makes it very likely that aggregate extraction did occur in earlier times. Moreover, it is noticeable that the mid 19th century Tithe Map field pattern seems to deliberately incorporate quarry areas in field margins, perhaps suggesting planned awareness of aggregate extraction patterns which were already well established when the enclosure boundaries were created. It is perhaps also relevant to note the large numbers of undated small pond features within the Lower Lugg area. Although these might be reasonably be interpreted as Post Medieval field ponds deriving from the pastoral agricultural regimes of the Lower Lugg, it may well be that many (especially those off the flood plain) originate from localised early aggregate extraction.

In addition to sand and gravel for construction purposes, it does seem possible that the clay resources of the area could have been a particular focus for early manufacturing activity. The origin of some local Medieval pottery types found in Hereford has not been identified (Boucher and Thomas 2002), and the Lower Lugg is one likely location for these missing kilns. It is surely also probable that the local clays were similarly worked in earlier times, though evidence of this is as yet entirely absent.

2.3.2 *Summary of 19th and early 20th century quarrying patterns in the Lower Lugg*

The pattern of quarrying revealed by the Tithe Map (Quarry Table 1, **Section 7**) and OS First Edition data (Quarry Table 2, **Section 7**) gives a good indication of the distribution and nature of quarrying activity in the Lower Lugg up to the early 20th century (Figure 6). There are significant numbers of quarries/former quarries (23 on the Tithe Map, 26 on the OS First Edition), but they are small in size, and dispersed away from the flood plain area. It should be noted that the spatial mapping of quarries from the Tithe map relates to fields with quarry names - not the quarries themselves - so superficially gives the false impression that some extraction areas were quite large.

Although the quarries are scattered through this outer zone, four principal clusters of activity can be recognised: the Ashgrove area, the Frankland's Gate/Sutton area, The Lyde/Portway area and the Bartestree area. These zones essentially represent targeted exploitation of sands, gravels and clays associated with the undulating flanks of the river valley.

2.3.3 *Analysis of 19th and early 20th century quarrying patterns in the Lower Lugg*

What is very obvious is that there is a close association between this earlier quarrying activity and the older drift and river terrace (fourth terrace especially) sand and gravel deposits. Clearly this preference is not accidental, and represents specific advantages which the geological and landscape context of these reserves offered in the economic and quarrying technology circumstances of the period.

Firstly, these deposits were easily accessible in hilltop/side locations with minimum overburden and maximum ease of 'working'. A hilltop/side offered a ready exposure of the mineral which could be dug into horizontally, with spoil and product easily disposed of downhill - major advantages where extraction is effectively undertaken by physical labour without mechanical aids. Secondly, the 'mature' geological character of the mineral at these same locations (especially the river terraces) offered 'pre-sorted' deposits, where different grades of sand, gravel and clay could be worked and sold 'as dug' without the need for additional washing and sorting processes. Thirdly, the hilltops were physically apart from (though still accessible to) the most intensive areas of established settlement/agriculture on the lower/younger gravel terraces fringing the river flood plain. They were therefore the least disruptive (in terms of other important land-uses) and most economically sensible areas of the landscape to be used more intensively for quarrying.

Although no systematic historical research has been undertaken into local quarrying, the archaeological and historic map evidence is sufficient to demonstrate that the 19^{th} and early 20^{th} century industry in the Lower Lugg remained relatively piecemeal, and that deposits were probably worked on an 'as needed' rather than continuous basis. While concentrations of quarrying developed for the reasons outlined above, these consisted of groups of essentially small and independently run operations to supply local markets. Significant local construction projects such as road improvements in the later 18^{th} and 19^{th} centuries, and the building of canal and railway infrastructure in the area during the mid 19^{th} century, must have stimulated peaks of demand.

The nearby presence of Hereford may also have been a key influence on the industry, particularly as larger scale expansion and replacement of housing and commercial building stock began to take place from the mid 19^{th} century onwards. This effect may be particularly relevant to the emergence of a local clay industry in the form of brickworks, some of which may have involved mineral extraction in previously un-quarried areas. Nevertheless, even with such new demands, it appears that the traditional quarrying zones were still able to meet local aggregate production requirements at least until the early 20^{th} century.

2.3.4 *Summary of early 20^{th} century to 1990 quarrying patterns in the Lower Lugg*

Up until the later 20^{th} century, sand and gravel extraction essentially continued to focus on the core 'established' areas, though increasing mechanisation and peaks of demand do seem to have led to increases in individual quarry size (**Section 7.1,** Quarry Table 3) and reduction in the overall number of quarries, with seven sites recorded as active in the post war period (Figure 7). The most obvious example of the trend is the establishment of the quarry to exploit the fourth terrace deposits crowning Sutton Walls. There had been a small quarry there in the past (possibly pre 19^{th} century), but when extraction re-commenced in the 1930s, it was on a significantly larger scale, and by the 1960s some two thirds of the sand and gravel capping of the hill within the Iron Age hillfort had been removed. The inception of the quarry was probably linked with the construction of the nearby Moreton-on-Lugg military base, and quarrying was certainly continuous through the war years (Kenyon 1954). Quarries in the Frankland's Gate, Ashgrove and Upper Lyde areas were also subject to at least intermittent use throughout the inter war period and into the 1960s (**Section 7.1,** Quarry Table 3). However, the 19^{th} century clay based industries had disappeared by the later 20^{th} century (as judged from the later OS map evidence).

The obvious new development of the early 20^{th} century is represented by the establishment of quarrying west of Bodenham village which apparently began in the 1920s (Herefordshire Council Minerals Planning files). Importantly, this was the first time commercial exploitation of the geologically young valley bottom sand and gravel resource had been attempted. Quarrying at Bodenham significantly expanded from the 1950s onwards and continued into the

1980s, when an application for further expansion to the south was rejected following a Public Enquiry. The site was subsequently landscaped as a series of amenity lakes.

Despite the cessation of quarrying at Bodenham, the development of the valley bottom resource via quarries of much increased scale (Figure 7) has been the principal trend of the late 20th century (**Section 7.1**, Quarry Table 4). The large Wellington/Moreton valley bottom site originally gained permission under Redland in 1985 (Herefordshire Council Minerals Planning files, see **Section 7.1**, Quarry Table 4 for summary of site history), with further extensions in 1987 and 1989, and by 1990 was one of the two most important sand and gravel quarries in the county (the other was a Stretton Sugwas to the west of Hereford where quarrying had ceased by the end of that decade).

To the south, permission for the extensive Lugg Bridge quarry was granted to Ready Mix Concrete (RMC) in 1990 following a Public Enquiry (Herefordshire Council Minerals Planning files, see **Section 7.1,** Quarry Table 4 for summary of site history). The eventual Lugg Bridge permitted area was in fact only part of a much larger zone of quarrying which had originally been jointly proposed in 1987 by Alexander Russell Ltd and RMC (Herefordshire Council Minerals Planning files, see **Section 7.1,** Quarry Table 5 for summary of site history). This was to have included three sites totalling 200 hectares in the valley bottom area south of Sutton St Nicholas (Pentall's Farm, Wergin's Bridge and Lugg bridge, Figures 8 and 9). Following appeal against initial planning rejection in 1987, the 1989 Public Enquiry recommended that Pentall's Farm and Wergin's Bridge should be rejected (essentially on grounds of landscape and environmental impact and issues concerning inadequate transport infrastructure), and that a modified Lugg Bridge site application should be allowed.

The post 1982 exception to the valley bottom emphasis was the 1989 permission for Portway/St Donat's quarry (Lafarge-Redland), situated west of Moreton on the old drift deposits and the lower slopes of the 3rd terrace, and incorporating an earlier 19th century quarry site (Herefordshire Council Minerals Planning files, see **Section 7.1,** Quarry Table 5 for summary of site history). Quarrying has yet to commence at this site.

2.3.5 *Analysis of early 20th century to 1990 quarrying patterns in the Lower Lugg*

At one level, the 20th century shift to the valley bottom sand and gravels simply represents improved technological capability to exploit what had previously been inaccessible deposits. In the valley bottom, the 'overburden' of alluvium must be removed to gain access to the mineral. Moreover, the underlying gravels must either be drained before extraction, or subject to 'wet working' methods. And finally the geologically 'immature' mixed mineral deposits must be subject to secondary washing processes before desired grades of 'pure' mineral can be produced. Up until the large scale mechanisation of the 20th century, not only did all these processes present technical problems, but there was little economic incentive to overcome such difficulties when ample supplies of mineral more suitable for small scale production and local use were readily available.

However, it is also important to stress that, given adequate demand for the product, the geological character of the valley bottom deposits also offers positive advantages for large scale commercial 'winning' of aggregate. Efficient production of a profitable range of aggregate products is best pursued where 'immature' sand and gravels offer predictable reserves of uniform mix and character. Moreover, because the valley bottom deposits are continuous (unlike the smaller outcrops of the geologically earlier material), investment in plant, infrastructure, and the additional costs of overdurden removal and drainage, can be undertaken within a commercial equation where such capital expenditure is justified by known access to relatively large areas of mineral (and where potential expansion of sites is also viable subject to land ownership and planning permission). In addition, because of the land-use history of the Lugg flood plain, and late enclosure of what had previously been common meadows, relatively large and regular parcels of land are potentially available for purchase in this context. This makes it that much easier for quarry companies to secure ownership of the extensive areas necessary for efficient modern quarrying.

The valley bottom reserves also presented ancillary advantages in terms of later 20th century environmental and planning control issues. Quarries in the valley bottom are automatically near to the principal road (A49) and rail (Cardiff to Manchester) access routes which exist along the same corridor, and this facilitates easier and more environmentally acceptable bulk transport of mineral products. The valley bottom is additionally removed from the principal areas of settlement which occupy the adjoining terraces beyond the flood plain, so the environmental impact of quarrying on residential areas is less immediate.

The flood plain also has limited modern potential in other land-use terms (excepting loss of high-grade agricultural land), so establishment of quarries in this zone does not significantly conflict with other modern development pressures. It is also true that, aesthetically, valley bottom quarries are less visible in the landscape than the earlier generation of hilltop sites, and potentially less problematic (and costly) in terms of subsequent reclamation/re-use. In this sense, not only did the 1980s reclamation of Bodenham quarry locally pioneer the perceived acceptability of the 'landscaped lakes' option, but the considerable pollution problems associated with the 1960s and 1970s waste infilling of the Sutton Walls quarry had clearly demonstrated the pitfalls and cost (short and long term) associated with 'restoration' in hilltop locations (Herefordshire Council Minerals Planning files, see **Section 7.1,** Quarry Table 4 for summary of site history).

Although the 1989 permission at Portway (St Donat's) might seem to stand against the valley bottom pattern, the failed 1980s applications for the extension of Bodenham quarry, and the proposed Pentall's Farm and Wergin's Bridge sites, strongly reinforce the trend. Together these effectively targeted a large proportion of the remaining flood plain area between Bodenham and Lugg Bridge (Figures 8 and 9). The original proposal to work the Pentall's Farm, Wergin's Bridge and Lugg Bridge sites sequentially using conveyors to transport the mineral to a common plant facility also emphasises the commercially attractive economies of scale offered by large sale working of the valley bottom area.

2.3.6 *Quarrying in the Lower Lugg Valley up to 1990: Conclusions*

The older pattern of quarrying in the Lower Lugg was characterised by small scale extraction of the geologically older and more naturally sorted sand and gravel deposits close to settlement areas and away from the flood plain. Although it is not possible on current evidence to discern pre 19th phases of this activity, this is likely to be a long established pattern. Clay extraction for brick production was significant in the 19th century, and clay industries (though not as yet precisely located) may also have been important in the Lugg at earlier times.

In the 20th century, and especially in the decade 1980 to 1990, there is an important shift in sand and gravel quarrying activity. This is not only towards mechanised working of fewer, larger sites, but also towards the exploitation of the continuous, geologically recent valley bottom sand and gravel resource (comprising 'immature' mineral deposits sealed beneath alluvium). This shift is underpinned by a range of advantages which this resource offered in the

20th century economic and environmental context. The commercial attractiveness of these deposits is emphasised not only by the permissions granted at Wellington and Lugg Bridge, but by the failed 1980s applications for the extension of Bodenham, and the dual Pentall's Farm and Wergin's Bridge site.

Figure 6: Distribution of 19th century quarries in the Lower Lugg Valley

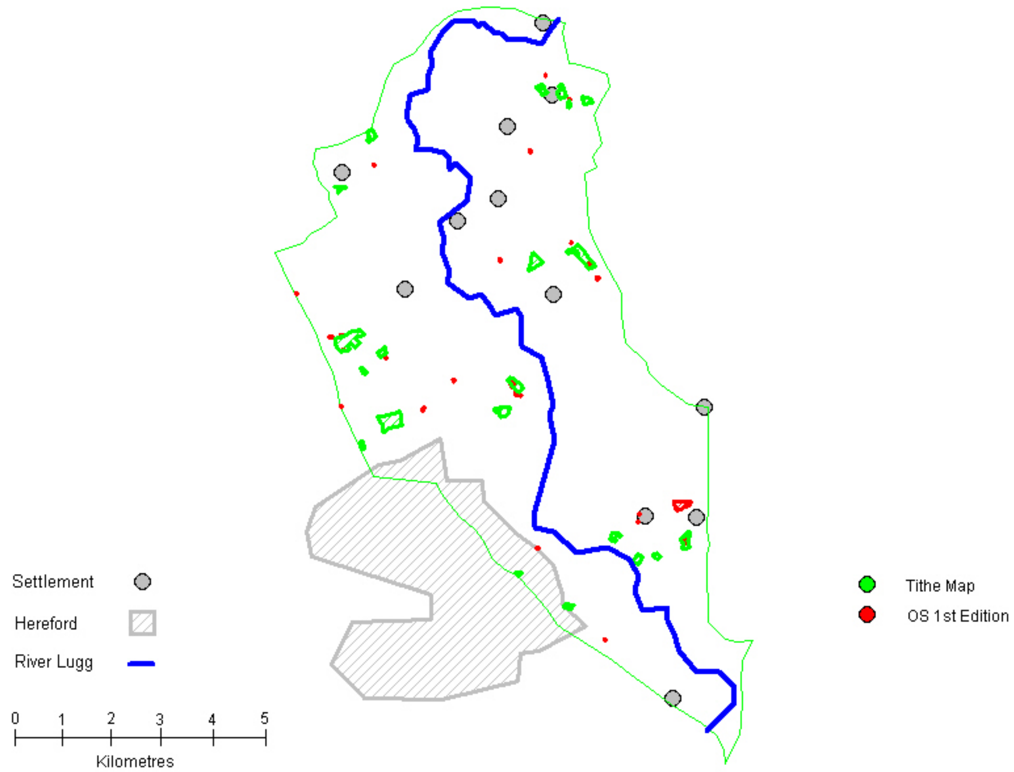


Figure 7: Distribution of mid to late 20th century quarries in the Lower Lugg Valley

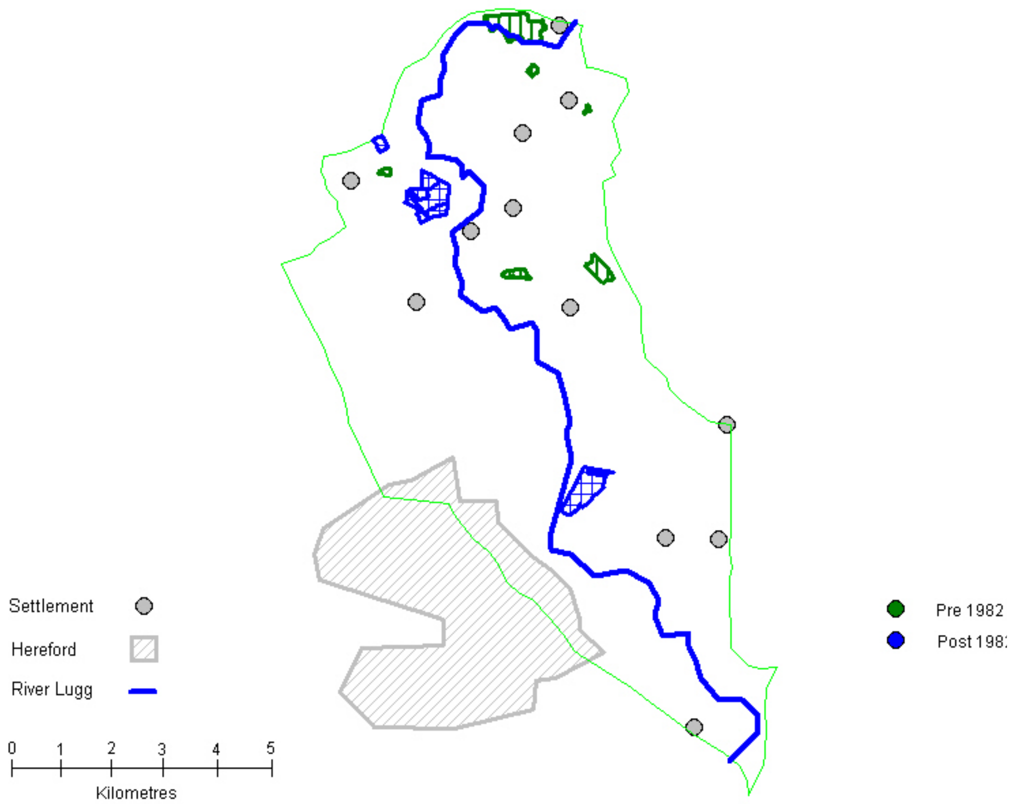


Figure 8: Failed 1980s Lugg Bridge, Pentall's Farm and Wergin's Bridge Applications

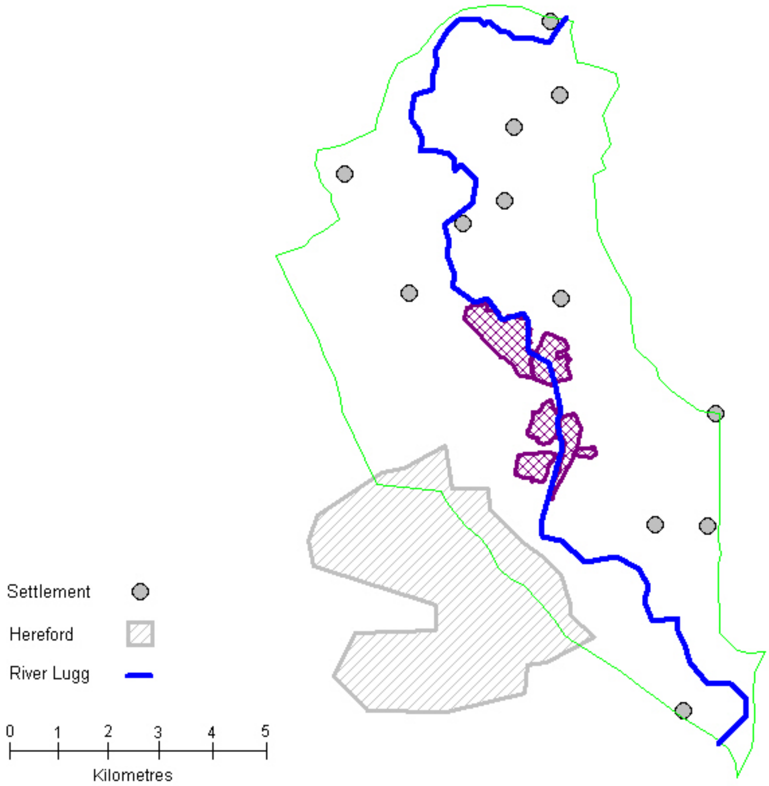
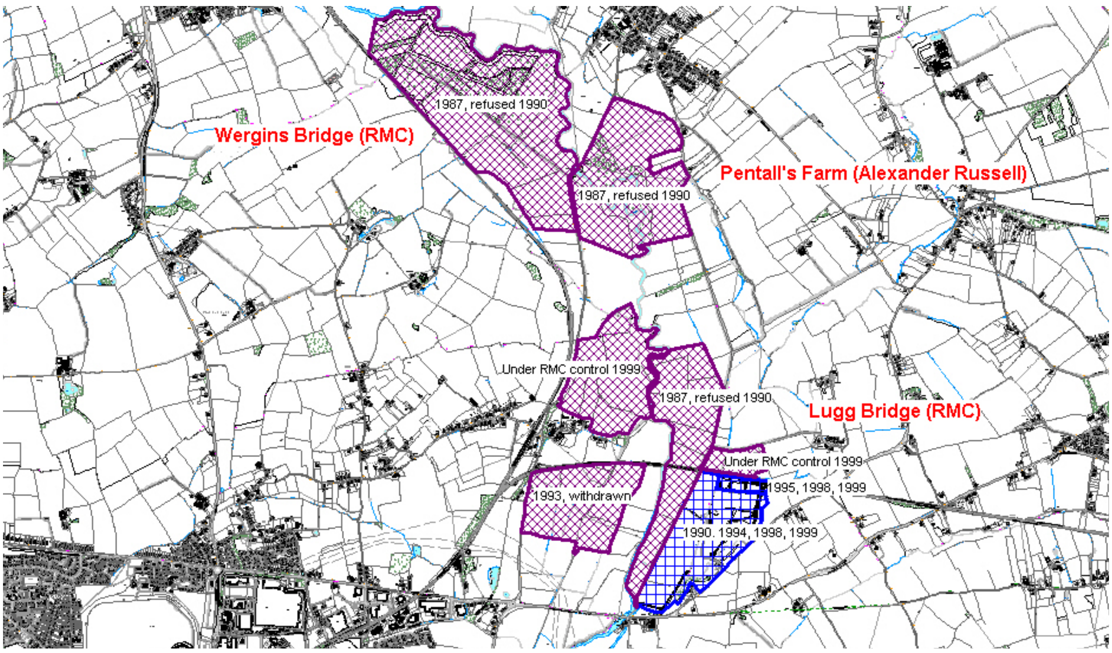


Figure 9: Failed 1980s Lugg Bridge, Pentall's Farm and Wergin's Bridge Applications (detail with Planning Application dates)



2.4 Current Minerals Legislative, Planning and Local Guidance Framework

2.4.1 *Legislation*

The process of mineral extraction in England and Wales has been under comprehensive control within the national planning system since the Town and Country Planning Act of 1947 was formerly enacted on July 1st 1948, so introducing general planning control over the development of land. Ongoing amendments to the 1947 Act were eventually consolidated in the Town and Country Planning Act of 1971. The 1971 Act was itself amended by the 1981 Town and Country Planning (Minerals) Act (which established the role of County Councils as the Minerals Planning Authority (MPA) for their areas), and was then replaced (in terms of mineral extraction) by the Town and Country Planning Act of 1990. One of the important provisions of the latter Act was the requirement for MPAs to prepare a Minerals Local Plan.

The 1990 Act has itself undergone further amendment, especially linked to the Planning and Compensation Act (1991) and the Environment Act (1995). In terms of minerals planning, these Acts collectively addressed the fact that the minerals permissions granted before 1982 were not time limited in terms of commencement of quarrying following the permission, and moreover that permissions granted before 1995 were not subject to any subsequent review of the planning conditions originally attached to them. This meant that permissions granted against the very different (and much less environmentally stringent) planning regimes of the post war period could be reactivated without alteration in the modern context.

The 1991 Planning and Compensation Act began addressing this issue by requiring MPAs to review the interim permissions from the period 1943-1948 which had been granted before the implementation of the 1947 Act and were thereafter renewed by all subsequent planning Acts. Operators were required to apply for registration of permissions where they wished these to remain active, and which would then be subject to updated applications and conditions. The 1995 Environment Act promulgated a similar review of all permissions granted between 1948-1982. The MPAs were required to assess all permissions within this period, and to publish a 'First List' of all those to retain permission thereafter (to be classified either as 'active' or 'dormant' quarries). Operators were given the opportunity to apply for retention of particular sites on the First List if they disagreed with the judgement of the MPA.

The net result of both these processes was that, following adoption of an MPA First List, no non First List 'old permission' sites within that MPA area thereafter retained permission, or the potential to gain future permission without being treated as a completely new application against modern planning frameworks and criteria. The 1995 Environment Act also importantly required that all existing permissions (First List and post 1982) would be subject to the cyclical Review Of Minerals Permissions (ROMP) process, thereby creating provision for regular updating of planning conditions attached to an active permission.

The most recent reorganisation of minerals planning processes derives from the Planning and Compulsory Purchase Act of 2004. By incorporating regional planning structures within the statutory process, this Act effectively increased regional control over local development documents, and so introduced greater centralisation of the planning framework. The Act required that each region put in place a Regional Spatial Strategy (RSS) to ‘set out the Secretary of State’ policies (however expressed) with respect to the development and use of land within the region’ (Planning and Compulsory Purchase Act 2004). This was immediately achieved by re-designating existing Regional Planning Guidance (including regional minerals policies) as the statutory Regional Spatial Strategy, though in due course fully revised Regional Spatial Strategies will be created.

At MPA level, the 2004 Act also requires that a local Minerals Development Framework (MDF) is put in place to define local minerals extraction activity. The MDF will replace existing Minerals Local Plan/UDP Chapter 11 provision, and will be defined via the Regional Spatial Strategy. One aspect of this process is to place a greater emphasis on public participation in local minerals policy development procedures

2.4.2 *Other relevant legislation*

While the 1990, 1991, 1995 and 2004 Acts underpin the modern development control process for mineral extraction, other legislation also directly includes minerals elements. These include The Town and Country Planning (Minerals) Regulations 1995, and the Country Planning Environmental Impact Assessment (EIA) Regulations England and Wales 1999 and Amendment Regulations 2000. The latter has a specific requirement for EIAs to be conducted in association with new applications or ROMP revisions.

A range of other legislation is also relevant to minerals extraction and planning issues. The current raft of intersecting Acts which are enforced by the Health and Safety Executive (Health and Safety, Mines and Quarries, Construction Design and Management, Control of Explosives, and Occupiers Liability) are important in so far as they define land-use conditions impacting on minerals planning processes. Another direct minerals planning constraint arises from the fundamental principle of Common Law which mitigates against granting a planning permission which has the result of undermining adjoining land.

Various components of environmental protection legislation also have specific relevance to minerals planning. In terms of the historic environment, the 1979 Ancient Monuments and Archaeological Areas Act protects Scheduled Ancient Monuments from all forms of development, with Listed Buildings similarly protected through the 1990 Planning (Listing Building and Conservation Areas) Act. Natural Environment protection is underpinned by the Countryside and Rights of Way Act 2001 which includes the designation of Sites of Special Scientific Interest (SSSIs), and the implementation of relevant European Natural Environment designations.

Planning impacts on both natural and historic environment are also additionally controlled by the supplementary Planning Policy Guidance framework. PPG 15 and PPG 16 deal with buildings and buried remains respectively, while PPG 9 covers both nature conservation and geological and geomorphological sites.

2.4.3 *Minerals Policy Statements/Minerals Planning Guidance*

The minerals planning structure is supported by a guidance framework which ensures the practical delivery of Government policy. The origin of this system can be traced to the Verney Committee report 'Aggregates: The Way Ahead' published in 1976. A key recommendation of the Verney report was the establishment of nine Regional Aggegate Working Parties (including the West Midlands Regional Aggregate Working Party or WMRAWP).

The Regional Aggregate Working Parties assisted Government in the development of national guidelines for the management of mineral extraction which became known as Mineral Planning Guidance (MPGs).

As part of the wider overhaul of the planning process arising from the Planning and Compulsory Purchase Act of 2004 the MPG framework is currently being replaced by Minerals Policy Statements (MPS). These 'set out the government's policy on minerals and planning issues and provide advice and guidance to local authorities and the minerals industry on policies and the operation of the planning system with regards to minerals. Minerals Planning Authorities (MPAs) must take their contents into account in preparing their local development plans (LDDs). The guidance may also be material to decisions on individual planning applications and appeals.' (MPS1 2006). MPS policies should also 'be taken into account by regional planning bodies (RPBs) in the preparation of Regional Spatial Strategies' (MPS 1 Introduction, Section 5).

MPS 1: Planning and Minerals (including Annexe 1: Aggregates) was published in November 2006 and replaces previous MPGs 1 and 6. 'It is the overall planning policy document for all minerals in England. It provides advice and guidance to planning authorities and the minerals industry and it will ensure that the need by society and economy for minerals is managed in an integrated way against its impact on the environment and communities.' (MPS 1 Summary)

The key objectives of the Government's mineral planning as set out in MPS 1 may be summarised as follows:

- To safeguard and conserve minerals as far as possible while maintaining supply to meet the anticipated need.
- To protect areas of designated landscape or conservation value.
- To minimise the production of waste and to encourage use of materials, including appropriate use of high quality materials, and the use of substitute or recycled minerals in place of primary minerals.
- To encourage sensitive working practices during minerals extraction and the sustainable transport of minerals, and to ensure high quality restoration and aftercare after extraction has ceased.
- To secure closer integration of minerals planning policy with national policies on construction, waste management and environmental protection.

MPS1 sets out a series of policies under headings of Exploration, Survey, Safeguarding [the mineral resource], Protection of Heritage and Countryside, Supply, Bulk Transportation, Environmental Protection, Efficient Use and Restoration.

Key elements of these policies in the terms of the Lower Lugg context include:

- Under *Safeguarding*, the need for definition of Mineral Safeguard Areas (MSAs) within local planning documents. MSAs ensure that 'proven resources are not needlessly sterilised by non mineral development, although there is no presumption that MSAs will be worked.'.
- Under *Protection of Heritage and Countryside* 'consider carefully minerals proposals within or likely to affect regional and local sites of biodiversity, geodiversity, landscape, historical and cultural heritage' and 'adopt a presumption in favour of the preservation of listed buildings, nationally important archaeological remains (including scheduled ancient monuments) in situ, and their settings……unless there are overriding reasons of national importance for the development to proceed.'.

- Under *Supply* ‘identify sites, preferred areas and/or areas of search….to provide greater certainty of where future sustainable mineral working will take place’ and ‘provide for the maintenance of landbanks, i.e. appropriate levels of permitted reserves.’.
- Under *Bulk Transportation* ‘seek to promote and enable the bulk movement of minerals by rail, sea or inland waterways to reduce the environmental impact of their transportation’ and ‘safeguard and promote rail links to quarries where there is potential to move minerals by rail.’.
- Under *Environmental Protection* ‘require minerals operators to seek and maintain effective consultation and liaison with the local community before submitting planning applications and during operation, restoration and aftercare of sites.’.
- Under *Restoration* ‘take account of the opportunities for enhancing the overall quality of the environment and the wider benefits that sites may offer, including nature and geological conservation and increased public accessibility, which may be achieved by sensitive design and appropriate and timely restoration.’.

The key concept of landbanks is further defined in Annexe 1 section 4 of MPS 1 (which replaces the previous treatment of this subject in the former MPG 6). It is noted that (my bullet points):

- ‘MPAs should use the length of the landbank in its area as an indicator of when new aggregate permissions for aggregate extraction are likely to be needed. The landbank indicators are at least 7 years for sand and gravel.’.
- ‘A large existing landbank bound up in very few sites should not be allowed to stifle competition.’.
- ‘MPAs should consider and report on the need to review policies in their local development documens (LDDs) as part of their annual monitoring to the secretary of state. This should be done in time to allow for action before the remaining provision falls below the agreed apportioned level.’.
- ‘MPAs should carry out…and publish the results of regular reviews of sites that have not been worked for 10 years or more to assess whether production is likely to begin again.’.

MPS 2: Controlling and mitigating the environmental effects of mineral extraction In England was published in March 2005 and replaces the previous MPG MPS 2 sets out the policies and considerations that the Government expects MPAs to follow when preparing plans and in considering applications for mineral development.

Only MPSs 1 and 2 are currently in place, so for the time being some MPGs remain in force pending the completion of the full MPS framework. MPGs 2,4,8,9 and 14 are of particular relevance to aggregate extraction in the Lower Lugg context.

MPG 2 covers applications, permissions and condition processes and offers advice on the operation of the development control system with respect to minerals. It should be noted that parts of it are now replaced by Annexes 1 and 2 of MPS 2.

MPG 4 sets out the use of the powers granted to Local Authorities by the 1995 Environment Act.

MPG 8 provides advice on dealing with the review process for old 1943-1947 minerals permissions which was required to be undertaken by MPAs by the Planning and Conservation Act (1990).

MPG 9 gives advice to minerals operators and MPAs with respect to the conditions to be attached to new minerals planning permissions.

MPG 14 advises minerals operators and the MPAs on the procedures to enact the minerals permission review processes required by the 1995 Environment Act. These comprise the one off 'First List' process (relevant to 1947-1981 minerals permissions) and the ongoing 'Review of Minerals Permissions' (ROMP) process (relevant to all post 1982 permissions).

2.4.4 *National and Regional Guidelines for Aggregate Provision*

An important adjunct to the MPS/MPG framework are the regional aggregate production targets, which are set by Government to ensure adequate aggregate supply to meet minimum regional needs.

These targets are provided within 'The National And Regional Guidelines for Aggregates Provision in England 2001-2016' issued by the Office of the Deputy Prime Minister in 2003.

The current 2001-2016 primary aggregate production figure for the West Midlands is 255 million tonnes, including 162 million tonnes of sand and gravel.

2.4.5 *West Midlands Regional Spatial Strategy (formerly RPG 11)*

Following the provisions of the 2004 Planning and Compulsory Purchase Act (see section 2.4.1 above), the West Midlands Regional Spatial Strategy (WMRSS) is currently set out within the document originally adopted in June 2004 under the title of Regional Planning Guidance for the West Midlands (RPG11). In minerals planning terms, it should therefore also be understood that the current WMRSS consequently derives from the MPG framework which was in place in 2004, and does not as yet embody the subsequent MPS 1 and MPS 2 revisions of the MPG system.

WMRSS (formerly RPG11) sets out 4 minerals policies:

- M1 Mineral working for non energy minerals
- M2 Minerals - Aggregates
- M3 Minerals - The use of alternative sources of minerals
- M4 Energy minerals

Policy M2 provides the regional apportionment for aggregate production in each of the West Midlands Counties as determined by WMRAWP against the 'The National And Regional Guidelines for Aggregates Provision in England 2001-2016' targets (see section 2.4.4 above).

This was calculated on the basis of known county production rates over the period 1999-2001 which were used to establish average county percentages of total regional output for this 3 year period (2.8% in the case of Herefordshire). These county percentage figures were then applied to the total regional apportionment figure to give a projected 0.283 million tonnes per annum in the case of Herefordshire (which closely compares to the actual 1999-2001 output of 0.282 million tonnes per annum). The local apportionment figures are reviewed annually by WMRAWP.

It should be noted that the pending Herefordshire Unitary Development Plan (including Chapter 11 which sets out minerals planning policy in Herefordshire against national and regional planning frameworks - see below) was designed to conform with WMRSS policies (though these were still in the guise of RPG11 at the time the UDP was written).

2.4.6 *Hereford and Worcester Minerals Local Plan 1997*

In line with the requirements of the Town and Country Planning Act of 1990, current minerals extraction policy in Herefordshire is set out in the Hereford and Worcester Minerals Local Plan of 1997 (which document predates the formation of Herefordshire as a Unitary Authority).

However, although that document is the only adopted reference point for local minerals policy planning at the time of writing, it is important to emphasise that the Local Plan was in fact only intended to cover the period 1994-2003, and is also now entirely out of date in terms of the post Planning and Compulsory Purchase Act (2004) minerals planning framework. At this point it is therefore effectively only a *de-facto* point of guidance pending the adoption of the Herefordshire Unitary Development Plan (see below). There is therefore officially no Local Minerals Plan for Herefordshire at the present time.

The 1997 Local Plan:

- Identifies the mineral resource (actively quarried and potential) in Hereford and Worcester.
- Sets out projected future demand as fixed by WMRAWP as a proportion of the West Midlands regional apportionment (which in 1997 derived from figures set in the 1994 MPG 6 'Annex A').
- Identifies key constraints on future mineral development, including environmental issues and issues of possible disruption to established landuses and potential development land (as set against the then current national legislation and the Minerals Planning Guidance framework).
- Defines 'preferred areas' for future mineral extraction where it is judged that future quarrying will be most acceptable against the above criteria (though it does not follow that preferred areas will automatically be granted planning permission).
- Considers after-use and potential positive contribution of former quarry sites to recreation, nature conservation and waste disposal facilities.
- Sets out policies for the extraction of minerals.

The key components of Local Plan with respect to sand and gravel extraction in the Lower Lugg were:

- That the sand and gravel resource of the Lower Lugg was a key element of the sand and gravel resource in Hereford and Worcester (precise percentage not given).
- That the identified demand for sand and gravel production in Hereford and Worcester between 1992 and 2006 was 22.86 million tonnes amounting to a projected annual output of 1.542 million tonnes.
- That existing permissions (20.561 million tonnes) would provide 13.5 years supply from 1994 onwards at this projected demand.
- That the addition of the 'Preferred Areas' totalling a further 9.136 million tonnes of reserve would ensure 19.5 years of supply at the designated rate of required production, ensuring adequate provision until 2014.
- That, within Herefordshire (and specifically the Lower Lugg), the permitted quarries at Wellington/Moreton (active extraction and Moreton preferred area), Lugg Bridge (preferred area) and Portway (preferred area) form part of the identified Hereford and Worcester sand and gravel reserve (It should be noted that, owing in part to the commercial

sensitivities of the quarry operators, breakdown of the contribution of particular sites to the projected regional totals are not given in the Plan, so the precise estimated allocation of these three sites in particular is not stated).

2.4.7 *Hereford and Worcester 'First List' 1998*

The 1997 Local Plan should also be read in conjunction with the 1998 Hereford and Worcester 'First List' of Mineral Planning Permissions (enacting the requirements of The Environment Act 1995 with respect to review of old permissions, see section 2.4.1) which was closed on 31st March 1998 (Herefordshire and Worcester First List 1998).

The importance of the First List with respect to the future of mineral extraction in the Lower Lugg is that it definitively established which existing mineral permissions in this area (and throughout Hereford and Worcester) would remain current after that date. The explicit review process focussed on the 1948 – 1982 permissions. However the document also included for reference those standing post 1982 permissions which were outside the immediate provisions of the 1995 act, but were thereafter subject to the rolling Review Of Mineral Permissions (ROMP) process which the Act also promulgated. Unsurprisingly perhaps, the Hereford and Worcester First List effectively confirms the permitted/preferred area quarrying sites set out in the Local Minerals Plan published in the previous year.

Within the Lower Lugg, only one of the 7 recorded pre-1982 quarries (OS map data, Herefordshire Council Minerals Planning Records, Herefordshire and Worcester First List 1998) was placed on the First List, and this was the site at Upper Lyde (where the original permission dated from 1965) which was classified as a ‘Dormant’ site. This means that all of the 6 other quarries recorded as active in 1948-1982 period (Ashgrove, Norton Court, Bodenham, Frankland's Gate, Sutton Walls and Bridge Farm, see **Section 7.1,** Quarry Table 4) can therefore be discarded as far as discussion of the likely future pattern of minerals extraction in the area is concerned (except, of course, in so far as those old permission areas could be the focus of completely new applications at some future point).

The existing Post 1982 permissions within the Lower Lugg were those at Wellington/Moreton (active quarry), Lugg Bridge (active quarry) and Portway (dormant). In effect then, the First List additionally adds the small quarry at Upper Lyde (which is not identified or defined as a preferred area in the Local Plan) to the Lower Lugg reserve already identified in the 1997 Local Minerals Plan.

2.4.8 *The Herefordshire Unitary Development Plan Chapter 11, Minerals: Key aspects*

As noted above, the period of the 1997 Local Minerals Plan framework extended only up to 2003 (although the document also variously offered other predictions as far as 2006 and 2014). Moreover, since the time of the 1997 Plan, Herefordshire and Worcester have reformed as separate Unitary Authorities (1998) and that also set the requirement for a new local minerals planning statement within Herefordshire's wider Unitary Development Plan (UDP) process. 'The Herefordshire Unitary Development Plan Chapter 11, Minerals' is currently at Revised Deposit Draft stage (inclusive of amendments arising from the 2005 UDP Public Inquiry and the Inspectors report published in 2006) and is due to be adopted (with the Herefordshire UDP as a whole) in 2007, at which time the 'current' Local Plan will be formally discarded.

It should be noted that following the terms of the Planning and Compulsory Purchase Act (2004), the UDP Chapter 11 will ultimately be superseded by a Herefordshire Minerals

Development Framework document. However, for the foreseeable future it should be assumed that the UDP (once adopted) will continue to structure minerals planning and extraction activity in Herefordshire.

The UDP Minerals Chapter 11 covers the period 2001-2011and aims to (UDP Section 11.2.1, my summary re-phrasing):

- Ensure the continued supply of aggregates to the local construction industry and to satisfy the wider aggregate needs arising in the region.
- Ensure that the environmental impact of extraction is minimised in respect of its effects on nearby communities, the landscape, nature conservation and biodiversity.
- Ensure that land used for mineral extraction is returned to a state suitable for a beneficial after-use.

Against these objectives, the plan aims to set out Herefordshire minerals policies consistent with RPG11 (now WMRSS). These policies (UDP Section 11.2.2, my summary re-phrasing):

- Establish criteria against which proposals for aggregate extraction can be assessed.
- Provide for appropriate mineral extraction to meet specialist needs.
- Safeguard mineral reserves from surface development.
- Encourage the use of secondary aggregates and recycling.
- Provide criteria for the assessment of proposals associated with minerals exploration.

The key components of the UDP Chapter 11 with respect to projected sand and gravel extraction in Herefordshire are that:

- the designated provision of sand and gravel in Herefordshire between 2001 and 2016 is 0.283 million tonnes per annum (as set by WMRAWP in RPG11/WMRSS policy M3, see 4.4.3 above).
- this estimated demand for sand and gravel aggregate is set against an existing permitted landbank (see section 4.3.8 outline of MPS 1, though note that the UDP derives from the concept as previously set out in the now obsolete MPG 6). The Herefordshire landbank equates to existing permissions totalling 5,950,000 tonnes. This consists of 5 quarries, with 4 of those (Wellington/Moreton, Lugg Bridge, Portway and Upper Lyde) within the Lower Lugg Valley (the other site is at Shobdon). The bulk of the landbank is at the Wellington/Moreton and Portway (St Donat's) sites (both of which were estimated in 2004 to have reserves of 2 million tonnes).
- the identified landbank therefore amply fulfills the requirement of the former MPG 6 (now MPS1, Annexe 1) for at least 7 years of permitted reserves beyond the end of the plan period in 2011, with 21 years of supply in place as at 1st January 2004.
- granting of permissions for quarrying beyond the permitted landbank would therefore only be considered if, due to unexpected circumstances, the regional apportionment cannot be met from that landbank source (see policy M3 below).

2.4.9 *The Herefordshire Unitary Development Plan Chapter 11, Minerals: Key policies*

The key minerals policies of the Unitary Development Plan Chapter 11 are set out as follows in the revised deposit draft:

M3 Criteria for new aggregate mineral workings

Planning applications for aggregate extraction will only be granted in exceptional circumstances, notably where the permitted aggregate reserves in the County for extraction prove insufficient to meet the county's sub regional apportionment. In such cases planning permission for extraction will only be granted where the site is not affected by one or more primary constraints or two or more secondary constraints unless the adverse effects on the constraints can be satisfactorily mitigated, or where the specialised nature of the mineral constitutes a material consideration sufficient to override the constraints, or there is no lesser constrained minerals bearing land elsewhere in the County.

Primary Constraints
1. Areas of Outstanding Natural Beauty;
2. Sites and species of international and national importance to nature conservation;
3. Scheduled Ancient Monuments and other archaeological sites of national or regional importance;

Secondary Constraints
1. Sites and species of local importance to nature conservation;
2. Groundwater Source Protection Zones 3 or Zones of Special Interest;
3. Land within or abutting a Conservation Area;
4. Archaeological constraints of lesser regional or more importance;
5. Where the site does not have access to an 'A' or 'B' class road;
6. The development would have an adverse visual impact on the landscape character of the area
7. Best and most versatile agricultural land
8. Ancient semi-natural woodland

Where a proposal satisfies the above constraints process, applicants will also be required to submit evidence to demonstrate the extent to which the development impacts on:
1. People and local communities;
2. Natural and cultural assets;
3. The highway network and other public Rights of Way;
4. Land stability;
5. Public open space;
6. Air, water and soil resources.

Unless such impacts can be satisfactorily mitigated, planning permission will be refused.

M7 Reclamation of mineral workings

Mineral extraction proposals will only be permitted where the proposed site can be restored to an agreed and beneficial use. Permission will only be granted where the proposed reclamation would be:

1. In scale and character with adjoining landscape and would make a positive contribution to meeting BAP targets;
2. Capable of being completed within a reasonable timescale;
3. Sufficiently detailed to achieve the proposed after use and its after care for an appropriate period. Proposals for the long term management of the site may be necessary.

Other policies potentially relevant to the Lower Lugg:

- M2 Borrow pits. Sets out conditions for excavation of local 'borrow pits' within the context of large civil engineering projects.
- M4 Non aggregate building stone and small clay production. Makes allowance for small scale clay extraction in the context of traditional landscape management, historic building repair and maintenance of local distinctiveness
- M9 Minerals Exploration. Sets out conditions for granting of permission for minerals exploration

2.4.9 *Permitted Development*

There is one additional category of permitted mineral extraction which is not controlled by this raft of legislation, guidance and local planning documents, and that arises from the Town and Country Planning (General Permitted Development) Order of 1995.

This essentially means that limited minerals extraction linked especially to agricultural management (both directly for land management purposes and indirectly in the context of works such as pond creation and agricultural building erection) may be permissible outside of the full minerals planning process, though not where production of mineral for commercial sale to third parties is concerned.

Although such works do not require full planning permission (subject to the constraints and exceptions specified in the Order), it is required that a period of notice is made to the Planning Authority.

2.4.10 *Prima facie conclusions*

For all the layered complexity of the planning framework – and the immediate confusion in local minerals planning terms because the 1997 Local Plan period has expired while the UDP Chapter 11 has not yet been adopted - the combined local and national planning structures do seem at face value to define a clear context for future quarrying activity in the Lower Lugg. In essence:

- It is a key requirement of national legislation and guidance that adequate levels of minerals supply should be maintained through (where possible) local production according to demand.
- The Lower Lugg is one of the principal resources of sand and gravel in Herefordshire. Given local production requirements and existing permissions, sustained quarrying will almost certainly continue in the Lower Lugg for the foreseeable future.
- The present pattern of planning constraints and conditions associated with environmental protection and concepts of sustainability (See MPS 1 and UDP Chapter 11 policies M3 and M7) confirms the historical/commercially driven trend towards preferential exploitation of the valley bottom sand and gravel deposits of the Lower Lugg. Indeed, it is unlikely, regardless of commercial practicality, that quarries in the traditional extraction areas on the raised outer terraces would now be able to satisfy transport, environmental mitigation, and restoration planning conditions. It is perhaps notable that the 'First List' quarry at Upper Lyde has yet to comply with modern ROMP conditions and so commence extraction.
- The combination of the 'First List' and the emphasis on extraction from permitted landbank deposits as determined against local demand requirements (UDP Chapter 11) means, in principle, that quarrying will be restricted to only four Lower Lugg sites at least until 2024. These are at Wellington/Moreton, Portway (St Donat's), Lugg Bridge, and Upper Lyde. Only in the 'exceptional circumstances' scenario where these sites could not meet identified demand would applications for new quarries be considered . The UDP does not anticipate that such a requirement will arise, though it does include policies against which additional applications would be determined.
- The principal threat of quarrying beyond the landbank is restricted to small scale operations for borrow pits and extraction under agricultural 'Permitted Development'.

2.5 Critical Analysis of Legislative and Planning Pramework

2.5.1 *Recent revision of national, regional and local planning frameworks*

A key complication in assessing minerals (and wider) planning issues at the present time is the still incomplete impact of the new national and regional planning processes arising from the Planning and Compulsory Purchase Act of 2004. As outlined above (**Section 2.4**), the Act has led to a new minerals planning structure associated with Minerals Policy Statements (MPS), Regional Spatial Strategies (RSS), and Minerals Development Frameworks (MDFs). However, in reality these have not yet fully replaced the previous national and regional planning and guidance frameworks. The old structure still explicitly survives in the remaining Minerals Planning Guidance (MPG) notes and Minerals Local Plan/UDP Chapter 11 documents, and implicitly remains in the reincarnation of Regional Planning Guidance 11 (RPG11) as the interim West Midlands Regional Spatial Strategy.

In theory at least, this process of change does not undermine the prevailing local development document arrangements. The Herefordshire UDP Chapter 11 will (following its adoption) be the identified reference point for local minerals planning for the next few years, and in any case it would probably not be practically possible to put in place a replacement Herefordshire Minerals Development Framework before the 2011 end of the UDP plan period. Moreover, since the structure of the UDP Chapter 11 is derived from the current West Midlands Regional Spatial Strategy (i.e. the renamed RPG 11), then in that sense it can be officially said to be properly in line with present national and regional minerals planning policy (and indeed to already effectively be an MDF by a previous name).

However, it is still hard to avoid the conclusion that the UDP Chapter 11 is in some ways compromised by the ongoing overhaul of the planning system. For example, the recent publication of MPS 1 and 2 directly replaces some of the earlier MPG framework on which the UDP is explicity based. The result must be a practical dis-juncture between the terms of the UDP and the terms of national policy, and these ambiguities will surely become further apparent as MPS and WMRSS structures are increasingly revised during the period the UDP is in force. It is not possible to define those effects at the present time, but it must ultimately be the case that the UDP Chapter 11 now offers less securely grounded definition of future minerals extraction patterns in Herefordshire than it did against the significantly different minerals planning context which obtained when the UDP process commenced.

2.5.2 *UDP landbank/demand equation*

It is important here to emphasise that the accuracy of the predictions on which the UDP Chapter 11 projects future aggregate production in Herefordshire is fundamental to whether or not the document provides a reasonable indication of the likely pattern of Lower Lugg sand and gravel extraction activity over the next two decades.

Firstly, the adequacy of the landbank to meet anticipated demand is only as good as the assumptions on which the production and reserve equation is based. It should be stressed that, although the 2003 regional sand and gravel allocation for the West Midlands is likely to be fixed at least for the medium term (nominally to 2016), the Herefordshire proportion of that is subject to annual review by WMRAWP.

The current Herefordshire allocation of 283,000 tonnes per annum is modest. It represents only 2.8% of regional production (see section 2.4.4), is negligible compared to counties such as

Staffordshire (6.6 million tonnes per annum/64.8% of regional total) and Warwickshire (1.03 million tonnes per annum/10.03% of regional total), and is the lowest projected production rate of any of the West Midlands counties (see WMRSS/RGG11 document). The historical reason for this is that Herefordshire is a rural county with limited aggregate demand. Moreover, since transport is one of the principal costs (financial and environmental) of aggregate production, distribution of Herefordshire aggregate to other parts of the West Midlands has not traditionally been considered commercially viable or environmentally acceptable.

However, it remains to be seen if this situation will remain true in the medium term. If future shortfalls/issues of sustainability of production become significant in the main aggregate producing counties, then increased extraction in Herefordshire (where production is currently low despite significant sand and gravel reserves) would be an obvious way to make up regional deficits. Local demand may in any case increase in line with economic growth in Herefordshire so requiring greater production for local needs. And, even if neither of these circumstances transpires, pro-active development of the local sand and gravel resource on the independent commercial initiative of the aggregate companies may still raise rates of local production over historical levels. It is important to realise that the regional allocation is effectively a projection of minimum production for overall regional planning purposes, not a constraint which prevents companies collectively producing over that level.

If, in any of these circumstances (or combinations of them), annual production exceeds the current predicted figure, then the existing landbank will be used up well before 2024, and new quarry areas will be required much sooner than currently predicted to continue to maintain future minimum production requirements.

Thirdly, the landbank itself is not necessarily absolutely fixed, but is based on current understanding of the volume of the mineral resource in the permitted areas (though the detailed information on which this assessment is based is not publicly available for reasons of commercial sensitivity). If the quality or extent of the mineral in the landbank does not meet expectation - and this may be especially relevant to the more geologically complex old drift/third terrace reserve at Portway (St Donat's) which amounts to a third of the current landbank - then new reserves will need to be found to meet allocation requirements. In fact, it should be noted (see 2.6.1 below) that since the Revised Deposit Draft of the UDP, the Lugg Bridge quarry has ceased production (although this was only a small part of the anticipated UDP period Landbank, and does not amount to a significant disruption of the UDP calculation).

Fourthly, it is also important to draw attention to the MPS 1 Annexe 1 statement on landbanks (see section 4.3.8 above) which has been published (November 2006) since the Herefordshire UDP Chapter 11 was written. This places an emphasis both on removal from the identified landbank of sites where extraction has not taken place for 10 years (e.g. Portway/St Donat’s in the Lower Lugg?) and in any event the need for annual review and revision by the MPA of the local landbank calculation. Moreover, MPS 1 Annexe 1 also notes that ‘a landbank of a few sites should not be allowed to undermine competition’ – a significant caveat which appears precisely relevant to Herefordshire where just 3 principal sand and gravel landbank sites (Portway/St Donat's, Wellington and Shobdon) are all in the hands of one operator (Tarmac).

So in the new light of MPS 1 Annexe 1, the UDP Chapter 11 treatment of landbank looks uncertain in two further ways. The UDP appears to fundamentally underplay the potential for the Lower Lugg landbank to diminish simply through revisions stemming from the straightforward application of national and regional planning policy. And it may be that, in the specific 'threes sites/one company' circumstances of sand and gravel extraction in Herefordshire, the landbank concept is in any case not actually a binding constraint on the opening of new quarries by any company other than Tarmac.

In essence then, the predictions of the UDP are based on a range of variables which are perhaps more complicated and less absolute than they first appear. Although it should be acknowledged that a series of objections questioning the Landbank equation were rejected by the UDP Inspector (Herefordshire UDP Inspectors Report 2006), it still seems that the nominal conclusion of the UDP that quarrying up to 2024 is most likely to be restricted the current permitted areas/landbank sites is actually far from certain. A scenario where applications for new quarries will arise well before 2024 (and maybe even within the 2011 UDP plan period) does need to be recognised as an entirely possible outcome of the current planning situation.

Ultimately, of course, it needs to be stressed that even in the UDP scenario, current landbank areas will only fulfil demand for the next 18 years. Clearly, in any circumstances, the next 50 years is likely to see significant additional quarry development in the Lower Lugg area.

2.5.3 *UDP abandonment of Preferred Areas*

In a scenario where new minerals planning applications are allowed in the short to medium term, it is also important to fully consider how the current planning system would or would nor constrain the target locations of those new applications.

An important corollary of the exclusive UDP emphasis on landbanks is that the previous 1997 Minerals Local Plan concept of Preferred Areas for future mineral extraction is implicitly held to be rendered obsolete. No preferred areas are defined in the UDP, and this strategy was upheld by the UDP Inspector in response to objections on this point (Herefordshire UDP Inspectors Report 2006). This means that, should the permitted landbank reserve prove to be inadequate, there is no stated planning pre-disposition to certain locations for the new quarries then needed to fulfil demand. On the adoption of the UDP, the location of new quarries will be determined purely by the incidence of commercially attractive mineral deposits and the constraints of the minerals planning policy framework.

This effectively means, *vis a vis* the 1997 Local Plan, an expansion of the future areas in the Lower Lugg where quarrying might be envisaged. For all the reasons outlined above, it does seem likely that future aggregate extraction activity will be limited to the valley bottom/flood plain zone between Bodenham and Lugg Bridge (the Lugg Meadows area south of Lugg Bridge being excluded by Herefordshire Nature Trust ownership and SSSI status). However, under the UDP, there is no obvious restriction on development of new quarries anywhere in that area, including the suite of old application sites (Bodenham, Pentall's Farm, Wergin's Bridge and areas north and west of Lugg Bridge, Figures 8 and 9) rejected back in the 1980s.

Of course, it must also be stressed that where preferred area status privileged the probability of successful planning applications, the pending *de facto* larger area where quarrying may become possible under the UDP has no such pre-disposition. Just because it may become realistic to make applications across a broader area than previously does not mean one or any of those applications will necessarily be successful when subject to assessment against detailed planning criteria (although the obligation to maintain supply effectively means that permission would have to granted somewhere).

As a final point, it should also be noted that the omission of preferred areas does again seem to leave the Herefordshire UDP at odds with the recently published MPS 1 document, where the preferred area concept is re-emphasised as ‘a means to provide greater certainty of where future sustainable minerals working will take place’ (MPS 1, 2006).

2.5.4 *Archaeological resource management and UDP policies M3 and M7*

The abandonment of preferred areas in a sense also means that the precise criteria for determining permission are that much more important under the terms of current UDP policy (especially for quarry companies trying to make commercially practical judgements about where to invest in applications with the best chance of success). This is perhaps especially relevant to archaeological resource management. Although sites of archaeological interest are defined as both primary and secondary constraints on granting of minerals planning conditions under UDP policy M3, the way those constraints are phrased poses considerable issues for their effective implementation, especially in the context of the Lower Lugg valley bottom area.

As the findings of other sections of this research assessment emphasise, understanding of the archaeology of the Lower Lugg alluvium is, beyond the Wellington excavated area, limited to relatively late surface features. Methods of effective archaeological sub surface prospection of the alluvium in advance of aggregate extraction are still of uncertain effectiveness. In other words, much of the likely future extraction areas remain devoid of visible archaeology, and only generalised predictions can be offered at this stage of likely categories of discovery (significant though the archaeological potential certainly is). However, this absence of hard evidence would make it very difficult to meaningfully effect in-situ preservation of the resource under UDP policy M3. In effect, the very areas where new quarrying is most likely to occur are those where current data would suggest there is least clearly definable archaeological interest under the terms of M3. This may be good news for quarry companies seeking to target the most 'objection free' areas, but it is bad news for the archaeological resource.

Moreover, even if archaeology is identified (or can be located by improved methods of evaluation), M3 focuses on defining the value of that archaeology in terms of its perceived local and national significance. Beyond Scheduled Monument Consent designation, there is no currently agreed format for determining such significance. The relevant sections of this resource assessment offer a preliminary attempt to do that, but it remains to be seen if such evaluation would be deemed to be sufficiently rigorous/defensible in the planning context.

The net result is that, in the Lower Lugg valley bottom area in particular, UDP Chapter 11 policy M3 effectively places far less weight on the value of archaeological factors than other criteria (especially those linked to natural environment) in determining minerals planning applications.

It should also be noted that policy M7, concerning restoration of mineral workings, makes no mention of archaeology or the historic environment (which absence is also repeated nationally in the recent MPS 1 document). While this omission presumably implicitly reflects the fact that the archaeology is destroyed by the quarrying activity, it also places no value on interpretatively referencing that destroyed resource as part of the reclamation process. This also effectively means that archaeology (and the whole accumulated history of the managed landscape before the inception of quarrying) has no significance placed upon it in terms of this component of determining a minerals planning application.

2.5.5 *Additional circumstances of permitted aggregate extraction*

Against the issue of large scale commercial quarrying (which is controlled by the national, regional and local minerals planning framework) it would be easy to discount the importance of the other circumstances where mineral extraction may occur, specifically associated with UDP policies M2, M4 and M9 and with agricultural Permitted Development.

However, these are important in the Lower Lugg with specific respect to archaeological resource protection. It is these categories of mineral exploitation which may result in continuing mineral extraction beyond the flood plain deposits, including occasional use of the 'old' quarry areas. Although borrow pit and local clay extraction would nevertheless be controlled within the established Development Control planning process (including potential for archaeological evaluation/recording), it should be noted that agricultural Permitted Development minerals extraction is potentially less easily mitigated by this mechanism.

2.5.6 *Conclusions*

- The valley bottom/flood plain area of the Lower Lugg will remain a zone of significant aggregate extraction into the foreseeable future.
- The immediate emphasis will be on the permitted landbank sites at Wellington/Moreton and Portway (St Donat's), plus the small quarry at Upper Lyde (subject to fulfillment of ROMP conditions).
- The UDP Chapter 11 assumption that this reserve will be sufficient to fulfil demand until 2024 remains to be seen (especially in the recent light of MPS 1), and there is a good chance that new quarries will be required to meet demand well within that period.
- Subject to assessment against the detailed planning process, the UDP Chapter 11 abandonment of the preferred area concept means that the whole Lower Lugg valley bottom area between Bodenham and Lugg Bridge appears to be potentially open to future quarry development.
- The UDP Chapter 11 effectively places limited value on archaeology in determining minerals planning applications, especially in the particular context of the Lower Lugg valley bottom area.
- It is possible that some small scale minerals extraction may continue outside the valley bottom zone, specifically in association with activity under agricultural Permitted Development.

2.6 Current Quarrying in the Lower Lugg Valley

2.6.1 *Development of quarrying in the Lower Lugg since 1990 (Figures 10 and 11****, Section 7.1****, Quarry Tables 5 and 6)*

Wellington/Moreton Under Redland and then Lafarge, the 1987 and 1989 northern and western extensions were subject to continued working through the 1990s. A further large extension incorporating the area of the former Moreton military camp was given permission in 2003, while the site was purchased in 2005 by Tarmac. Tarmac have undertaken considerable re-investment, and under a 2005 permission have built a rail transhipment facility, as well as adding a breeze block manufacturing plant to the original washing plant. The railway transhipment facility is currently primarily used to import material from the Shobdon quarry for breeze block manufacture. It should also be noted that a planning application for a further large extension to the south (incorporating the preferred area defined in the 1997 Hereford and Worcester Minerals Local Plan) has recently been submitted, though may need to be re-submitted before being considered by the MPA. The total amount of landbank reserve (including the latest application area) is (according to the figures in the UDP) 2 million tonnes.

Lugg Bridge Operated by Ready Mix Concrete/Cemex, Lugg Bridge has been the other major active operation in the last 15 years. The original 1990 permission was subject to revision in 1994, while a northern extension was granted in 1995, with permission further revised and updated in 1998 and 1999. An application for a large western extension was withdrawn in 2003, although two areas to the north were noted as being under RMC control in 1999 (though no planning applications have arisen relating to these). The quarry ceased operation in 2005, at which point the ROMP process would have required submission of an Environmental Impact Assessment for further renewal. Although it is not clear from available data if the existing quarry is held to be 'worked out', the failure to renew the permission in 2005 (as required by the conditions of the 1999 renewal) does mean that any resumption of quarrying at Lugg Bridge would require a completely new application effectively as a fresh site.

Portway (St Donat's) The permission was renewed under ROMP in 2004, though quarrying cannot commence there until an adequate site access is made. The site was purchased by Tarmac from Lafarge in 2005 (along with Wellington), and at the time of writing work is commencing on the new access route. It is unclear if this is being done to maintain the permission against ROMP requirements, or with a view to actual commencement of quarrying under the new owners. The site is stated in the UDP to have landbank reserves of 2 million tonnes, but because of the geological context on the old drift/third terrace, the quality and consistency of the mineral may be commercially problematic. This perhaps explains why quarrying has not yet commenced against a permission first granted in 1989, although Tarmac's recent purchase was presumably based on an informed view that the site is commercially viable.

Upper Lyde Relating to an original permission of 1965, the quarry was placed on the 'First List' in 1998. Owned by Hussar Minerals, the site is small by modern standards, with an estimated reserve of only 210,000 tonnes. It is again associated with potentially less commercially viable old drift deposits, and cannot go into operation before ROMP conditions (relating to environmental impact and site access) have been satisfied. Quarrying does not seem likely to commence in the immediate future.

2.6.2 *Critical analysis of recent quarrying trends*

The purchase of Wellington/Moreton and Portway (St Donat's) by Tarmac, combined with the cessation of activity at Lugg Bridge, effectively gives Tarmac a monopoly on current aggregate production in the Lower Lugg (and in Herefordshire as a whole since they also operate the quarry at Shobdon). The re-investment in Wellington in particular seems to be connected to scaling up the rate of extraction at the site compared to the pattern of operation employed by Redland/Lafarge during the previous 20 years (although there are no hard data available to support this assertion).

In addition, the construction of the rail interchange facility at Wellington is a potentially significant development. Although the immediate purpose is to permit import of aggregate from Shobdon for secondary treatment at the Wellington plant, it clearly also facilitates over the longer term increased capacity for export of mineral products. Moreover, it evidently also offers a more environmentally friendly (and cost effective) mechanism for bulk removal of mineral products away from the Lower Lugg. As such, this is an improvement which explicity fulfils the recently published MPS1 Bulk Transportation policy with its stated emphasis on the desirability of rail transport of minerals products (see section 2.4.3).

These changes perhaps help to confirm the fragility of some of the UDP assumptions with respect to the future sand and gravel landbank/local demand provision in Herefordshire. The re-development of Wellington, and the use of the rail transhipment facility appear to make it commercially viable to increase production of aggregate from Tarmac's local holdings (which now effectively represent the whole Herefordshire landbank), to export mineral products to markets beyond Herefordshire, and to use up the landbank at a rate well beyond the UDP predictions. What is more, the 'green' credentials of the rail transhipment process in the Lower Lugg *vis a vis* other regional aggregate producing areas still reliant on road transport could support an argument (directly underpinned by the MPS 1 Bulk Transportation policy) that Herefordshire can and should now supply a greater proportion of the allocated West Midlands production target than has hitherto been the case.

What can be certainly said is that, even before the UDP is adopted, the context of local quarrying is already different to that assumed by the UDP Final Deposit Draft. The precise outcome in terms of future production patterns remains to be seen, but the idea that there will be no justification for new quarries in the Lower Lugg before 2024 looks highly questionable. Tarmac’s pro-active transport and infrastructure development of the Wellington site in exact fulfilment of recently stated Government policy (and in close proximity to an additional vast commercial resource of sand and gravel) could very well be the beginning of a rather different story.

Figure 10: Current quarries in the Lower Lugg Valley (permitted area/landbank within the Herefordshire UDP)

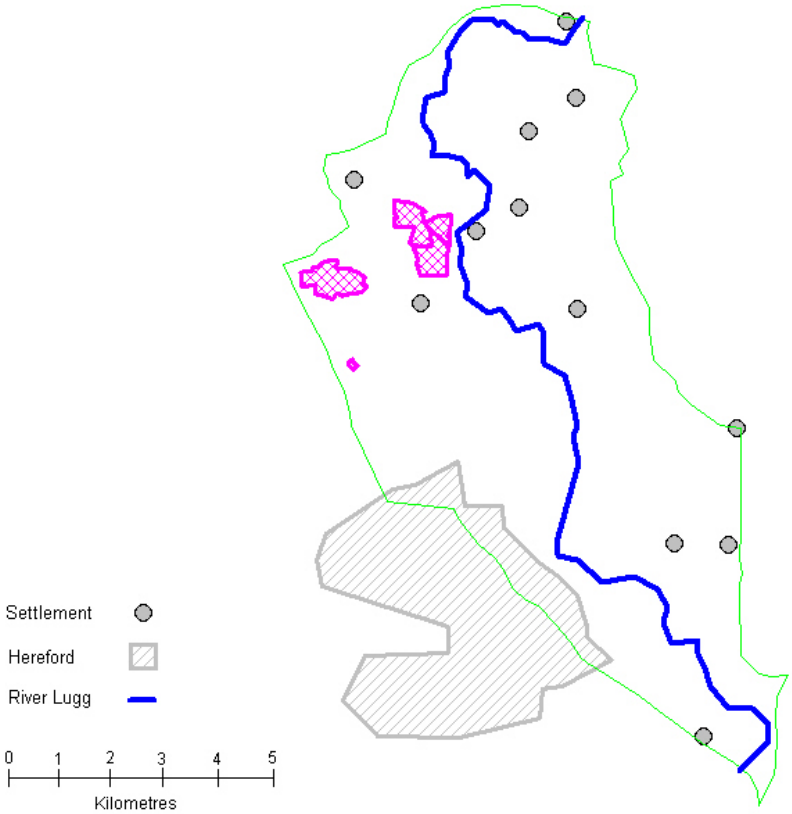
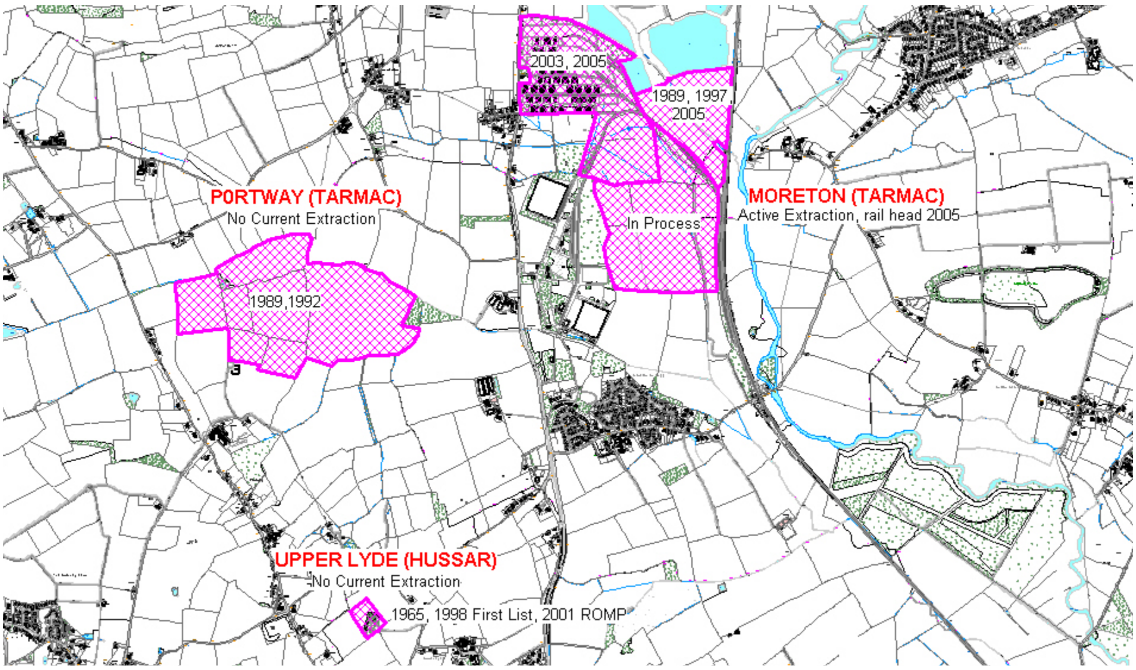


Figure 11: Current quarries in the Lower Lugg Valley (detail)



2.7 Aggregate Extraction Context Overall Conclusions

2.7.1 *The archaeology of quarries in the Lower Lugg Valley*

- **There is a rich and distinctive resource of sand/gravel and clay quarrying remains in the Lower Lugg valley, with the main areas of historic activity exploiting the geologically older deposits associated with the raised valley margins.**

- **This resource has not been subject to systematic analysis of its archaeological character and chronological development. There is considerable potential for identification and investigation of early quarrying activity in the area, including pre 19th century clay industries.**

2.7.2 *Present status and future development of Lower Lugg Valley quarrying*

- **Major mineral extraction will continue in the Lower Lugg in the foreseeable future, initially associated with the existing permitted/landbank sites at Wellington/Moreton and Portway/St Donat's (the latter yet to commence production). The additional small permitted/Landbank site at Upper Lyde (First List) does not seem likely to commence production in the immediate future.**

- **The geological character of the Lower Lugg mineral resource, commercial constraints, and the national and local minerals planning framework, strongly suggest that future minerals extraction will be focussed on the valley bottom mineral deposits between Bodenham and Lugg Bridge.**

- **Although the pending 'Herefordshire UDP Chapter 11: Minerals' predicts no requirement for new quarries before 2024, large scale expansion of quarrying in the valley bottom zone is possible (and likely) well before that.**

- **In any scenario, it is reasonably predictable that significant extraction of the remaining valley bottom sand and gravel resource will occur in the next 50 years.**

2.7.3 *Archaeological resource management implications*

- **The principal threat to the archaeological resource from quarrying is associated with the clearly defined flood plain zone between Bodenham and Lugg Bridge.**

- **Current recognition of archaeological issues within the local minerals planning process (pending UDP Chapter 11: Minerals policy M3) is unlikely to permit effective protection of the resource 'in situ' in the specific context of this zone.**

- **There remains a small scale (but unpredictable) aggregate extraction threat to the archaeological resource in the valley margin areas principally associated with agricultural Permitted Development.**

- **There is no current planning policy provision for recognition of the historic environment in quarry after-use proposals.**

- **The eventual revision of the UDP Chapter 11 to create a new Minerals Development Framework for Herefordshire will create the opportunity in the medium term to further influence local minerals planning structures with respect to archaeological resource management.**

3.1 Critical Review of the Geology, Pedology and Geomorphology of the Lower Lugg Valley

3.1.1 *Introduction*

This report provides a critical review of the known geological, pedological and geomorphological information pertaining to the Lower Lugg study area. The report is split into two main parts with geological and pedological data sources being reviewed in sections 3.1.2 to 3.1.4 and Pleistocene and Holocene geomorphological information being reviewed in sections 3.1.5 to 3.1.8. Sections 3.1.2 and 3.1.3 summarise the known information relating to the bedrock geology and the superficial geology of the study area. Section 3.1.4 summarises the principal soil associations in the Lower Lugg study area, while section 3.1.5 concludes with a critical evaluation of the geological pedological data sources consulted. Published and unpublished information on the Pleistocene and Holocene geomorphology of the study area is then summarised and critically assessed in sections 3.1.5 and 3.1.6. The report ends with an outline of the substantive conclusions that can be drawn from the reviewed data sources (section 3.1.8).

Geology and Pedology of the Lower Lugg Study Area

3.1.2 *Bedrock Geology*

The bedrock geology of the Lower Lugg study area is relatively simple and is summarised here using BGS 1:50,000 digital map data (Sheet 198) and the accompanying memoir produced by Brandon (1989) as the principal sources. The study area is located on the Plain of Hereford, which is underlain by the Lower Old Red Sandstone of the Upper Silurian and Lower Devonian. The vast majority of the study area is occupied by a lowland landscape that is underlain by the easily weathered Upper Silurian and Lower Devonian bedrock of the Raglan Mudstone Formation (Figure 12). The succession of the Raglan Mudstone Formation comprises a repetitive sequence of fining-upward cycles of sandstones and mudstones with calcretes. Brandon (1989) indicated that sandstone generally forms about 10% of the succession. The eastern and western flanks of the study area are framed by the Raglan Mudstone whilst the lower lying central area, principally consisting of the Lugg valley floor, is capped by superficial glacial, periglacial and fluvial deposits from the Quaternary.

To the north and east, the study area is fringed by an undulating plateau made up of the more resistant bedrock of the St. Maughans Formation (Figure 12). The younger Devonian St. Maughans Formation overlies the Raglan Mudstone and similarly consists of mudstones, sandstones and calcretes but here the sandstones make up 25-30% of the sequence and the cycles are generally thinner (Brandon 1989). Because of the higher proportion of sandstone, the formation is generally more resistant to erosion than the Raglan Mudstone and, as a consequence, it forms the higher ground to the north and east of the study area. The northern boundary of the study area is delineated by Dinmore Hill, which is composed of the more resistant mudstone/sandstone mix of the St. Maughans Formation. The bedrock ridge that includes Dinmore Hill dominates the local landscape in the northern part of the study area and extends eastward, forming the elevated plateau around Bromyard.

The other notable variation in bedrock geology is found on the south eastern margin of the Lower Lugg study area where the Woolhope Dome rises sharply above the Raglan Mudstone Formation at Mordiford (Figure 12). The Woolhope Dome principally consists of Silurian limestones (e.g. Woolhope Limestone Formation), shales (e.g. Upper Ludlow Shales Group) and sandstones (e.g. Haugh Wood Formation; Brandon, 1989) and, like Dinmore Hill in the northern part of the study area, it dominates the southern landscape at the confluence between the River Lugg and the River Wye.

3.1.3 *Superficial Geology*

In this section, the superficial deposits of the Lower Lugg study area are described in general terms as the Quaternary geomorphology of the area is outlined in greater detail in sections 3.1.5 to 3.1.6. The nature and distribution of superficial deposits in the study area are summarised here using BGS 1:50,000 digital map data (Sheet 198) and the accompanying memoir produced by Brandon (1989) as the principal sources.

Much of the lower lying land in the study area, which principally consists of the Raglan Mudstone Formation, is overlain by superficial glacial, periglacial and fluvial deposits dating from the Pleistocene and the Holocene. Brandon (1989) categorised these superficial deposits into four groups based on their relative age. The oldest of these groupings, the 'Older Drift', mostly occurs to the east of the River Lugg as small relict areas of till and outwash gravels from a pre-Devensian glaciation. The second oldest group consists of remnants of a flight of four gravel terraces of the River Lugg. The third group, the 'Newer Drift' is the product of the last glaciation. This left extensive deposits on the western margins of the study area and largely obliterated evidence of the earlier glaciation. This glaciation was of Late Devensian age, lasting from about 26,000 to 14,000 years ago. Its deposits include tills, gravels of various types and substantial solifluction (head) deposits that formed beyond the ice margins. The youngest group of Quaternary sediments, including river alluvium, colluvium and peat, belongs to the post-glacial Holocene epoch, dating from about 11,500 years ago to present.

Group 1 - Older Drift Deposits

The oldest superficial deposits in the Lower Lugg study area include isolated sheets of glaciofluvial gravels thought to be the deposits of a single pre-Devensian glaciation. They form hill cappings or patches on hillside benches or spurs and were formerly widespread but have largely been obliterated by the subsequent Late Devensian glaciation. The principal deposits mapped on the BGS 1:50,000 scale digital map (Sheet 198) are found immediately west of the road bridge at Bodenham, west of Wellington on Adzor Bank and the most extensive mapped unit is in the Burghill area at the western margin of the study area (Figure 13). The greater weathering and dissection of these deposits, their relatively high base level, and their relationship with Devensian deposits make it clear that they are older than the deposits ascribed to the Late Devensian glaciation. It is thought that only periglacial conditions resulted from the generally cold climates of the Early and Middle Devensian, and in view of the uncertain status and possible limited extent of the penultimate 'Wolstonian' glaciation, it is believed that these 'older drift' deposits are more likely to belong to the even earlier Anglian glaciation – making them more than 400,000 years old (Richards, 2005).

Group 2 - Devensian River Terrace Deposits

South of Bodenham and beyond the Late Devensian ice limit, the remains of four gravel terraces have been identified in the Lower Lugg study area. Each terrace remnant rests on bedrock and is part of a formerly widespread aggraded sheet. The individual remnants are well separated vertically (Table 1) and, in general, the higher the terrace the more it is dissected and the more widely distributed are the remnants. The 4th Terrace, the Sutton Walls Member, is the highest and oldest of the terraces and remnants of it have been identified and mapped as a capping layer on the hill at Sutton Walls, in the north west of the city of Hereford and the largest expanse is located immediately north east of Lugwardine (Figure 13). The 3rd Terrace, the Kingsfield Member, can be found in patches on the western slopes of the Lugg valley between Bodenham and Marden, with further isolated patches mapped north of New Court

Table 1: Details of the Devensian terrace deposits in the Lower Lugg Valley (after Brandon, 1989; Maddy, 1999; Richards, 2005).

Terrace	Name	Maximum thickness	Height of base above OD		Estimated age	
			Bodenham	Bodenham	OIS*	yrs BP
4th	Sutton Walls Member	7.6 m	77 m	95 m **	10	~ 350,000 - 340,000
3rd	Kingsfield Member	3 m	65 m	79 m	8	~ 300,000 - 250,000
2nd	Moreton on Lugg Member	6 m	54 m	69 m	6	~ 190,000 - 130,000
1st	Marden Member	2 m	57 m ***	66m	4	~ 75,000 - 60,000

* oxygen isotope stage; ** at Sutton Walls; *** at Moreton on Lugg

and on the edge of Hereford (Figure 13). The 2nd Terrace, the Moreton on Lugg Member, is better preserved than the 3rd and 4th Terraces and occurs relatively frequently on the lower slopes along the eastern edge of the Lugg valley. It is particularly prevalent between Bodenham and Marden but significant remnants have also been identified immediately south east of Sutton St. Nicholas, north west of New Court and also, to the west of the River Lugg, at Moreton on Lugg (Figure 13). The 1st Terrace, the Marden Member, is less well preserved than the 2nd Terrace, probably because it lies within a few metres of the present floodplain and was either removed by meltwater flooding during the last glaciation or obscured by subsequent outwash gravels. The principal remnants of the 1st Terrace are located at Bodenham, at The Vern, adjacent to the River Lugg at Marden and immediately south east of Moreton on Lugg (Figure 13).

The relative ages of these terraces are clear due to their differences in elevation but Brandon (1989) indicated that there is little evidence of their absolute ages. Richards (2005) argued that the terraces were likely to be deposited during four separate phases of aggradation during Pleistocene Cold Stages and that they represent the deposits of a much larger Lugg river system that existed between the Middle Pleistocene and Late Pleistocene glaciations. In the absence of absolute dating control, Maddy (1999) used correlations with deposits in the Wye valley and valleys to the west and south of the Malvern Hills to ascribe approximate ages to the four Lugg terraces. He suggested that the 4th Terrace dates from oxygen isotope stage 10, the 3rd Terrace dates from oxygen isotope stage 8, the 2nd Terrace dates from oxygen isotope stage 6 and the 1st Terrace dates from oxygen isotope stage 4 (Table 1).

Group 3 - Newer Drift Deposits

Brandon (1989) categorised superficial deposits associated with the last, Late Devensian, glaciation as Newer Drift. These deposits are widespread in the study area although they are commonly overlain by more recent postglacial sediments. They mantle valley floors, hillslopes and interfluves alike, and largely retain their glacial and glaciofluvial geomorphology. Deposits present in the study area that are associated with the last glaciation include till, moraines, sheets of outwash gravels and solifluction (head) deposits.

Within the limits of the study area, glacial till is chiefly located in the vicinity of Wellington on the western edge of the Lugg valley floor. Brandon (1989) suggested that this deposit is probably an ablation till, laid down during deglaciation. Hummocky topography, kettle-kame moraine deposits are located in isolated patches of the study area to the north of Wellington and running roughly between Burghill and Hereford at the south west extremity of the study area (Figure 13). Glaciofluvial sheets of Late Devensian sand and gravel are distributed throughout much of the study area and underlie much of the modern alluvium on the Lugg valley floor. The glaciofluvial sheet deposits also occur at the surface on the periphery of the existing valley floor with substantial tracts located on the western valley edge in the Wellington area, on the eastern valley edge around Bodenham, The Vern and at Lugg Meadows (Figure 13). Periglacial solifluction (head) deposits are distributed widely within the study area and occur in often substantial patches at the foot of valley slopes. They are particularly prevalent on the eastern slopes of the Lugg valley and in association with tributary systems such as the Little Lugg and the Frome (Figure 13). On the BGS 1:50,000 maps these periglacial deposits are not differentiated from more recent Holocene colluvial deposits due to the difficulty of distinguishing the two in the field.

Group 4 - Superficial Holocene Deposits

The most dominant superficial deposit in the study area associated with the Holocene is riverine alluvium (Figure 13). Holocene fluvial deposits in the Lower Lugg study area are extensive and cover the width of the river's considerable valley floor, capping substantial deposits of gravel. The fine-grained overbank alluvium is commonly 2 - 3 m thick and is, for the most part, comprised of fairly homogenous, stoneless, fine sandy to clayey silt with a uniform reddish brown colour derived from the Lower Old Red Sandstone. Brandon (1989) suggested that the top 0.5 – 1.0 m of gravels on the Lugg valley floor may also be attributed to the Holocene, having been reworked by the river in this time.

Colluvium is likely to represent the second most significant Holocene deposit in the Lower Lugg study area. These deposits are typically found at the base of valley slopes and are likely to be particularly prevalent in those areas where the valley sides are steep. In the case of the Lower Lugg, this means that the most extensive deposits of Holocene colluvium are likely to be found in tributary valleys such as the Little Lugg. As has previously been indicated, Holocene colluvial deposits are not differentiated from Late Devensian solifluction (head) deposits on the BGS 1:50,000 digital map (Sheet 198) due to the difficulty of distinguishing between the two types of deposit in the field.

Significant accumulations of peat within the study area do not appear on the BGS 1:50,000 digital map (Sheet 198). Brandon (1989) suggested that peat was once a widespread deposit in the study area but intensive drainage schemes and modern agricultural methods have led to its removal in all but a small number of sites. The most significant accumulations of peat may be expected to be found today within palaeochannels on the Lugg valley floor. This suggestion is supported by local investigations undertaken by Dinn and Roseff (1992) and Jackson and Miller (2004) who reported the presence of well-developed peat layers within palaeochannels excavated in the Wellington Quarry area.

3.1.4 *Pedology*

Data sources relating to the soils of the Lower Lugg study area are relatively sparse and, as a consequence, this summary largely draws on information obtained from the 1:250,000 scale map (Sheet 2) produced by the Soil Survey of England and Wales and the technical guide authored by Ragg *et al*. (1984). In an earlier review of the Lugg catchment, Terra Nova (2002) indicated that the distribution of the principal soil associations correlates strongly with the bedrock and superficial geology, the topography and the hydrology of the Lower Lugg study area. Typical argillic brown earth soils have developed on the elevated bedrock of the Raglan Mudstone Formation, whilst typical alluvial gley soils and typical brown alluvial soils dominate lower lying valley floor environments, with typical stagnogley soils occurring occasionally on gently sloping ground composed of glacial till.

In all, the 1:250,000 scale map (Sheet 2) produced by the Soil Survey of England and Wales indicates the presence of six principal soil associations, described by Ragg *et al*. (1984), in the Lower Lugg study area.

<u>811c - Hollington</u>

The Hollington association occupies much of the Lugg valley floor in the study area, providing deep, stoneless, reddish, fine silty and clayey alluvial soils. Typical alluvial gley soils of the fine silty Hollington series are dominant but, north and east of Hereford, clayey soils of the Compton and Clyst series are more common on the broad meadows. Soils of the Hollington association often suffer from winter and spring floods which restrict their land use and, as a consequence of this risk of flooding and the difficulty of working wet, heavy soils, they are usually under permanent grassland.

<u>561b - Teme</u>

Principally found at the southernmost limit of the study area where the Lugg valley floor merges with that of the Wye, the Teme association comprises deep, permeable, fine silty, typical brown alluvial soils. Most of the soils are well drained in this area because stream levels are as much as 3 m below the floodplain and the permeable deposits locally rest on gravels. Despite this, the soils of the Teme association can occasionally become waterlogged due to flooding, particularly in winter. Where the soils are protected from flooding by embankments they can produce valuable agricultural crops but, where embankments are not present, permanent grass is usually grown as it is least damaged by floods.

<u>561d - Lugwardine</u>

The Lugwardine association, dominated by typical brown alluvial soils, occupies much of the valley floor in the northernmost part of the study area around Bodenham. Reddish, fine silty soils, which are uniformly deep, stoneless and permeable, have developed in the thick riverine alluvium. Unless they are protected by embankments, the Lugwardine soils in this area of the Lugg valley are subject to winter and spring floods and, as a consequence, these naturally fertile (but slightly acidic) soils are most commonly under permanent grassland.

541w - Newnham

Located in patches on the margins of the Lugg valley floor (e.g. around Wellington, south east of Sutton St. Nicholas, east of Hereford), the Newnham association includes reddish and occasional brownish, mainly well drained soils that develop principally on river terrace deposits. The association is dominated by reddish, coarse, loamy typical brown earth soils of the Newnham series. The soils can be quite stony and they often rest on gravel at relatively shallow depth, which helps to ensure they are well drained. The development of coarse, loamy soils on level terrace surfaces encourages cultivation and soils of the Newnham association are extensively used for cereals, although fruit and potatoes are also locally important in the Lugg valley.

711k - Vernolds

Soils of the Vernolds association occur as isolated patches on the western margins of the Lugg valley floor (e.g. between Wellington and Moreton on Lugg) and are generally restricted to the bottoms or lower slopes of partially enclosed hollows or depressions. They develop on gently sloping ground that is often composed of till and are mainly reddish brown, fine silty, slowly permeable soils. The association is dominated by the Vernolds series, which is a typical stagnogley soil. Their slowly permeable subsoil means they can often be waterlogged during winter months and they are most commonly covered with permanent grassland.

571b - Bromyard

The Bromyard association dominates the higher ground and effectively frames the soil associations found on the lower slopes and the valley bottoms in the study area. Consisting of typical argillic brown earths, soils of the Bromyard association closely reflect the underlying bedrock. Most commonly in the Lower Lugg they are well drained, reddish, fine silty soils developed over mudstones but occasionally they can be coarse, loamy soils where they develop over sandstones. Although they can be susceptible in places to short-term waterlogging in winter, they provide ground conditions that are suitable for mixed farming.

3.1.5 *Evaluation of the Geological and Pedological Data Sources*

Relatively few data sources were found concerning bedrock geology and soil associations in the Lower Lugg study area but sources relating to superficial geology were greater in number. All the information sources consulted have been published and are in the public domain. This includes all of the literature and map sources (both paper and digital formats) produced by the British Geological Survey and the Soil Survey of England and Wales. The critical evaluation of data sources pertaining to bedrock geology, superficial geology and pedology are outlined in turn below.

Bedrock Geology

The bedrock geology of the Lower Lugg study area is relatively simple and, as a consequence, it is well understood. The straightforward nature of the bedrock geology means that the limited number of information sources available in this field has not had an adverse impact on our level of understanding. The published BGS 1:250,000 scale map (52N 04W Mid-Wales and Marches) and BGS 1:50,000 scale map (Sheet 198) are available in both paper and digital formats (the digital 1:50,000 scale map is incorporated in the Lower Lugg Valley GIS Database) and provide comprehensive coverage of the bedrock geology in the study area. The

1:50,000 map sheet is also accompanied by the memoir authored by Brandon (1989). The commentary supplied by Brandon (1989) is thorough and provides good quality information, based on field observations, which complements and enhances the 1:50,000 digital map data. Despite the limited number of sources, the available BGS maps and the commentary provided by Brandon (1989) means that our current understanding of the bedrock geology of the Lower Lugg is very good and compares favourably with the knowledge of bedrock geology elsewhere in Britain.

Superficial Geology

Superficial geological deposits in the Lower Lugg study area have been the subject of considerable attention from a number of well-qualified researchers. In the first instance, the published BGS 1:50,000 scale map (Sheet 198) is available in both paper and digital formats (with the digital version being incorporated in the Lower Lugg Valley GIS Database) and provides detailed information on the distribution of superficial geological deposits in the study area. Brandon (1989), in the memoir that accompanies the map sheet, provides an excellent commentary on the nature of the surficial deposits, particularly those that date from the Pleistocene. Deposits dating from the Holocene, which occupy a substantial proportion of the surface of the Lower Lugg study area, are not described in the same level of detail. The relative lack of attention devoted to Holocene surficial deposits, however, is a shortcoming that is evident in BGS descriptions and interpretations of superficial geology elsewhere in Britain.

Research conducted in the study area in the last 15 years, most notably by Richards (1994; 1997; 1998; 1999; 2005) and, to a lesser extent, Maddy (1997;1999), provides good quality information relating to the nature and distribution of Pleistocene glacial and fluvial deposits. Unfortunately, the PhD thesis produced by Richards (1994) could not be obtained for this review but publications arising from his doctoral research suggest it would be a valuable source worth consulting. If a small collection of literature sources is to be collated and gathered as a Lower Lugg library resource, then efforts to secure a copy of this thesis should be made. In all, the investigations reported by Brandon (1989), Maddy (1997; 1999) and especially Richards (1994; 1997; 1998; 1999; 2005) means that the distribution and nature of superficial geological deposits, particularly those dating from the Pleistocene, are better understood in the Lower Lugg study area than they are in many other parts of Britain.

Pedology

Collating material for the summary of pedological conditions in the Lower Lugg study area was similar to the collation of bedrock geology sources in that only a limited number of data sources could be found. Those sources that were obtained, namely the 1:250,000 scale map (Sheet 2) produced by the Soil Survey of England and Wales and the technical guide authored by Ragg *et al*. (1984), provided good quality baseline information on soil associations and, to a lesser degree, soil series in the study area. The coarse scale of the map consulted, its unavailability in digital format and the lack of 1:25,000 scale coverage of the study area can all be cited as shortcomings, as can the regional nature of the Ragg *et al*. (1984) volume (it describes soil associations found throughout midland and western England). It is suggested, however, that the pedological information sources relating to the Lower Lugg study area, although limited in number and scope, provide good quality baseline information and are comparable to those that can be found in most other areas of Britain.

Geomorphology of the Lower Lugg Study Area

3.1.6 *Pleistocene Glacial History and Drainage Network Evolution*

The Pleistocene geology and geomorphology of the Lower Lugg area have been studied by a number of investigators. A particular focus for this research has been the nature and extent of Pleistocene glaciations in the area and the impact these have had on the evolution of the Lugg drainage network. Investigations in this area have been conducted by numerous researchers: Pocock (1925); Dwerryhouse and Miller (1930); Luckman (1970); Cross and Hodgson (1975); Brandon (1989); Hey (1991); Barclay *et al*., (1992), Maddy (1997; 1999); Coope *et al*., (2002); and, most notably, Richards (1994; 1997; 1998; 1999; 2005). These investigations are the principal sources that contribute to our current understanding of the Pleistocene geomorphological development of the Lower Lugg study area. The summary presented here is largely taken from the comprehensive review of this topic provided by Richards (2005).

Herefordshire may have been glaciated on numerous occasions during the Pleistocene but geological and geomorphological evidence can only be used to document the incursions of two ice masses (Richards, 2005). The first of these occurred around 430,000 years ago during the Anglian Cold Stage (OIS 12) in the Middle Pleistocene (Figure 3; Richards, 1998; Coope *et al*., 2002). Evidence for glaciation at this time within the Lower Lugg study area is found in the form of the glaciofluvial deposits that Brandon (1989) termed the 'Older Drift' and is outlined in Section 2.2. The second glaciation took place during the Late Devensian Dimlington Stadial (OIS 2) approximately 18,000 years ago (Brandon, 1989; Richards, 2005). The widespread deposits from this glaciation can be found across much of the study area and were termed the 'Newer Drift' by Brandon (1989; see section 3.1.4).

Evidence for Pleistocene Cold Stage fluvial systems has also been found in the form of terrace deposits in the Lower Lugg study area, which reflect at least four stages of gravel aggradation in the Middle-Late Pleistocene (Figure 3; Brandon, 1989; Maddy, 1999; see section 3.1.4). Much of this gravel is likely to have been provided by frost weathering and high runoff rates that existed in periglacial environments during OIS 10, 8, 6 and 4 (Richards, 2005). However, it is likely that the northerly derived drainage pattern was supplemented by meltwater from ice-sheets and glaciers that occupied the Welsh Massif during some of the Pleistocene Cold Stages (Richards, 2005).

Prior to the Middle Pleistocene (Anglian) glaciation, the River Lugg was the major drainage route in central Herefordshire (Figure 15A; Richards, 1994; 1998; 1999). To the east of the Lower Lugg study area another large system, the Mathon River (Barclay *et al*., 1992), flowed parallel to the Lugg and then swung southwards along the western margins of the Malvern Hills. At this time, the River Wye was probably a tributary of the River Lugg (Hey, 1991). The gravels that were deposited by these northerly-derived river systems and their tributaries are the oldest Pleistocene deposits in Herefordshire and have been classified as the Mathon Formation (Richards, 1994; 1998; Maddy, 1999) although these deposits lie outside the boundary of the Lower Lugg study area. These gravels were reworked as an ice-sheet of Middle Pleistocene (Anglian) age extended from Wales, across the Lower Lugg study area, into eastern Herefordshire. Following the incursion of this glacier the Lugg maintained a southerly flowing course similar to its pre-glacial configuration, while the Mathon River swung eastward, through a gap in the Malvern Hills, to join the River Severn at Worcester, thereby forming the present course of the River Teme (Figure 15B; Richards, 2005). Minor changes subsequently occurred in the organization of tributaries of the River Lugg and Teme on the St.

Maughans Plateau, between Leominster and Bromyard, largely as a result of the release of meltwater from lakes trapped at the margins of the retreating Middle Pleistocene ice-sheet.

This northerly-derived drainage network in Herefordshire persisted for around 400,000 years until disrupted by glaciation during the Late Devensian. The most striking effect of the Late Devensian glaciation was probably the emergence of the River Wye as the major drainage route in the region (Figure 15C). Whilst the catchment area of the Wye expanded, the Lugg catchment decreased as the Late Devensian ice-sheet diverted the Rivers Teme and Onny eastwards to the River Severn (Pocock, 1925; Dwerryhouse and Miller, 1930; Cross and Hodgson, 1975). While upper parts of the Lugg catchment were subject to glaciation during the Late Devensian, its lower course largely remained marginal to the piedmont ice-lobe occupying the Hereford Basin (Richards, 2005). The Late Devensian ice-sheet spread across the Hereford Basin as a large piedmont outlet glacier, fed by ice-fields covering the Welsh Massif. Ice-flow within the basin, while exhibiting local deviations, generally moved from west to east, reaching its maximum extent to the west of the Lower Lugg valley, on the western extremity of the study area (Figure 14).

The Pleistocene deposits of Herefordshire represent discrete phases during *c*. 500,000 years of landscape and fluvial system evolution. Despite the paucity of absolute biostratigraphic control there is no doubt that Herefordshire and the Lower Lugg study area have been subject to both Middle and Late Pleistocene glaciation. Whilst this paucity can still be addressed where Late Devensian glacial deposits are concerned, Richards (2005) suggested that it is unlikely that the small depositional remnants associated with Middle Pleistocene glaciation will yield further biostratigraphic clues. However, he indicated that the landscape of Herefordshire, including the Lower Lugg study area, presents a fine example of the effects of glaciation on the lowland margins of a major ice-centre during the Cold Stages of the Pleistocene (Richards, 2005).

3.1.7 *Holocene Valley Floor Development*

The geomorphological development of the Holocene valley floor environment in the Lower Lugg study area has been investigated by a small number of researchers. Relatively few field-based investigations have been undertaken in the study area and, as a consequence, reconstructions of Holocene valley floor development have been based on a limited amount of geomorphological and sedimentological evidence. The main source of primary, field-based data in the study area stems from doctoral research conducted by Roseff (1992). Field investigations carried out by Roseff (1992) were undertaken at Wellington Quarry, in the upper reaches of the study area, and findings from these investigations remain the principal source of Holocene geomorphological and sedimentological data in the Lower Lugg study area. Subsequent work carried out at the same site (e.g. Dinn and Moran, 1996; Terra Nova, 2002; Jackson and Miller, 2004; Brown *et al*., 2005) has been supplemented by smaller-scale investigations conducted elsewhere in the study area at Lugg Bridge (Jackson and Pearson, 1996; Terra Nova, 2001), Eau Withington (Hurst and Pearson, 1995) and Lugg Meadows (Pearson and Roseff, 1996). These smaller-scale studies have added to our knowledge but the scale of investigations at Wellington Quarry means that our understanding of Holocene valley floor and river system development in the Lower Lugg stems almost entirely from this single site. Consequently, this review largely draws on the findings from Wellington Quarry investigations and the principal sources consulted were Dinn and Roseff (1992), Dinn (1996), Terra Nova (2002) and Jackson and Miller (2004).

Two exposures of sedimentary sections at Wellington Quarry form the basis for reconstructions of Holocene valley floor and river system development in the Lower Lugg (Figure 16). The sections were first investigated by Roseff (1992) and although some of the interpretations made regarding Holocene valley floor evolution have subsequently been refined, they still represent the most comprehensive source of sedimentological information from the Wellington Quarry site (Jackson and Miller, 2004). The two sedimentary sections ran across the valley floor, broadly east to west, and were set approximately 200 m apart. They were located within the Wellington Quarry complex about 500 m west of the present course of the River Lugg (Dinn and Roseff, 1992). In broad terms, the two sections consist of three fine-grained alluvial units overlying a coarser unit of gravels and sands. Jackson and Miller (2004) indicated that the fine-grained alluvial units, which represent floodplain deposits, vary in thickness and are present across most of the Wellington Quarry site. The fine-grained units are as much as 3 m thick in places and rest on an uneven bed of glaciofluvial gravels and sands that are up to 8 m deep (Dinn, 1996). In section, the sequence of fine-grained floodplain deposits is interrupted by the presence of former river channels that are infilled with more complex sedimentary fills.

The fine-grained alluvium that blankets much of the valley floor in the Lower Lugg study area is underlain by thick deposits of glaciofluvial gravels and sands (Figure 16). Resting on the uneven surface of this gravelly layer, Jackson and Miller (2004) identified a fine-grained unit of red-brown alluvium. This unit typically consists of fine silty clay with a significant component of mixed gravels and is a strong red-brown in colour. The red-brown unit is present across most of the Wellington Quarry site and rarely exceeds a thickness of 0.30 m.

Overlying the lower red-brown alluvium at Wellington Quarry is a yellow-brown/grey alluvial unit. This unit, which varies in colour, is mainly composed of silts and clays that are laminated in places. The unit also varies widely in depth across the Wellington Quarry site, often exceeding 1.00 m in thickness. A unit of yellow-brown alluvium, which is thought to correspond with the unit at Wellington Quarry, has also been reported elsewhere in the Lower Lugg study area at Lugg Bridge (Jackson and Pearson, 1996; Terra Nova, 2001) and Eau Withington (Hurst and Pearson, 1995).

Immediately below the modern topsoil, the uppermost alluvial unit at Wellington Quarry is a red-brown layer of silty clay with occasional granules and fine gravels. This unit, which overlies the yellow-brown/grey alluvium, is present across most of the Lower Lugg valley floor. At Wellington Quarry it typically extends to a depth of 0.50 – 0.75 m, although it is over 1.00 m thick in places. At the base of the upper red-brown alluvial unit at Wellington Quarry, a buried soil layer has been reported (Dinn and Roseff, 1992). Dinn (1996) indicated that the buried soil layer is brown in colour, usually about 0.20 m thick and contains evidence of Roman activity.

The floodplain sequence at Wellington Quarry is interrupted by the presence of palaeochannels with complex sedimentary fills (Figure 16). At the base of these former channels, layers of organic-rich, peaty sediments, which are variable in depth, have been reported (Dinn and Roseff, 1992). The basal peat layers are overlain by more complex sedimentary sequences. These vary in character between palaeochannels but generally contain series of interleaving fine-grained alluvial spreads and lenses (Jackson and Miller, 2004). The capping layer found in most palaeochannel fills is a unit of fine silty material that is very similar in character to the upper red-brown alluvium found in the floodplain deposits.

Reconstruction of Holocene Valley Floor Development in the Lower Lugg

Using evidence recovered from Wellington Quarry, Dinn and Roseff (1992), Terra Nova (2002) and Jackson and Miller (2004) have all made attempts to reconstruct processes of Holocene valley floor development in the Lower Lugg. These sources are synthesised here to provide an up-to-date account of our understanding of Holocene valley floor and river system evolution in the study area.

At the end of the Pleistocene and beginning of the Holocene, the valley floor at Wellington Quarry was occupied by a braided river system (Terra Nova, 2002; Jackson and Miller, 2004). The valley floor would have been largely free from vegetation cover and occupied by a high-energy river system, reworking gravel sediments deposited during Late Devensian deglaciation. The braided system would have had multiple active channels flowing round gravel islands that were continually shifting due to in-stream erosion and deposition processes (Terra Nova, 2002). The basal layer of gravels and sands recorded in the extended sedimentary sections at Wellington Quarry (Figure 16; Dinn and Roseff, 1992) represent the deposits of this braided river system and the undulating surface of the unit reflects the multiple channels and braid bars that would have formed in the Late Pleistocene River Lugg.

As interglacial conditions were restored in the early Holocene and woodland cover became established, water and sediment discharge in the River Lugg would have declined (Jackson and Miller, 2004). As stream energy levels dropped, the size of material being transported by the river would also have declined and the Lugg would have rationalised into a single-channel system, with cut-off meanders and ox-bow lakes developing in former channel positions (Terra Nova, 2002). Fine-grained vertical accretion, driven by overbank flood events, is likely to have been the main mechanism of sedimentation at this time, resulting in the deposition of the lower red-brown alluvial unit at Wellington Quarry (Dinn and Roseff, 1992; Terra Nova, 2002). The newly formed single-thread river channel is likely to have undergone a limited amount of lateral migration during the early Holocene but, overall, is likely to have been characterised by lateral stability (Jackson and Miller, 2004).

Table 2: Radiocarbon dates from Wellington Quarry (Dinn and Roseff, 1992).

Sample site	Lab. number	Sample material	$\delta^{13}C$	Uncalibrated ^{14}C age	Calibrated age range (2 σ) - cal BP	Calibrated age range (2 σ) - cal BC / AD
Wellington - North Section	OxA-2878	Bone	-22.8%	1180 ± 60	1270 - 960	AD 680 - AD 990
Wellington - North Section	OxA-2879	Wood	-29.7%	2260 ± 70	2430 - 2080	480 BC - 130 BC
Wellington - South Section	OxA-2880	Wood	-29.3%	6790 ± 80	7770 -7450	5820 BC - 5500 BC
Wellington - South Section	OxA-2881	Wood	-29.5%	6930 ± 80	7850 - 7580	5900 BC - 5630 BC
Wellington - South Section	OxA-2882	Charcoal	-24.2%	4990 ± 70	5930 - 5590	3980 BC - 3640 BC
Wellington - South Section	OxA-2883	Charcoal	-26.7%	3070 ± 70	3460 - 3080	1510 BC - 1130 BC

The main palaeochannel identified in the southern sedimentary section at Wellington Quarry (Dinn and Roseff, 1992) is considered to represent a former course of the River Lugg. Radiocarbon dates obtained from the bottom of the basal peat layer in this palaeochannel indicates that the peaty deposits had begun to form by 7850 – 7580 cal BP (OxA-2881; Table 2) and 7770 – 7450 cal BP (OxA-2880; Table 2; Dinn and Roseff, 1992). Charcoal retrieved from above the basal palaeochannel fill was also dated by Dinn and Roseff (1992) and indicated that peat accumulation had ceased by 5930 – 5590 cal BP (OxA-2882; Table 2). Dinn and Roseff (1992) implied that this main palaeochannel was incised during the Holocene. Jackson and Miller (2004), however, offered an alternative suggestion that the palaeochannel represents the gradual infilling of a channel that was active during the Late Devensian and abandoned during the early Holocene as the Lugg rationalised into a single-channel system.

The dated peat deposits recorded in the main palaeochannel at Wellington Quarry may reflect a prehistoric phase of valley floor stabilisation that occurred after the lower red-brown alluvium was deposited across the Lower Lugg valley floor. Terra Nova (2002) indicated that this period of peat accumulation corresponds with a phase of woodland expansion at Wellington Quarry and suggested that it may represent a sustained period of infrequent flooding and limited overbank sediment deposition.

The yellow-brown/grey alluvium, which overlies the lower red-brown alluvium in the floodplain deposits at Wellington Quarry, represents a second phase of Holocene alluviation in the Lower Lugg. The sediments in this unit, which is also present in patches at Lugg Bridge and Eau Withington, are likely to have been derived from the erosion of yellowish soils found on the Silurian rocks in the upper reaches of the Lugg catchment (Terra Nova, 2002). Jackson and Miller (2004) suggested that the unit was being laid down from the early Holocene through to the later Iron Age and that it represents several depositional periods interspersed with phases of relative floodplain stability. This interpretation is supported by the presence of a thin band of organic or humic material, first reported by Roseff (1992) and Dinn and Roseff (1992), which divides the yellow-brown alluvial unit into two horizons. Jackson and Miller (2004) also reported Roman and Iron Age features cut into the surface of the unit, providing an end date for its accumulation. In contrast, the unit’s relationship with earlier prehistoric features is more ambiguous as it both seals some and is cut into by others, confirming the interpretation that the unit accumulated over a long period of time and that phases of sedimentation were interrupted by periods of stasis (Jackson and Miller, 2004).

Charcoal recovered from the main palaeochannel at Wellington Quarry was dated by Dinn and Roseff (1992) and indicates that the complex sequence of sediments overlying the basal peat layer was being deposited by 3460 – 3080 cal BP (OxA-2883; Table 2). Jackson and Miller (2004) reported that archaeological artefacts recovered from this complex sedimentary sequence indicate that it was laid down over a broad period of time, from the Bronze Age to the Roman period. The complexity of the channel fill sequence, which contains a series of interleaving spreads and lenses, is likely to reflect numerous short-lived episodes of overbank flooding and sediment deposition.

There is clear evidence at Wellington Quarry for a sustained phase of valley floor stabilisation and human occupation during the Roman period. A distinctive buried soil layer, which is brown in colour and usually about 0.20 m thick (Dinn, 1996), overlies the yellow-brown/grey floodplain deposits and underlies the upper layer of red-brown alluvium. The soil layer contains significant quantities of Roman finds and is cut by, or seals, a range of Roman period features (Jackson and Miller, 2004). Dinn and Roseff (1992) reported three infra-red stimulated luminescence (IRSL) dates obtained from this surface, which dated to 1780 ± 200 cal BP, 1750 ± 200 cal BP and 1670 ± 200 cal BP (lab reference 784b; Table 3). Work in the north-eastern corner of Wellington Quarry showed that this soil layer remained as a stable ground surface into the post-Roman period, with ridge and furrow formation affecting it before deposition of the upper red-brown alluvium (Jackson and Miller, 2004). The evidence recovered from Wellington Quarry indicates that this floodplain layer represents a soil horizon that developed during a long period of relative fluvial stability and limited overbank flooding, which lasted from the late Iron Age to the later part of the early medieval period (Jackson and Miller, 2004).

The palaeochannel identified in the northern sedimentary section at Wellington Quarry by Roseff (1992; Figure 16) was an active channel during the Roman period. The channel feature

Table 3: Infra-red stimulated luminescence dates from Wellington Quarry (Dinn and Roseff, 1992).

Sample site	Lab. reference	Age range - cal BP	Age range - cal BC / AD
Wellington - North Section	784a	920 ± 200	1030 ± 250 AD
Wellington - North Section	784b	1670 ± 200	280 ± 200 AD
Wellington - North Section	784b	1750 ± 200	200 ± 200 AD
Wellington - North Section	784b	1780 ± 200	170 ± 200 AD

is much smaller than the main palaeochannel reported in the southern sedimentary section and may represent a former course of Wellington Brook. Archaeological finds recovered from the base and surface of the channel fill show that the stream was flowing during the Roman period and for some time after (Dinn and Roseff, 1992). A sample of wood retrieved from near the base of the palaeochannel was radiocarbon dated to 2430 – 2080 cal BP (OxA-2879), whilst a piece of red deer bone recovered from within the channel fill dated to 1270 – 960 cal BP (OxA-2878; Table 2; Dinn and Roseff, 1992). Dinn and Roseff (1992) suggested that the stream was utilised as a resource during the Roman period, with finds of iron slag and hammer scale pointing towards industrial use of the riparian zone.

Overlying the Roman occupation layer is the upper red-brown alluvium, which occurs throughout the Wellington Quarry site and is also reported at Lugg Bridge (Jackson and Pearson, 1996; Terra Nova, 2001), Eau Withington (Hurst and Pearson, 1995) and Lugg Meadows (Pearson and Roseff, 1996). This layer also forms the uppermost fill in some palaeochannel depressions and hollows at Wellington Quarry (Jackson and Miller, 2004). The sediments that make up the unit are thought to derive from the erosion of reddish-brown soils formed on the Devonian rocks of the Lower Lugg catchment (Terra Nova, 2002). This unit seals all Roman and earlier deposits and has been recorded as sealing medieval ridge and furrow in one area of Wellington Quarry, indicating its relatively late deposition (Jackson and Miller, 2004). Dinn and Roseff (1992) obtained an IRSL date of 920 ± 200 (lab reference 784a; Table 3) from near the base of the unit. This date suggests that the red-brown alluvium was accumulating by the end of the early medieval period, marking a renewed phase of floodplain sedimentation in the Lower Lugg. As with preceding phases of Holocene sedimentation, the upper red-brown alluvium was deposited by vertical accretion processes during overbank flood events.

Following rationalisation of the Lugg into a single-thread river system during the early Holocene, Terra Nova (2002) suggested that the position of the channel has remained relatively stable to the present day. Dinn and Roseff (1992) provided evidence to demonstrate that the Lugg has continued to exhibit lateral channel stability since at least the early part of the medieval period. A parish boundary 500 m east of Wellington Quarry follows the course of the contemporary River Lugg. Parish boundaries are generally held to have been established at least by AD 1180 and, in most cases, a good deal earlier (Dinn and Roseff, 1992).

At Lugg Bridge, Eau Withington and Lugg Meadows, as well as Wellington Quarry, there is evidence of a late Post-Medieval phase of alluviation as Medieval archaeological remains have, in places, been buried beneath the upper red-brown alluvium. Pearson and Roseff (1996) reported that early 19th century dolestones (associated with the management of the area as Lammas meadows) were buried by the red-brown alluvial deposits, indicating that this most recent phase of alluviation has taken place within the last 200 years. Terra Nova (2002) point out, however, that medieval land management practices such as ridge and furrow remain exposed on the floodplain surface in some areas, indicating that this latest phase of fine-grained alluviation has affected some parts of the valley floor more than others.

3.1.8 *Evaluation of the Geomorphological Data Sources*

As indicated in the critical evaluation of geological and pedological data sources (section 3.1.3 and 3.1.4), the Pleistocene geomorphology of the Lower Lugg study area has been subject to rigorous research and is well understood, comparing favourably with other parts of Britain. Most of the literature sources pertaining to the Lower Lugg's Pleistocene geomorphology have been peer-reviewed, published and are in the public domain. In comparison, information sources relating to the Lower Lugg's Holocene geomorphology are limited in number and very few have been subject to the peer-review process. As a consequence, our current state of knowledge concerning the Holocene geomorphological development of the Lower Lugg study area is, in many ways, more limited than our understanding of its geomorphological development during the Pleistocene. The critical evaluation of data sources relating to Pleistocene geomorphology and Holocene geomorphology are outlined in turn below.

Pleistocene Geomorphology

A good number of published literature sources relating to the Pleistocene geomorphology of the Lower Lugg study area were collated for this review. In combination, these sources (e.g. Brandon, 1989; Maddy, 1997; 1999; Richards, 1994; 1997; 1998; 1999; 2005) provide a good understanding of Pleistocene glaciations, Pleistocene river terrace deposits and Pleistocene drainage network evolution in the Lower Lugg valley. The knowledge of Pleistocene landscape and fluvial system evolution provided by researchers in this field is particularly impressive given the relative paucity of Pleistocene-aged sedimentary deposits that have been preserved in the study area. The level of understanding provided by the various pieces of Pleistocene geomorphological research allowed Richards (2005) to conclude that the landscape of Herefordshire, including the Lower Lugg study area, presents a fine example of the effects of glaciation on the lowland margins of a major ice-centre during the Cold Stages of the Pleistocene.

Holocene Geomorphology

Published sources relating to Holocene geomorphology and, in particular, Holocene valley floor development in the Lower Lugg study area are limited in number. Investigations carried out at Wellington Quarry by Roseff (1992) provided field-based sedimentary descriptions of a good quality, although some of the fluvial interpretations regarding depositional processes and channel development have subsequently been brought into question. In all though, the work undertaken by Roseff (1992) constitutes a good source of Holocene geomorphological information and the descriptions of the exposed sections at Wellington Quarry remain as the principal source of sedimentological field data in the Lower Lugg study area (Jackson and Miller, 2004). Unfortunately, the PhD thesis produced by Roseff (1992) could not be obtained for this review (which instead relied on results reported in the Dinn and Roseff (1992) publication) but it is suggested that a copy of the thesis would be a valuable addition to any Lower Lugg library resource.

The work reported by Dinn and Roseff (1992) remains as one of the very few published sources that is principally concerned with the geomorphological evolution of the Lower Lugg valley floor during the Holocene. Other investigations that have been undertaken subsequently (e.g. Dinn and Moran, 1996; Terra Nova 2001; Jackson and Miller, 2004; Brown et al., 2005) do add to our understanding but, in general, they have a number of shortcomings. In the first instance, these subsequent investigations have largely had an archaeological or palaeoenvironmental focus and, as a consequence, Holocene geomorphological information has been generated almost as a by-product. Valley floor investigations have also been concentrated, to a large extent, at the Wellington Quarry site in the upper reaches of the Lower Lugg study area. This means that our knowledge of Holocene valley floor and river system development in the Lower Lugg stems almost entirely from a single study site. Extrapolating the findings from one site and applying them to the entire valley floor area of the Lower Lugg is not something that can be done with confidence. The natural variability that is inherent in river systems means that extrapolating limited geomorphological research findings over such distances is fraught with difficulty. As a consequence of these shortcomings, the reconstructions of Holocene valley floor development that exist for the Lower Lugg are considered to be ‘broad-brush’ in nature and overly simplistic. In all, the lack of published studies, the lack of geomorphologically-focused research (such as that conducted by Macklin *et al*. (2004) in the Arrow Valley and by Brown *et al*. (2004) in the Frome Valley) and the concentration on a single investigative site means that our geomorphological understanding of Holocene valley floor development in the Lower Lugg study area is limited and does not compare favourably with other parts of Britain.

Conclusions

3.1.9 *Key Conclusions*

Outlined below is a list of the substantive conclusions that can be drawn from the critical review of the known geological, pedological and geomorphological information sources for the Lower Lugg study area.

- The bedrock geology of the study area is relatively straightforward and BGS 1:50,000 scale map data (Sheet 198) and the memoir produced by Brandon (1989) mean that it is well understood.
- The distribution of superficial geological deposits is mapped at the 1:50,000 scale by the BGS (Sheet 198) and the nature of the deposits, particularly those dating from the

Pleistocene, is described in detail by Brandon (1989). These information sources are supplemented by published research on Pleistocene glacial and fluvial deposits, most notably by Richards (1994; 1997; 1998; 1999; 2005), which has enhanced our understanding of the superficial geology of the area.

- Superficial deposits dating from the Holocene are not mapped or described in as much detail. There are also few published studies relating to the study area's Holocene surficial deposits and, as a consequence, our knowledge of these deposits is limited.
- Soil associations and series in the study area have not been the subject of much research but the 1:250,000 scale map (Sheet 2) produced by the Soil Survey of England and Wales, and the technical guide authored by Ragg *et al*. (1984), represent good sources of baseline pedological information.
- Pleistocene glaciations, Pleistocene river terrace deposits and Pleistocene drainage network evolution in the Lower Lugg have been investigated by a number of well-qualified researchers. Despite the relative paucity of Pleistocene-aged sedimentary deposits in the study area, our understanding of Pleistocene landscape and fluvial system evolution is good, comparing favourably with other parts of Britain.
- Published data sources relating to the geomorphological development of the Lower Lugg valley floor during the Holocene are limited. Research by Roseff (1992) and Dinn and Roseff (1992) constitutes a good source of Holocene geomorphological information and the descriptions of the exposed sections at Wellington Quarry remain
- as the principal source of sedimentological field data in the study area. Subsequent to this research the lack of published studies, the lack of geomorphologically-focused research and the concentration on a single investigative site means that our geomorphological understanding of Holocene valley floor development in the Lower Lugg study area is limited and does not compare favourably with other parts of Britain.

Finally, the critical review has allowed the local, regional and national significance of the geological, pedological and geomorphological resource in the Lower Lugg study area to be assessed. Observations regarding these assessments are outlined below.

- The relatively simple bedrock geology of the Lower Lugg study area means that it is of little significance at the regional or national scale.
- The superficial geology of the area is of greater significance than the bedrock geology. The nature and distribution of Pleistocene sedimentary deposits in the study area and their relationship with Pleistocene glacial and periglacial stages means that the superficial geological deposits are certainly of regional, and probably national, significance
- Data pertaining to pedological conditions in the study area are limited but baseline information on the soil associations and series present in the Lower Lugg suggest that the pedological resource is likely to be only of local and regional, but not national, significance.
- In terms of glaciations, fluvial terraces and drainage network evolution, the Pleistocene geomorphology of the Lower Lugg study area is well understood. The study area's geographical location, at the periphery of former ice-sheets, means that its Pleistocene geomorphology is likely to be nationally significant. Richards (2005) indicated that the landscape of Herefordshire, including the Lower Lugg study area, presents a fine example of the effects of glaciation on the lowland margins of a major ice-centre during the Cold Stages of the Pleistocene.
- Previous studies, although limited, suggest that the reconstruction of Holocene valley floor development in the study area has considerable potential. The potential for investigating Holocene human-river interactions in the Lower Lugg is also rich due to the favourable conditions that exist in the study area for high rates of alluvial architecture and

archaeological site preservation. This potential suggests that the Holocene geomorphology of the Lower Lugg study area could be of national significance.

Figure 12: Bedrock geology of the Lower Lugg study area (after BGS 1:50,000 map sheet 198 and Brandon, 1989)

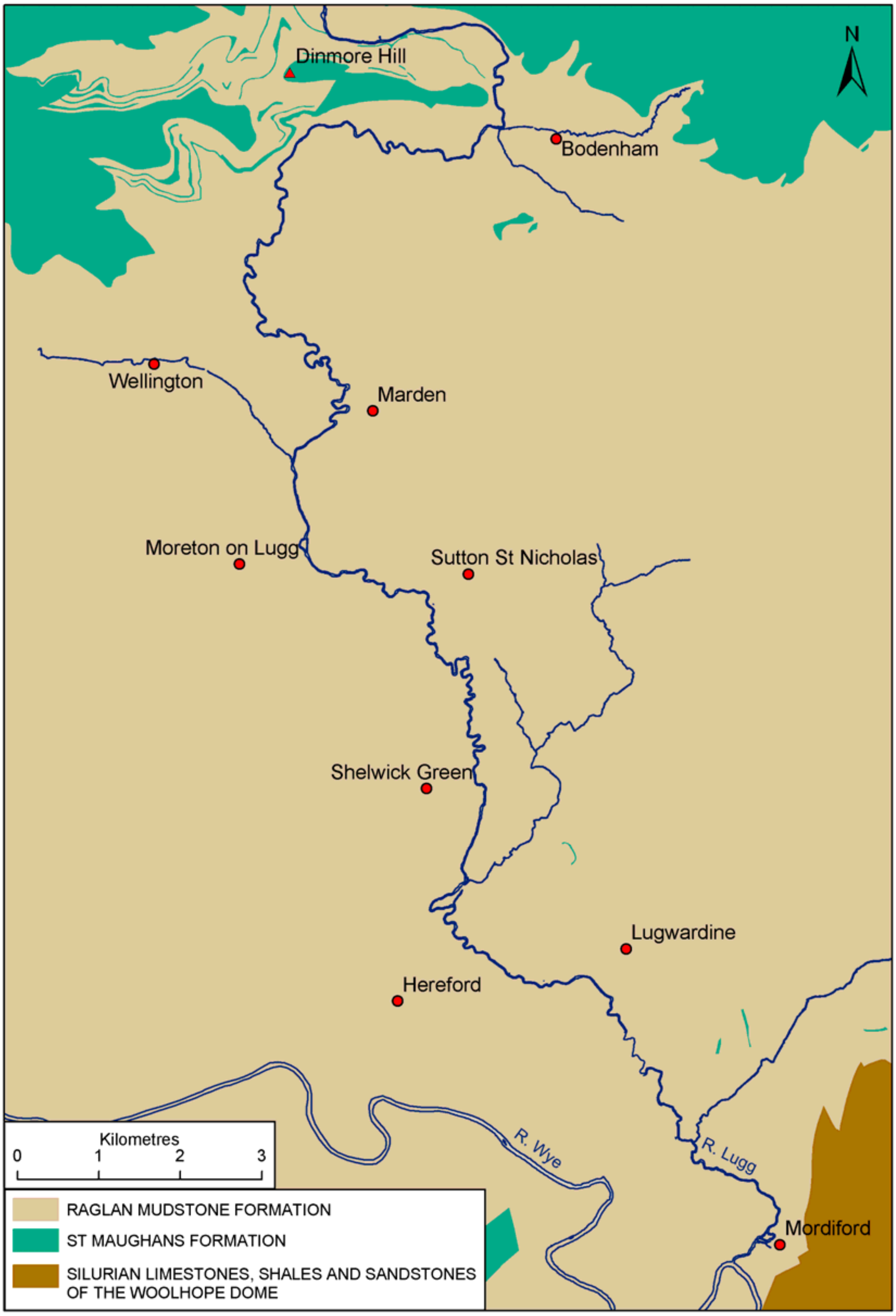


Figure 13: Superficial geology of the Lower Lugg study area (after BGS 1:50,000 map sheet 198 and Brandon, 1989)

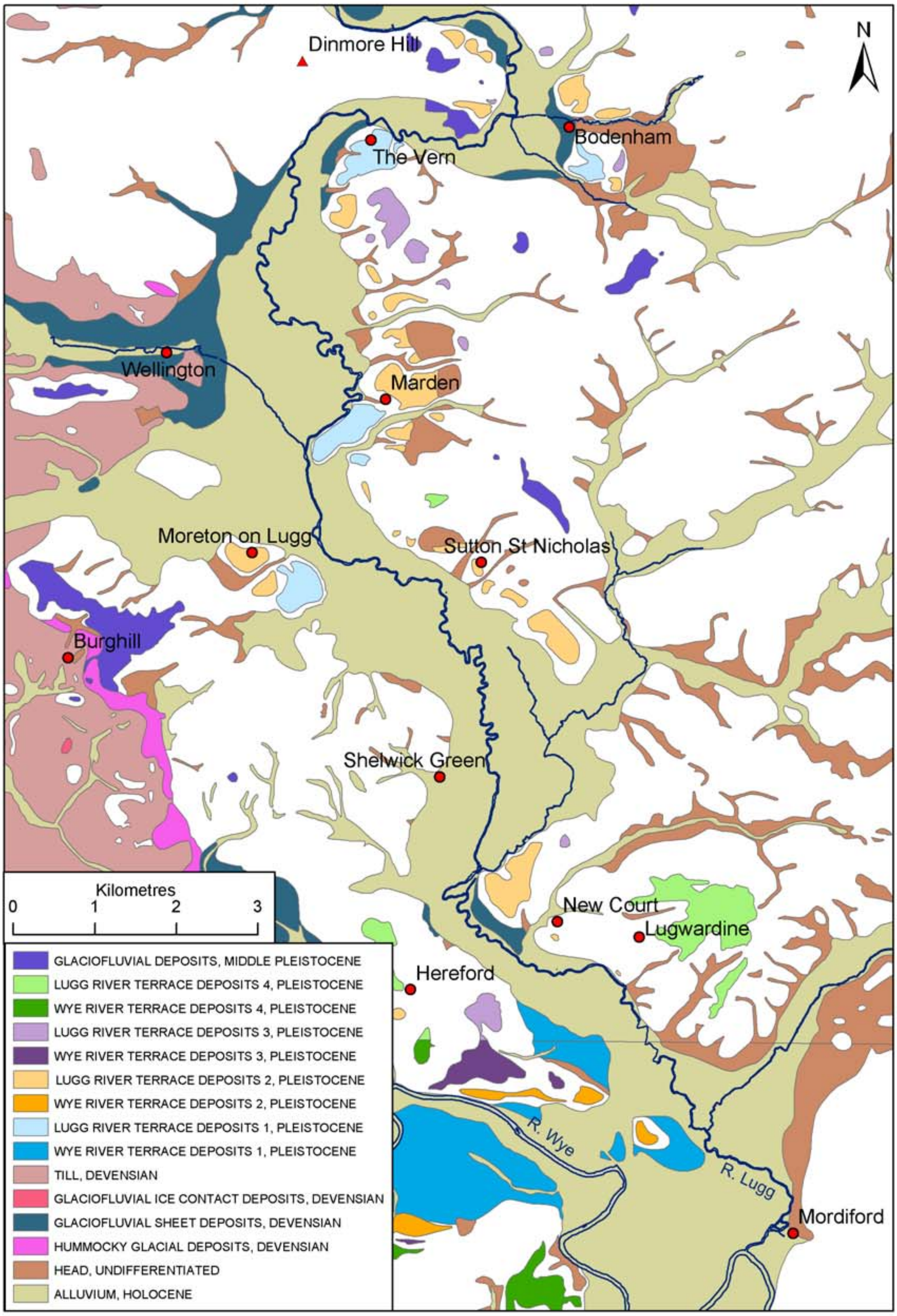


Figure 14: Pleistocene glacial limits and river terrace deposits in the Lower Lugg study area (after BGS 1:50,000 map sheet 198; Brandon, 1989; Richards, 1999)

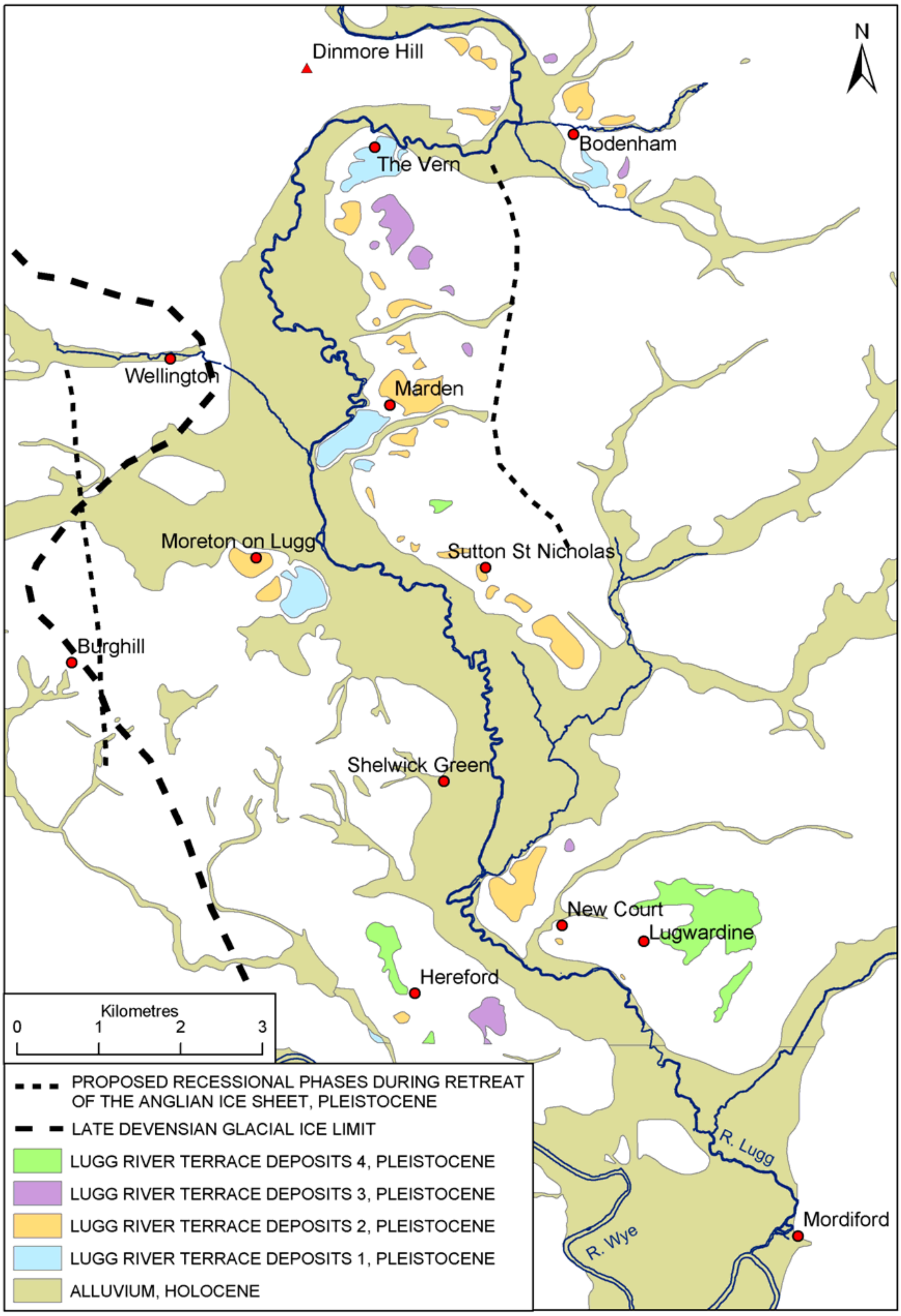


Figure 15: Quaternary drainage network evolution in the Lugg basin (Richards, 2005, p.130)

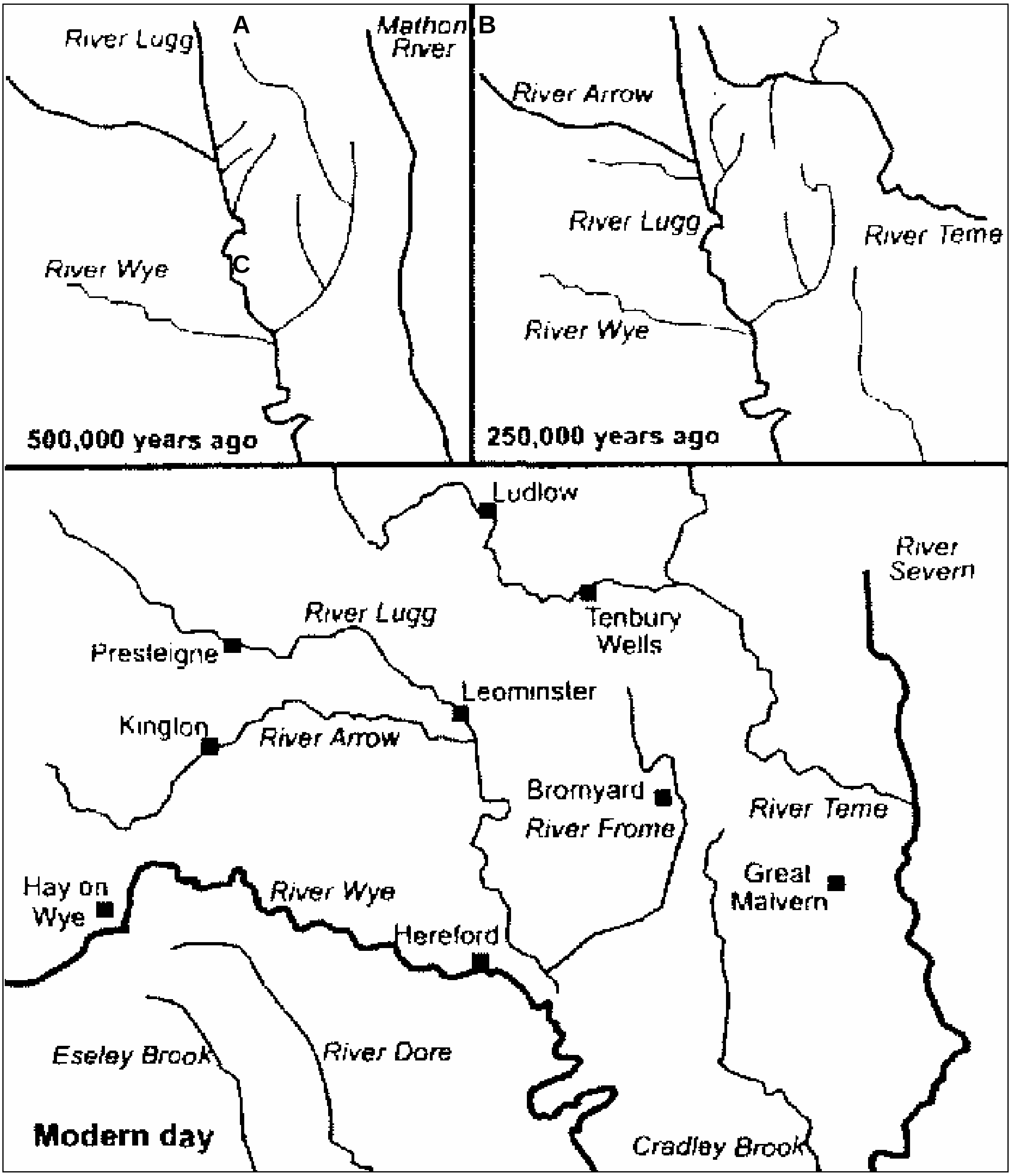
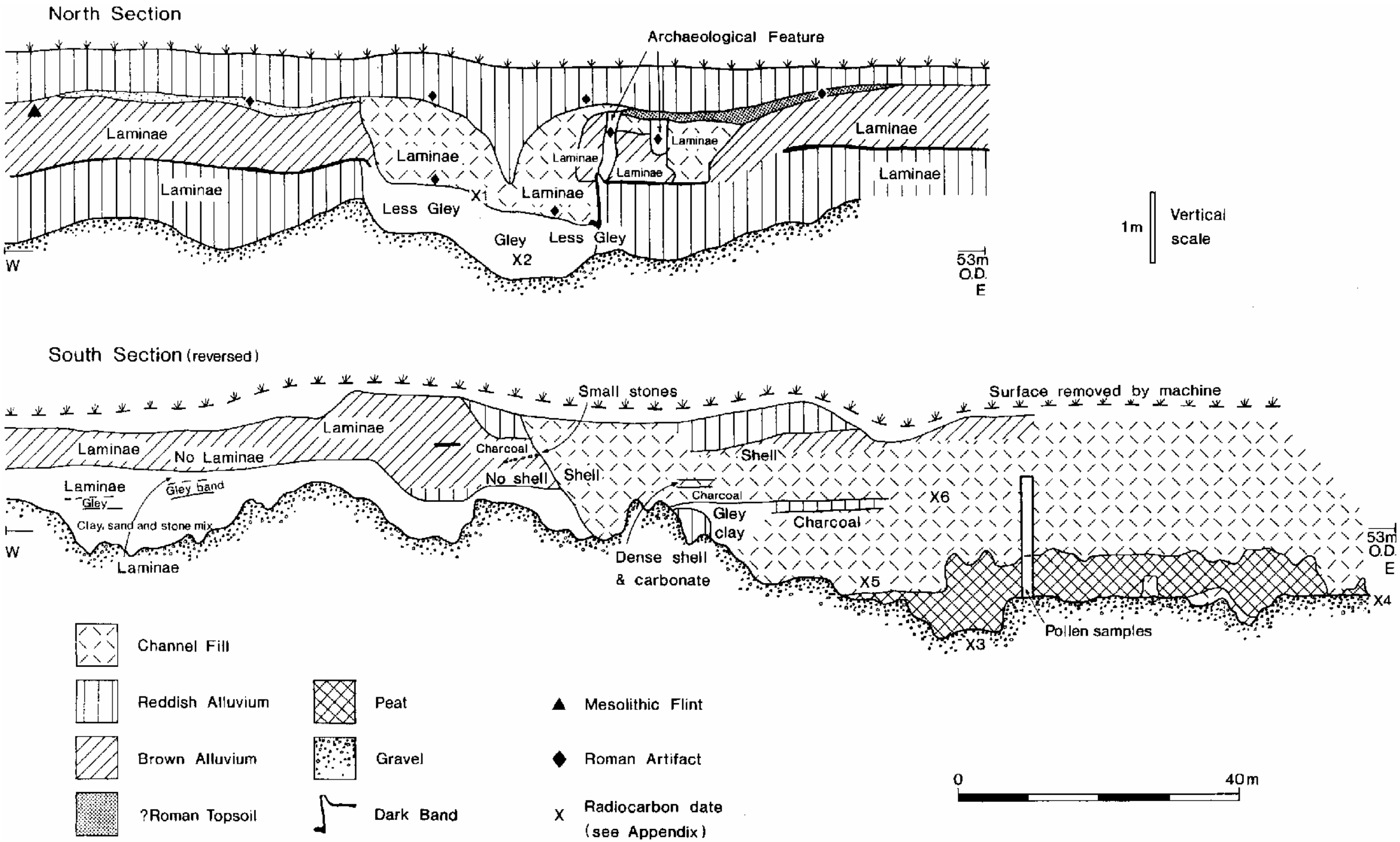


Figure 16: Exposed sedimentary sections at Wellington Quarry (Dinn and Roseff, 1992, p. 146)



3.2 Critical Review of Late Quaternary Palaeoenvironments in the Lower Lugg Valley

3.2.1 *Introduction*

This report provides a critical review of known palaeoenvironmental data sources from the Lower Lugg study area. The report begins by summarising the context, scope and scale of palaeoenvironmental investigations that have been conducted in the study area. This has been done firstly by looking at studies concerned with Late Pleistocene palaeoenvironments and, secondly by examining studies relating to Holocene palaeoenvironments. A critical evaluation of the palaeoenvironmental investigations undertaken in the Lower Lugg study area is then presented and the report ends with an outline of the substantive conclusions that can be drawn from the reviewed data sources.

Palaeoenvironments in the Lower Lugg Study Area

3.2.2 *Late Pleistocene Palaeoenvironments*

Until recently, there was no published pollen diagram reflecting the Late Pleistocene vegetation history of the Lower Lugg study area. Palaeoenvironmental investigations, which shed light on patterns of Late Pleistocene vegetation cover, had been undertaken in nearby study sites within the Severn catchment in Shropshire (e.g. Church Stretton – Rowlands and Shotton, 1971; Crose Mere – Beales, 1980) and within the Wye catchment in Wales (e.g. Rhosgoch Common – Bartley, 1960; Elan Valley – Moore and Chater, 1969; Brecon Beacons – Chambers, 1982; Llangorse Lake – Jones *et al*., 1985). Studies within the region, however, had generally been conducted in upland environments, particularly blanket mires, and the pollen diagrams produced rarely had adequate dating control (Brown *et al*., 2005). As a consequence, findings from these studies could not be used to infer Late Pleistocene palaeoenvironmental conditions in lowland environments such as the Lower Lugg Valley. The lack of evidence from the Lower Lugg and the contrasting environmental characteristics of nearby investigation sites meant that there was a significant gap in the study area's Late Pleistocene palaeoenvironmental record. This gap in the record has recently been addressed in palaeoenvironmental research carried out by Brown *et al*. (2005) at Wellington Quarry, in the upper reaches of the Lower Lugg study area. These investigations have produced the first Late Pleistocene pollen diagram for the Lower Lugg and, as such, the Brown *et al*. (2005) publication represents the only source of primary, field-based data concerning Late Pleistocene palaeoenvironments in the study area. Consequently, this publication is the sole information source used here to summarise our current understanding of Late Pleistocene palaeoenvironmental conditions in the Lower Lugg study area.

The investigation reported by Brown *et al*. (2005) centred on sediments recovered from a palaeochannel fill in the north of the Wellington Quarry site (Figure 17). Pollen analysis was conducted on a small sediment monolith (4 x 4 x 40 cm) retrieved from the base of this palaeochannel. Brown *et al*. (2005) indicated that the size of the palaeochannel fragment, which was 20 – 30 m wide, and its location on the valley floor were important in relation to the interpretation of the pollen diagram. Situated within the Wellington Quarry site, the palaeochannel lay 500 m to the west of the present day course of the River Lugg. It was also interpreted as being located on the remnants of a raised terrace between the River Lugg and one of its tributaries, Wellington Brook. This placed the palaeochannel at a considerable distance from the low-gradient slopes of the Lower Lugg's valley sides. The size of the palaeochannel and its location allowed Brown *et al*. (2005) to presume that the vast majority of the pollen contained within the sediment monolith was sourced from vegetation occupying the valley floor environment of the Lower Lugg study area.

The sampled monolith contained sediments from a depth of 1.82 – 2.22 m below the ground surface and was described by Brown *et al*. (2005) as having four principal sedimentary units (Figure 18). The upper 1.82 – 1.88 m layer of the monolith was composed of mottled grey sandy silts and was underlain by a mottled grey-blue clay unit extending from 1.88 – 2.00 m depth. A layer of black silty clay with a significant amount of organic material was present at 2.00 – 2.20 m depth and rested on a gravel unit that extended beyond a depth of 2.25 m. Loss-on-ignition results were also plotted by Brown *et al*. (2005; Figure 18). The loss-on-ignition trend broadly followed the field stratigraphy with an increase towards the base of the monolith and particularly below 2.00 m depth where the increased presence of organic material was first noted. Brown *et al*. (2005) suggested that the sedimentary sequence clearly represented the abandonment of a channel that was subsequently infilled by clay deposited from standing water (in an oxbow lake) and later by fine-grained overbank alluvium.

Five radiocarbon dates were obtained on organic samples retrieved from the sediment monolith (Figure 18; Table 1). To maximise temporal resolution, AMS dating was used on the humin fraction of small samples of organic-rich clay. Brown *et al*. (2005) indicated that the radiocarbon calibration curve for the Late Pleistocene period is complex and, as a consequence, the AMS dates retrieved from the monolith overlap at the 2 σ (95.4%) probability level and all the samples can be bracketed by the dates of 16,350 – 13,650 cal BP. At the 1 σ (68.3%) probability level, Brown *et al*. (2005) noted the presence of age reversals for samples WQ1-WQ2 and WQ4-WQ5. The cause of this was not known but Brown *et al*. (2005) suggested it may reflect the use of the humin fraction which can produce aberrant dates up to 500 years too old. Overall, the consistency of the 2 σ age ranges suggested the dates provide an estimate for the date of the time window but not its temporal duration. Taking these issues with radiocarbon dating into consideration, Brown *et al*. (2005) indicated that the five dated samples imply that the organic sediments from the monolith were accumulating during the late Dimlington Stadial and into the early Windermere Interstadial.

High resolution pollen analysis was undertaken on the organic-rich clay sediments retrieved in the monolith and the pollen diagram produced is shown in Figure 19. The entire diagram is dominated by herb species and Brown *et al*. (2005) divided it into three local pollen assemblage zones:

- WQ1 (2.08 – 2.05 m depth) – zone dominated by *Cyperaceae* (sedges) but also *Poaceae* (grasses), *Asteroideae* (aster) and spores of *Equisetum* (horsetail). The only trees represented were *Pinus* (pine) and *Salix* (willow).
- WQ2 (2.05 – 1.93 m depth) – zone dominated by *Cyperaceae* (sedges) and *Poaceae* (grasses). Towards the top of the zone there is a gradual increase in *Poaceae* (grasses) and a concomitant fall in *Cyperaceae* (sedges).
- WQ3 (1.93 – 1.89 m depth) – zone dominated by *Cyperaceae* (sedges) and *Poaceae* (grasses) with low values of *Pinus* (pine), *Betula* (birch) and *Lactuceae* (lettuce).

The pollen diagram covers a relatively short period of the Late Pleistocene, spanning the late Dimlington Stadial and the early Windermere Interstadial. The valley floor environment in this part of the Lower Lugg study area appears, at this time, to have been almost completely open and dominated by species-rich grassland, which Brown *et al*. (2005) suggested may have been maintained by herbivore grazing. In this period, the palaeochannel (from which the sediment monolith was retrieved) had already been abandoned and was probably an oxbow lake, occupied by standing water. The floodplain adjacent to the former channel was occupied by wet grassland with some *Salix* (willow).

Table 1: Radiocarbon dates from the Late Pleistocene pollen analysis at Wellington Quarry (after Brown *et al*., 2005).

Sample ID	Lab. number	Sample depth - cm	$\delta^{13}C$	Uncalibrated ^{14}C age	Calibrated age range (2 σ) - cal BP	Calibrated age range (2 σ) - cal BC
WQ1	WK9317	188-189	-30.8±0.2	12,824 ± 69	15,850 - 14,350	13,900 - 12,400
WQ2	WK9318	193-194	-31.2±0.2	12,988 ± 78	16,150 - 14,550	14,200 - 12,600
WQ3	WK9319	198-199	-31.4±0.2	12,543 ± 78	15,550 - 14,150	13,600 - 12,200
WQ4	WK9320	202-203	-31.6±0.2	13,156 ± 59	16,350 - 14,850	14,400 - 12,900
WQ5	WK9321	206-207	-31.1±0.2	12,003 ± 62	15,250 - 13,650	13,300 - 11,700

Brown *et al*. (2005) indicated that the pollen diagram could also be used to get some idea of prevailing climate conditions in the Lower Lugg study area. A lack of trees and thermophilous indicators, particularly in pollen assemblage zone WQ2, suggests climatic conditions significantly colder than today. The increase in zone WQ3 of *Sparganium* (bur-reed) and *Typha* (bulrush) pollen may represent climatic amelioration in the early part of the Windermere Interstadial as the semi-thermophilous, aquatic *Typha* (bulrush) suggests a minimum mean July temperature 1 – 4°C below present. Brown *et al*. (2005) indicated that subtle changes in the valley floor environment could also be picked out from the pollen diagram. In zone WQ1 high sedges, aquatic and wetland plants dominate, whereas in zone WQ2 the grassland element increases and *Betula* (birch) appears in the region. In zone WQ3 several scrub-like trees and shrubs appear, many of which could be considered as pioneer types colonising the valley floor under more temperate climatic conditions. Preliminary analysis of Coleoptera and Chironomids from the same sediment monolith broadly supported the interpretations made from the pollen analysis. The Coleoptera and Chironomid evidence indicated changing wetland conditions in the early part of the time window and scrub invasion and heathland development in the later period, associated with ameliorating climatic conditions.

3.2.3 *Holocene Palaeoenvironments*

Few investigations relating to Holocene palaeoenvironments have been undertaken in the Lower Lugg study area. In a review of alluvial archaeology in the Herefordshire valleys, Dinn (1996) indicated that the Lower Lugg valley floor environment had the potential to provide well-preserved and well-stratified palaeoenvironmental remains but that, up to that point, the potential had not been fully explored. Six years later, in a review of the ancient Lugg landscape, Terra Nova (2002) pointed out that pollen from Lower Lugg study sites at Wellington Quarry and Lugg Bridge Quarry had been analysed. The pollen analyses from these two sites appear to represent the only substantive Holocene palaeoenvironmental research undertaken in the Lower Lugg study area. Unfortunately, the unpublished report produced by Pearson and Greig (2000), which assessed environmental remains from Lugg Bridge Quarry, could not be obtained for this review. Higher resolution analysis of a more extensive pollen profile from Wellington Quarry was undertaken by Greig (1998) and was supported by radiocarbon dates, making it the more important of the two palaeoenvironmental studies. The results from the pollen analysis by Greig (1998) were incorporated in the report on Wellington Quarry investigations between 1986 and 1996 produced by Jackson and Miller (2004). This report represents the principal information source used here to summarise the extent of our knowledge concerning Holocene palaeoenvironmental conditions in the Lower Lugg study area.

The pollen analysis reported by Greig (2004) was carried out on sediments retrieved from the Wellington Quarry site in 1989 (Figure 17). The sampled profile was recovered from the base of the main palaeochannel fill in the exposed southern sedimentary section described by Dinn and Roseff (1992; Figure 20). Six 25 cm monolith boxes were used to sample a 1.50 m profile that extended from 1.00 – 2.50 m below the ground surface. Samples were not taken from the uppermost 1.00 m of the palaeochannel fill as the sediments were mostly minerogenic clays and silts that were considered unlikely to contain sufficient well-preserved pollen for analysis. The six sediment monoliths that made up the 1.50 m profile were examined at a high resolution, with pollen analysis being conducted on sub-samples taken at 2 cm intervals.

Table 2: Radiocarbon dates from the Holocene pollen analysis at Wellington Quarry (after Jackson and Miller, 2004).

Sample ID	Lab. number	Sample depth - cm	$\delta^{13}C$	Uncalibrated ^{14}C age	Calibrated age range (2 σ) - cal BP	Calibrated age range (2 σ) - cal BC / AD
WQM 100/2	OxA-12639	100-102	-29.0	1379 ± 32	1340 - 1260	AD 610 - AD 690
WQM 130/2	OxA-12663	129-130	-25.9	3535 ± 29	3900 - 3690	1950 BC - 1740 BC
WQM 150/2	OxA-12638	149-150	-26.5	3669 ± 37	4150 - 3870	2200 BC - 1920 BC
WQM 170	OxA-12662	169-170	-27.0	3940 ± 29	4510 - 4290	2560 BC - 2340 BC
WQM 185	OxA-12688	185	-28.4	3904 ± 31	4420 - 4240	2470 BC - 2290 BC
WQ6*	OxA-2883	*c*. 134	-26.7	3070 ± 70	3460 - 3080	1510 BC - 1130 BC
WQ5*	OxA-2882	*c*. 180	-24.2	4990 ± 70	5930 - 5590	3980 BC - 3640 BC
WQ4*	OxA-2881	*c*. 250	-29.5	6930 ± 80	7850 – 7580	5900 BC – 5630 BC
WQ3*	OxA-2880	*c*. 250	-29.3	6790 ± 80	7770 -7450	5820 BC – 5500 BC

* samples dated by Dinn and Roseff (1992)

Four radiocarbon dates obtained on samples from the exposed southern section by Dinn and Roseff (1992) were initially used to provide an outline chronology for the Wellington Quarry pollen profile (Table 2). These dated samples, however, came from various parts of the exposed section (see Figure 20) and could therefore only give a rough idea of the date of a similar level in the pollen profile. The chronology of sediment deposition was improved with the addition of five further radiocarbon dates that were obtained on organic material from the pollen profile itself (Table 2; Greig, 2004). The new dates came from waterlogged plant macrofossils, which are only preserved in wet and anoxic conditions and are therefore unlikely to be reworked (Meadows *et al*., 2004). The integrity of these samples and their original environmental context within the 1.50 m sediment profile means that they are more likely to correctly date the pollen sequence than the samples obtained by Dinn and Roseff (1992). Meadows *et al*. (2004) indicated that the five new dates are consistent with the relative ages implied by their stratigraphic position in the vertical sequence and with the two dated samples (WQ3 and WQ4 in Table 2) found at the gravel bed surface of the palaeochannel by Dinn and Roseff (1992). The apparent age reversal at 1.70 m and 1.85 m depth (WQM170 and WQM185 in Table 2) was not considered problematic as the two age ranges lie well within the margin of error for the two measurements. Greig (2004) produced a date/depth curve with the new radiocarbon dates, which he used to estimate the age of material at different depths in the pollen profile. He suggested that from 1.30 – 1.85 m depth, where the date/depth curve was fairly even, the estimated dates are probably reliable. Estimated dates were considered less reliable where there was a sharp change of direction in the curve at 1.00 – 1.30 m and 1.85 – 2.00 m depth.

Together, the four dates provided by Dinn and Roseff (1992), the five new dates and the date/depth curve reported by Greig (2004) provide a strong chronology for the 1.50 m pollen profile. The dates from the gravel bed surface provided by Dinn and Roseff (1992) show that the sequence of deposits in the pollen profile began to accumulate, initially as a woody peat, some time after 7850 – 7450 cal BP. The new dates reveal a sediment accumulation rate that was more or less even from 4500 – 4300 cal BP to 3900 – 3700 cal BP. Thereafter, rates of sediment deposition were much lower to the top of the pollen profile, which dates to 1340 – 1260 cal BP (Greig, 2004).

Pollen analysis was carried out on the 1.50 m sediment profile by Greig (2004) and the pollen diagram produced is shown in Figure 21. Greig (2004) divided the pollen diagram into four pollen assemblage zones (W1-W4 in Figure 21), reflecting the principal changes in vegetation type and cover.

<u>W1 (2.36 - 1.76 m depth) – Late Mesolithic to Early Neolithic (*c*. 7700 - *c*. 5900 cal BP)</u>
An approximate date for the start of this zone is given by the dated gravel bed deposits provided by Dinn and Roseff (1992) although, as Greig (2004) acknowledged, these samples could pre-date the onset of peat accumulation by a considerable period. The end of the zone is dated by extrapolation, using the date/depth curve, from the dated material at 1.85 m depth (Table 2).

The zone is dominated by tree pollen (*c*. 80%), with large amounts of *Alnus* (alder), *Quercus* (oak), *Tilia* (lime) and *Ulmus* (elm) reflected in Figure 21. The pollen data led Greig (2004) to suggest that there was two main types of woodland covering the landscape of the Lower Lugg during the Late Mesolithic and the Early Neolithic. First, in the immediate vicinity of the site, which was a developing peat bog at the time, dense alder carr covered the wetter valley floor areas, with *Alnus* (alder) and *Quercus* (oak) present alongside wetland and aquatic plants. The second type of woodland occupied much of the drier land in the landscape and was populated by *Quercus* (oak), *Ulmus* (elm) and *Tilia* (lime), with a *Corylus* (hazel) understorey. Greig (2004) pointed out that this second type of woodland contained more *Tilia* (lime) than the pollen percentage of around 40% would suggest (Figure 21), because the insect-pollinated lime tree spreads only about 12% the amount of pollen that is spread by wind-pollinated trees such as *Quercus* (oak) and *Ulmus* (elm). The tree-dominated pollen zone probably represents natural forest cover – the prehistoric ‘wildwood’ of Rackham (1980) – at its maximum extent in the study area.

Greig (2004) suggested that the presence of occasional pollen records such as *Crataegus* (hawthorn), *Prunus* (sloe or cherry) and *Sambucus nigra* (elder) may show that openings were being made in the woodland by human activity, allowing these light-demanding trees a chance to grow. The local presence of open land is hinted at further in occasional records of herbs such as *Plantago lanceolata* (ribwort plantain), which probably grew as weeds in open ground resulting from human activity. There is also an occasional cereal pollen record, probably from crops. Greig (2004) indicated that the recovery of Mesolithic and Neolithic flints at Wellington Quarry shows that people were in the Lower Lugg study area during this early period and their activities probably caused the signs of slight woodland disturbance seen in the pollen record.

W2 (1.68 - 1.50 m depth) – Early Neolithic to Late Neolithic (*c*. 5900 - *c*. 4000 cal BP)
This zone is distinguished from zone W1 by more woodland clearance, more cultivated land and more grassland (Greig, 2004). The pollen diagram shows fluctuating records of *Quercus* (oak) and *Tilia* (lime), suggesting increased forest disturbance, and further evidence of openings in the wildwood is provided by the presence of *Betula* (birch), *Crataegus* (hawthorn), *Prunus* (sloe), *Fraxinus* (ash) and *Ilex* (holly), which are characteristic of secondary woodland. Pollen from weeds such as *Rumex* (dock), *Artemisia* (mugwort) and *Urtica* (nettle), which are typical of disturbed, often cultivated, soils, is first seen in this zone. Cereal pollen is present in the zone from a depth of 1.54 m, which the date/depth curve estimated as representing a date of *c*. 4100 cal BP. Greig (2004) also noted the presence of charcoal in this part of the sediment profile which, along with weed and cereal pollen, provides a strong indication of human activity. Grassland plants such as *Plantago lanceolata* (ribwort plantain) have a continuous record from this zone in the pollen diagram and *Poaceae* (grasses) is also seen to increase.

Indicators of woodland disturbance, the existence of charcoal, the presence of weed and cereal pollen and the increase in grassland plants amount to considerable evidence of small woodland clearances, the use of fire, the appearance of cultivated fields and the use of land for grazing at this time. All of these factors reflect an increasing human impact on the changing nature of the vegetation in the Lower Lugg study area (Greig, 2004).

W3 (1.48 - 1.18 m depth) – Late Neolithic and Bronze Age (*c*. 4000 - *c*. 2900 cal BP)
The main vegetation change in this zone is reflected in a sharp decrease in *Tilia* (lime) pollen, from about 40% to 5%. Greig (2004) suggested that this represents evidence of the extensive clearance of lime woods during the later Neolithic or earlier Bronze Age. He pointed out that the lime woods are likely to have grown on potentially good quality land in the Lower Lugg study area, making their clearance for agriculture a worthwhile undertaking. The *Quercus* (oak) and *Alnus* (alder) woods on the valley bottom, however, largely seem to have been unaffected at this time, although fluctuating pollen percentages may reflect anthropogenic disturbance. Land that was cleared in this period may have been abandoned after a short time, allowing scrub and secondary woodland to grow because there is evidence of a range of pioneer trees that spring up in woodland clearances such as *Betula* (birch), *Crataegus* (hawthorn) and *Acer* (maple). Pollens records of cereals, herbs associated with cultivated land and grassland plants also become more or less continuous in this zone. Greig (2004) suggested that the pollen evidence of human activity rates in this part of the Lower Lugg study area was particularly strong in the period c. 4100 – 3900 cal BP but less strong thereafter.

W4 (1.16 - 1.00 m depth) – Iron Age, Roman and Early Medieval (*c*. 2900 - *c*. 1300 cal BP)
The *Quercus* (oak) and *Alnus* (alder) carr vegetation that remained in the valley was cleared, along with *Corylus* (hazel), by an early stage in pollen zone W4. This left a local landscape with very little tree cover, although localised stands of *Pinus* (pine) do seem to have grown up.

As the valley floor tree cover decreased there was a concomitant increase in grassland plants and *Pteridium* (bracken), together with increases in some weeds and cereals (Figure 21). Greig (2004) suggested that this points towards meadow, pasture and some cultivated land occupying the valley floor of the Lower Lugg study area, much as it does today. The increase in *Cyperaceae* (sedges) indicates that wet areas, probably swamp environments, still existed on the valley floor. Greig (2004) summarised by indicating that the start of zone W4 represents a further phase of increased woodland clearance in the Lower Lugg study area at the end of the Bronze Age or start of the Iron Age. From this point onwards, the area seems to have been characterised by the familiar pattern of a traditional cultural landscape, with cultivated land, grassland, hedgerows and occasional stands of remaining woodland.

3.2.4 *Evaluation of the Palaeoenvironmental Data Sources*

Studies investigating Late Pleistocene and Holocene palaeoenvironments in the Lower Lugg study area have been few in number. This is particularly true where studies which have incorporated high-resolution pollen analysis and adequate dating control are concerned. Studies of this kind have been restricted to a published Late Pleistocene palaeoenvironmental investigation undertaken by Brown *et al*. (2005) and an unpublished analysis of a Holocene pollen profile conducted by Greig (1998; 2004). These two studies generated high quality palaeoenvironmental information but they both centred on sediments retrieved from Wellington Quarry and provided interpretations of Late Pleistocene and Holocene vegetation change that do not necessarily transfer to the wider Lower Lugg study area. From this perspective, more studies, which incorporate a similar level of analytical detail and dating control, need to be undertaken elsewhere in the Lower Lugg to achieve a more complete understanding of changing palaeoenvironmental conditions across the study area during the Late Pleistocene and Holocene. The critical evaluation of information sources relating to Late Pleistocene palaeoenvironments and Holocene palaeoenvironments are outlined in turn below.

<u>Late Pleistocene Palaeoenvironments</u>

The Wellington Quarry study by Brown *et al*. (2005) represents the only detailed investigation of Late Pleistocene palaeoenvironments in the Lower Lugg study area. The research reported by Brown *et al*. (2005) is of a good quality, with high resolution pollen analysis being undertaken and accompanied by five new radiocarbon dates. Pollen analysis though, was carried out on a 40 cm sample of palaeochannel sediments, which only covered a relatively short period of the Late Pleistocene. Issues relating to the nature of the radiocarbon calibration curve also meant that the temporal resolution of the five dated samples was low. Consequently, the study provided an insight into palaeoenvironmental conditions in the Lower Lugg study area but only for a short, vaguely defined period of the Late Pleistocene. The high resolution pollen analysis did, however, provide a detailed record of changing vegetation conditions in the Wellington Quarry area of the Lower Lugg between *c*. 16,000 and *c*. 13,500 cal BP. Also, the pollen diagram produced is one of the few in England that spans the late Dimlington Stadial – Windermere Interstadial boundary (Brown, 2003; Brown *et al*., 2005) and, from this point of view, analysis of the 40 cm sediment monolith at Wellington Quarry can be seen as representing a Late Pleistocene vegetation record that is of national significance. Perhaps of equal importance, the Brown *et al*. (2005) study demonstrated that the potential for reconstructing detailed records of Late Pleistocene vegetation change in the Lower Lugg study area does exist. The study suggests that organic-rich peat layers in other valley floor palaeochannels (such as those reported by Pearson and Roseff (1996) at Lugg Meadows) are likely to preserve pollen, Chironomid and Coleopteran evidence that may provide valuable records of Late Pleistocene palaeoenvironmental conditions, which can be used to extend the limited temporal coverage provided by Brown *et al*. (2005).

Holocene Palaeoenvironments

More palaeoenvironmental studies relating to Holocene patterns of vegetation change have been carried out in the Lower Lugg study area, including investigations at Lugg Bridge Quarry (Pearson and Greig, 2000) and Lugg Meadows (Pearson and Roseff, 1996). Palaeoenvironmental data from these sites are patchy, providing only outline vegetation information and no chronometric dating control. The only Holocene palaeoenvironmental investigation that incorporated high resolution pollen analysis and robust radiocarbon dating control was conducted by Greig (1998; 2004) and was undertaken at the Wellington Quarry site. The reconstructed record of palaeoenvironmental conditions provided by this study extends throughout much of the Holocene and gives a detailed account of vegetation changes that, temporally, is well constrained by nine radiocarbon dates. Perhaps the study's only shortcoming is that the pollen profile did not extend back to the early part of the Holocene. Greig (2004) indicated that the importance of the palaeoenvironmental investigations at the Wellington Quarry site is reflected in the fairly long, very detailed and well-dated sedimentary sequence, which provides evidence for the increasing impact of human activity on the nature of the vegetation cover in the Lower Lugg study area. As with the Brown *et al*. (2005) study, the investigations conducted by Greig (1998; 2004) also demonstrated that the Holocene valley floor alluvium in the Lower Lugg study area has significant palaeoenvironmental potential.

3.2.5 *Conclusions*

Outlined below is a list of the substantive conclusions that can be drawn from the critical review of the Late Pleistocene and Holocene palaeoenvironmental information sources for the Lower Lugg study area.

- There have been very few detailed studies investigating Late Pleistocene and Holocene palaeoenvironments in the Lower Lugg study area.
- Only one detailed study concerning Late Pleistocene palaeoenvironments has been conducted in the study area. This study, undertaken at Wellington Quarry by Brown *et al*. (2005), provides good quality information on changing patterns of vegetation cover but only for a relatively short period of the Late Pleistocene.
- The pollen diagram produced by Brown *et al*. (2005) is one of the few in England that spans the Dimlington Stadial – Windermere Interstadial boundary and can be seen as representing a Late Pleistocene vegetation record that is of national significance.
- Only one detailed study concerning Holocene palaeoenvironments has been conducted in the study area. This study, undertaken at Wellington Quarry by Greig (1998; 2004), provides a very detailed and well-dated record of vegetation changes throughout much of the Holocene.
- The pollen diagram produced by Greig (1998; 2004) provides a detailed record of the increasing impact of human activity on patterns of vegetation cover in the study area. The level of detailed incorporated in the pollen diagram means that this information source is likely to be of regional, and possibly national, significance.
- Together, these two studies provide a good understanding of changing vegetation conditions in the vicinity of Wellington Quarry during specific periods of the Late Pleistocene and Holocene.

- Both studies relied principally on pollen evidence but Brown *et al*. (2005) demonstrated the potential for using Coleoptera and Chironomids to enhance reconstructions of Lower Lugg palaeoenvironments.
- The lack of detailed studies, however, means that our overall understanding of changing palaeoenvironmental conditions in the Lower Lugg study area during the Late Pleistocene and Holocene is patchy and far from complete.
- A number of significant temporal gaps in the palaeoenvironmental record exist, most notably during the middle and later parts of the Windermere Interstadial and the early part of the Holocene.
- The focus on Wellington Quarry sediments means that there are also large gaps in the spatial coverage of palaeoenvironmental studies. Sites elsewhere in the study area need to be investigated, in a level of detail that matches that used by Brown *et al*. (2005) and Greig (1998; 2004), to provide a fuller understanding of changing palaeoenvironmental conditions in the Lower Lugg during the Late Pleistocene and Holocene.
- The studies undertaken by Brown *et al*. (2005) and Greig (1998; 2004) serve to enhance our knowledge but, perhaps more importantly, they demonstrate the potentially rich Late Pleistocene and Holocene palaeoenvironmental record that is preserved in the valley floor alluvium of the Lower Lugg study area.

Figure 17: Plan of the Wellington Quarry site showing palaeochannel features and the sample locations of sediments used in (A) Late Pleistocene pollen analysis and (B) Holocene pollen analysis (after Brown *et al*., 2005, p. 20)

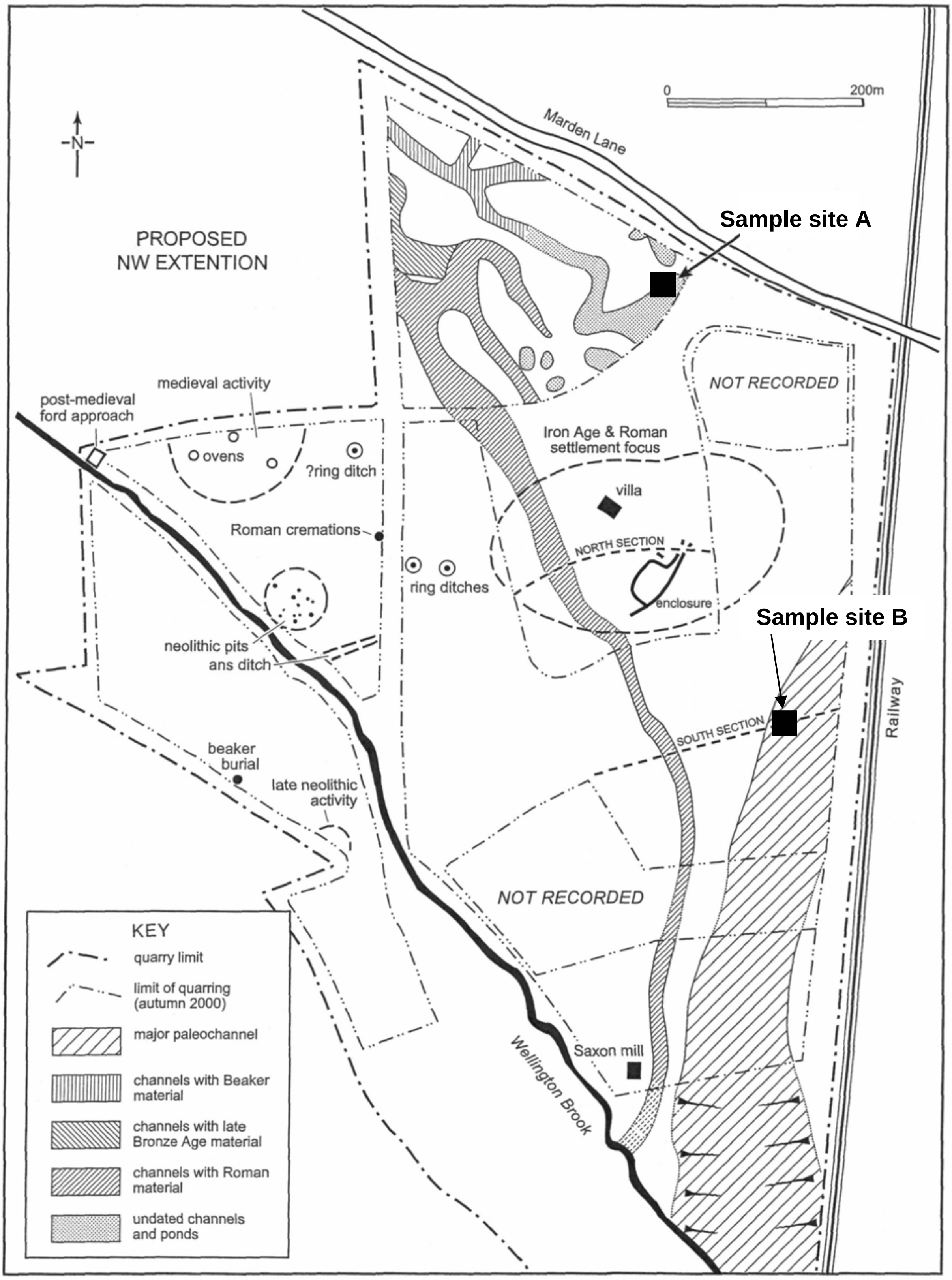


Figure 18: Stratigraphic column, loss-on-ignition, radiocarbon dates and pollen zone boundaries from the Late Pleistocene pollen core profile (Brown *et al*., 2005, p. 23)

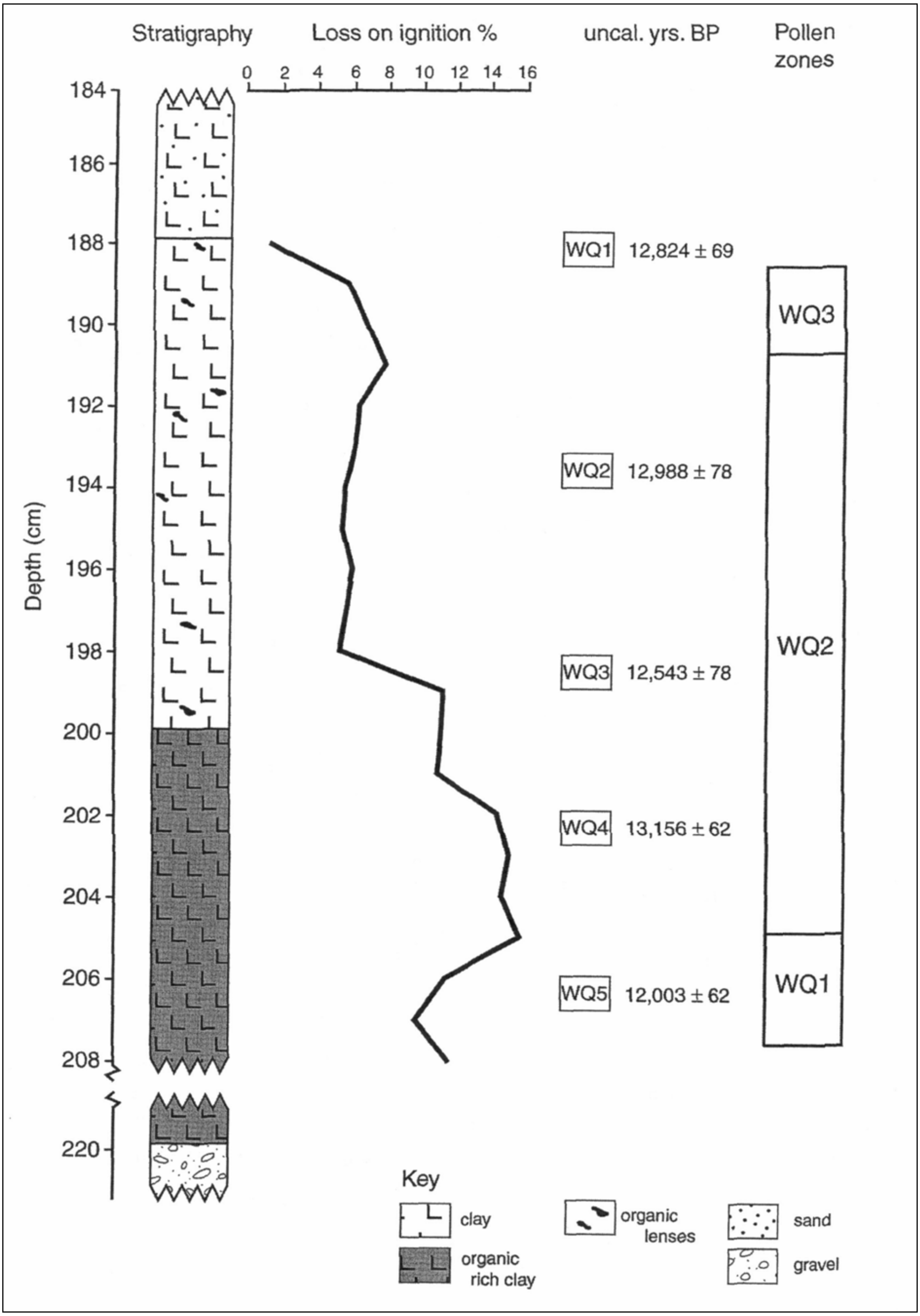


Figure 19: High resolution Late Pleistocene pollen diagram from Wellington Quarry (Brown *et al*., 2005, p. 25).

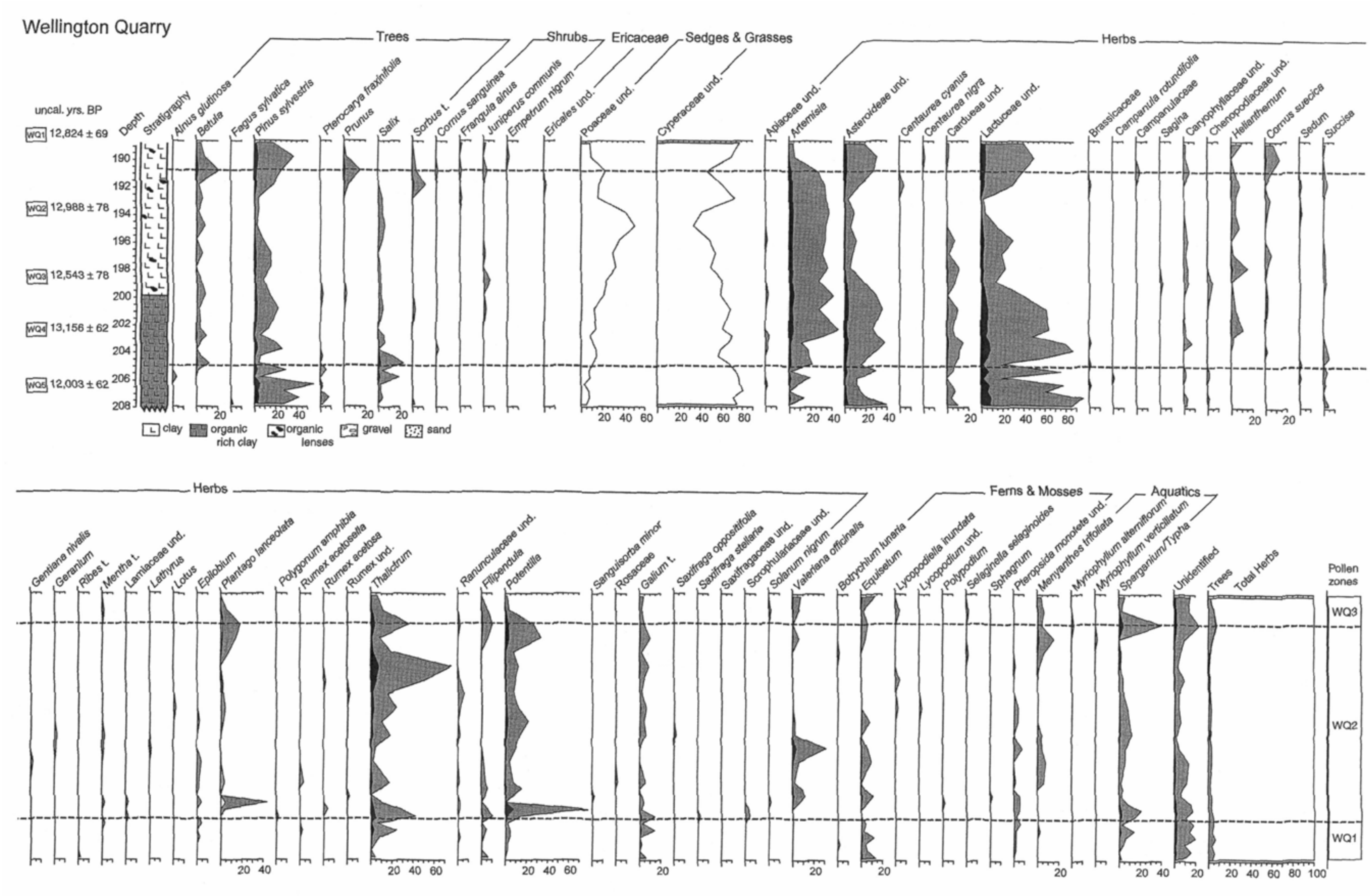


Figure 20: Exposed sections at Wellington Quarry showing the context of the sampled sediment column used in the Holocene pollen analysis (after Dinn and Roseff, 1992, p. 146).

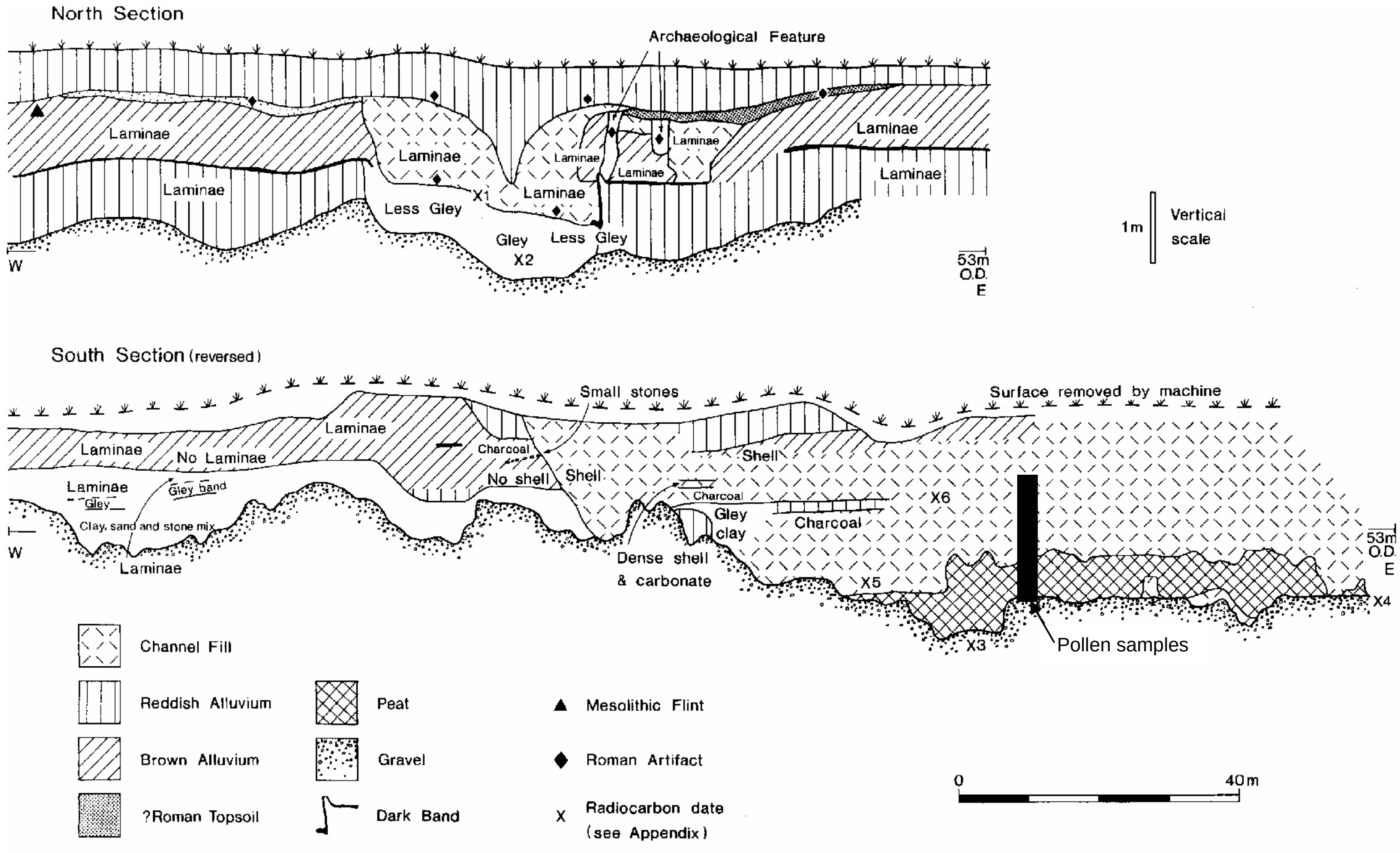


Figure 21: High resolution Holocene pollen diagram from Wellington Quarry (Jackson and Miller, 2004).