RPS Planning, Transport and Environment

INDEX DATA	RPS INFORMATION
Scheme Title A65 Hellifield Blong Preston Bypass	Details Palaeoenvironmental Report.
Road Number A65.	Date April 1995.
Contractor Barton Howe Warren B Blackledge.	
County North Yorkshire.	
OS Reference SD 85	
Single sided ✓ Double sided	
A3 0 Colour 0	

40013/96

A65 HELLIFIELD AND LONG PRESTON BYPASS
NORTH YORKSHIRE

PALAEOENVIRONMENTAL REPORT

Date	Originator	Checked	Approved	Status
April 1995	D Johnson (BHWB)	E Dennison (BHWB)	J Micklethwaite - Howe (BHWB)	Final

The Department of Transport
Yorkshire and Humberside Regional Office
Construction Programme Division
Jefferson House
27 Park Place
Leeds LS1 2SZ

Barton Howe Warren & Blackledge
5 North Hill Road
Headingley
Leeds LS6 2EN

on behalf of

Pell Frischmann Consultants Limited
George House
George Street
Wakefield
WF1 1LY

A65 HELLIFIELD AND LONG PRESTON BYPASS

NORTH YORKSHIRE

PALAEOENVIRONMENTAL REPORT

CONTENTS

2 INTRODUCTION

2.1 In January 1995, Dr Richard Tipping was commissioned by Anthony Walker and Partners (now Barton Howe Warren and Blackledge) to assess the palaeoenvironmental implications of the proposed A65 Hellifield to Long Preston bypass, North Yorkshire, and to provide an indication of any further work that might be required to analyse any palaeoenvironmental deposits which would be affected by the scheme. This report has been compiled from Dr Tipping's assessment (Tipping 1995), with appropriate advice from Dr Tipping. It should be noted that any errors or inaccuracies in this report remain the responsibility of Barton Howe Warren and Blackledge.

2.2 This report combines information gained from:

(i) a comprehensive desk-top survey of past palaeoenvironmental research into the late Quaternary history of the Craven lowlands;

(ii) data obtained from commercial geotechnical investigations, primarily borehole logs, commissioned by Pell Frischmann Consultants Limited;

(iii) a limited programme of site investigations carried out on 21st February 1995.

3 SYNTHESIS OF EXISTING RESEARCH

3.1 Introduction

3.1.1 In order to explore the deficiencies of the late Quaternary record for the Craven lowlands, it is necessary to review existing data in broadly chronological order, highlighting contrasting interpretations and the current resolutions to such difficulties. In all cases, dates are referred to in uncalibrated years before present (bp); present is conventionally defined as the year 1950.

3.2 Dimlington Stadial (*c.*25,000-16,000 bp)

3.2.1 This period defines the maximal Devensian glaciation. The basal Quaternary deposit exposed and recovered in deep boreholes is lodgement till ("boulder clay"), dating to this phase. This is often in excess of 20m thick (Arthurton, Johnson & Mundy 1988) and, although usually restricted to low ground, can be found up to 500m OD. Rocks within the upper Ribble and Aire valley tills are exclusively of local origin (Johnson 1985), fed by a local ice-cap on the Mallerstang-Wild Boar Fell, north of Hawes, which forced Lake District ice west of the Ribble valley (Raistrick 1930, 1933; Mitchell 1991).

3.2.2 The till in the valley floor east of Hellifield, extending below Gargrave, is moulded into prominent landforms called drumlins, stream-lined till domes deposited by fast-moving ice-streams (Rose & Letzer 1977). Their long-axes indicate ice-streaming down the Aire valley, but those on the southern edge between Hellifield and Barnoldswick are oriented down the Ribble valley, diverging around Flambers Hill (NGR SD878522) (Raistrick 1930, 1933; Johnson 1985; Arthurton et al 1988). Sections through the drumlins suggest that three types can be defined, those composed entirely of till, those in which fluvioglacial sands and gravels comprise the major part, and till-smeared rock domes or roches moutonnees (Raistrick 1930). The Hellifield-Skipton-Barnoldswick drumlin field is now regarded as a feature of the maximal glaciation, rather than a product of deglaciation.

3.2.3 There are almost no drumlinoid landforms in the area between Hellifield and Long Preston, which has a much more subdued topography. Distinctive glacial landforms are rare, but Raistrick (1933) crudely mapped a moraine crossing the Ribble valley between Halton West (NGR SD845545) and Hellifield (NGR SD855565). Johnson (1985) also mapped this feature, as well as a second moraine up-valley of Halton West, possibly across the valley at Cow Bridge (NGR SD827569).

3.2.4 From borehole data and rare streambank sections, Arthurton et al (1988) examined these glacial deposits in more detail, interpreting them as being highly complex glacial, fluvioglacial and glacio-lacustrine deposits (their "Ribble Drift Complex"). Rather than seeing these deposits as representing a halt in ice-retreat, albeit of uncertain chronological significance (Raistrick 1933; Johnson 1985), Arthurton et al (1988) viewed this area as one of concentrated sub-glacial drainage and ponding.

3.2.5 This sequence of deposits appears to lie against a pronounced bedrock ridge at Hellifield (Johnson 1985), though whether this constriction had an effect on sedimentation is unknown. Arthurton et al (1988) describe a sequence of eight deep boreholes on the line of a proposed dam between Deep Dale Head (NGR SD830557) and Holme Bridge, near Long Preston (NGR SD844580), in which laminated silts and clays are interbedded with sands, sandy gravels and "tills" in a stratigraphic sequence up to 54m thick at Arnford Wood (NGR SD837560). However, the identification of till from borehole logs is notoriously difficult, and their interpretations are open to question; it is exceedingly unlikely that *in situ* lodgement till, a product of sub-glacial deposition, can be distinguished from supraglacial or even reworked "deformation" till in borehole logs.

3.2.6 This notwithstanding, the landforms in the area between Arnford and Holme Bridge are more characteristic of fluvioglacial deposits. Subdued sand-and-gravel kame deposits are mappable between Arnford (NGR SD830556), Gallaber (NGR SD850560) and Bendgate (NGR SD845575), with shallow "kettle-holes", laid down during deglaciation. Fluvioglacial sands and gravels overlie till in sections above Halton Bridge (NGR SD850554), and there are suggestions of a second younger, though still fluvioglacial, terrace surface between Gallaber and Halton Bridge (Arthurton et al 1988).

3.3 Devensian Lateglacial *sensu lato* (*c.*16,000-10,000 bp)

3.3.1 In the Ribble valley floor at Arnford, boreholes reveal a thick sequence of silts and clays, often strongly laminated and up to 13-14m thick, overlying "till" (Arthurton et al 1988). Laminated clays are found to *c.*130-132m OD, and probably extended upstream above Cow Bridge to merge with Lake Settle (see figure 1). Johnson (1985) identified a lake-floor behind the "moraine" at Halton Bridge, in the general area of these boreholes, inferring a moraine-dammed lake, named here as the Arnford Lake (see figure 1). Arthurton et al (1988) logged a section in "stoneless clay" here (NGR SD844554).

3.3.2 This lacustrine sequence is overlain by fluvioglacial gravels (Arthurton et al 1988), and this stratigraphy can be compared with sections seen lower down the Ribble valley, near Clitheroe (Earp et al 1961) and at Skipton gasworks (Raistrick & Woodhead 1930). However, at Skipton railway bridge, within the same "lake-flat" between Cononley and Gargrave, Raistrick (1926) recorded up to 10.3m of laminated lacustrine clays overlain not by coarse gravels but by Holocene silts (see 3.4.10 below). This relationship between the laminated clays and silts and the overlying Holocene silts and peat is also seen in the "moraine"-dammed Lake Settle, north-west of Cow Bridge (Raistrick 1930, 1933; Arthurton et al 1988). Arthurton et al (1988) report borehole data from Gildersleets sewage works, south of Settle (NGR SD808633), where up to 7m of laminated silts is recorded. These laminated silts lie at much lower altitudes than south-east of Cow Bridge, where similar lake sediments are preserved up to 130-132m OD. Within Lake Settle, these silts appear to have been eroded at some time prior to the deposition of Holocene sediments.

3.3.3 The assignment of an age to these numerous lacustrine deposits, particularly those overlain by coarse gravels, has not been fully explored in the literature. Their deposition behind apparent cross-valley moraines (Raistrick 1927) would imply that the lakes were formed by meltwater release when the ice retreated, and this would be supported by the occurrence of clay deposited directly on till. Laminated sediments are very common proglacial deposits but the frequency of sites where coarse gravels replace the lacustrine deposits, often erosively, indicates a dramatic deterioration in conditions with gravel deposition.

3.3.4 Although there is no dating evidence available, it is perhaps most reasonable to infer that these gravel deposits date to the final cold snap of the Devensian Lateglacial, the Loch Lomond Stadial (*c.*11,500-10,000 bp). The capping of laminated clays and silts in the Arnford Lake by purported tills (Arthurton et al 1988) may also be explained by the return of periglacial conditions in the Loch Lomond Stadial, with the re-deposition of deformation till from drumlin sides and slopes across the basin; there is no evidence for glacier re-advance in the Craven Lowlands during the Loch Lomond Stadial. Erosion of the upper layers of laminated sediments within Lake Settle probably also occurred within, possibly towards the end of, the Loch Lomond Stadial.

3.3.5 In smaller isolated lake basins there is better evidence for the chronology of Devensian Lateglacial sedimentological changes, and also for vegetation changes, since a few basins have been palynologically investigated (pollen-analysed). Raistrick and Blackburn (1938) explored the macro- and micro-fossil history of a former lake at Linton Mires, near Cracoe north of Skipton. Analyses were restricted to the Holocene, but the stratigraphy suggested that beneath a coarse silt, as indicative in its way of the accelerated sediment erosion of the Loch Lomond Stadial as the coarse gravels in major valleys, there was a lake marl or calcareous mud dating to the warm phase prior to the Stadial, the Lateglacial Interstadial (*c.*13,000-11,500 bp). Linton Mires was re-examined by Jones and others (Jones 1977; Bartley, Jones & Smith 1990). They appear equivocal over the ages of the basal sediments, but it seems likely that a Loch Lomond Stadial age can be confirmed for the silt band. Pigott and Pigott (1963) still provide the most secure data on Late Devensian vegetation history for the area, from Malham Tarn, north of Malham, although this site has not been radiocarbon-dated, and interpretation is confounded by the use of an inappropriate arboreal pollen sum.

3.4 **Holocene Period** (*c.*10,000 bp to present)

3.4.1 Less is securely known of the environmental changes in the Craven Lowlands in the present interglacial than that of the preceding glacial phase. Sedimentological and geomorphological changes are known but poorly understood, principally because of a degree of confusion by early workers over the probable origins and sources of sediment observed in boreholes and temporary sections. Vegetation changes are more clearly understood from the relatively recent work of Jones (Jones 1977; Bartley et al 1990), particularly the course of human impact on the woodlands, but there are quite severe difficulties in the correct interpretation of the pollen records because of uncertainties in the radiocarbon chronology for his sites.

Lacustrine Deposits

3.4.2 Given the cappings of "till" and gravel immediately beneath the present ground surface, at *c.*138m OD at the lowest altitude, the Arnford Lake may have been completely infilled by or during the Loch Lomond Stadial. However, upstream of the Cow Bridge moraine, it is argued that the much larger Lake Settle continued to exist in the Holocene period (Raistrick 1930, 1933; Arthurton et al 1988). The level surface of valley-floor deposits lies consistently at around 124m OD and this contour line, when traced upvalley from Cow Bridge, appears to effectively delineate the maximal extent of the lake; flood-waters in February 1995 lay across the present floodplain to this altitude. Lake Settle probably extended from below Borks Hill (NGR SD828580) across to Wigglesworth Hall (NGR SD812576), and to the north-west beyond Rathmell (NGR SD805600) to west of Gildersleets (NGR SD806626), and to Settle itself (Raistrick 1930). It is probable that excellent exposures were created during construction of the A65 Settle bypass.

3.4.3 Gravels are apparently absent within Lake Settle. However, there is no evidence for sustained lacustrine sedimentation from Devensian Lateglacial to Holocene times, although Raistrick (1933) assumed this to be the case. It is most likely that intense down-cutting of perhaps 20m+, accompanied by lateral erosion, removed evidence for gravels capping the laminated silts within Lake Settle, and truncated the upper surface of laminated silts also. At Gildersleets there is an unreported thickness of alluvial sands overlying the laminated silts (Arthurton et al 1988); the contact, conformable or erosive, is unknown. Also near Settle (the precise location is unrecorded), near the edge of the deposits, Raistrick (1933) reported the following sequence of deposits:

surface soil & made ground	- 1'6" (0.45m)
sand	- 0'6" (0.15m): archaeological finds: Roman bronzes and glass
peat	- 3'6" (1.06m): archaeological find: "stone celt" (a possible Neolithic polished stone axe) at the base of the peat
sand	- 0'9" (0.23m): "bones of deer etc."
silt and clay	- unknown depth

3.4.4 Again, near Long Preston (but exactly where is unrecorded) Raistrick (1933) briefly described a find of *Bos primigenius* (aurochs) beneath 10'6" (3.20m) of peat. In the same paper Raistrick mentions a find of a dug-out canoe from the now-infilled Giggleswick Tarn (NGR SD806647). This lake-basin lies above Lake Settle, and was never a part of the lower-lying lake, but it is important since the canoe is the only reliable evidence that lakes continued to exist into the later Holocene period.

3.4.5 The first point to be made of these sedimentary sequences is the very real potential for archaeological discoveries at sites near Long Preston. This fully endorses the recommendations made by both Northern Archaeological Associates (Fraser & Speed 1992) and Anthony Walker and Partners (1994) for stratigraphic investigations to accompany road construction. There must be a considerable likelihood of locating archaeological deposits within the Holocene sediments of Lake Settle (see 4.3 below).

3.4.6 Given this, however, it must be pointed out with regard to Raistrick's interpretations, that neither peat or sand are lacustrine sediments. At present, organic deposits are best interpreted as floodplain peats and sand as alluvial (river-derived) in origin.

Alluvial deposits

3.4.7 The current probability is that all deposits overlying the laminated silts of Lake Settle are semi-terrestrial and not lacustrine in origin. Enough is known to suggest that within the Holocene sediments there is preserved evidence for accelerated alluvial sedimentation from a more active River Ribble.

3.4.8 Virtually nothing is known of the Holocene histories of river systems in the Craven Lowlands. Earp et al (1961) mapped three terrace surfaces above the present Ribble south-west of Clitheroe, and one surface on the Aire at Skipton; some if not all of these terraces are almost certainly of Late Devensian age. Arthurton et al (1988) describe two alluvial fans entering Lake Settle, one fed by the Long Preston Beck (NGR SD828583-SD834575) and the other on the opposite side of the valley from the Wigglesworth Beck (NGR SD812577); this interpretation of the Long Preston deposits is disputed in 4.4.3 below. The ages of these features are totally unknown. The Long Preston "fan" is clearly a multi-phase feature, the beck having incised and built up (aggraded) at least twice. Whilst the earliest phase should date to the Late Devensian period, later phases may well date to some time in the Holocene period (4.6 below).

3.4.9 Some information is known of Holocene fluvial activity from sites in the lower Aire valley, and these limited analyses emphasise both the lack of data for Craven and also the potential for survival of deposits. In the late 1920's temporary sections were exposed in the Aire floodplain at Armley, near Leeds (Raistrick & Woodhead 1930). Four metres of basal coarse gravels were overlain by 0.40m of organic-rich sands containing peat (not *in situ*) and tree trunks and branches of oak (*Quercus*), alder (*Alnus*), birch (*Betula*) plus holly (*Ilex*), hazel (*Corylus*) and willow (*Salix*). This undoubted Holocene assemblage was then overlain by 3m of fine gravels, sands and silts. This sequence was interpreted as indicating continuous deposition but, as in Lake Settle, there was a reluctance to identify hiatuses in deposition.

3.4.10 A modern interpretation would probably recognise the lower gravels as being Late Devensian (see 3.3.4 above), with an hiatus until some time after the colonisation of alder, post-7500 bp. From that time onwards, alluvial deposits aggraded in one stacked fill of deposits, though by no means necessarily in one continuous event. Further upstream at Skipton railway bridge, Raistrick (1926) logged 1-3m of alluvial silt above Late Devensian laminated lacustrine sediments (see 3.3.1 above), on the surface of which he recovered bones of *Equus* (horse), *Bos* (ox) and Ovicaprids (sheep/goat), a probable post-Neolithic assemblage. But this was in turn buried by a further 3.5m of fluvial sands and fine gravels. Smith (1986) argued for burial of a soil by "flood loam" at around the time of the alder rise at Cow Gill, Gordale near Malham, and for alluvial fan deposition at the same time at Linton Mires.

3.4.11 Bartley (1964) was able to refine the age of alluvial deposits within the Calder valley near Elland by pollen analysis, and demonstrated that alluvial deposition was intermittent and separated by prolonged hiatuses. An early Holocene gravel was overlain by peaty clays representing shallow pools on the gravel surface, dated to a period after the alder rise, as at Armley (see 3.4.9 above). But the superseding 3.67m of coarse sand could be shown to post-date 5,000 bp as it contained pollen forest clearance indicators. "Flood loams" spread across the peat at Linton Mires post-5,000 bp (Bartley et al 1990). South-east of Leeds, Gaunt, Coope and Franks (1970) recorded similar fluvial sequences, with a major hiatus between Late Devensian fine-grained sediments and a coarser sandy gravel radiocarbon dated to 4280 ± 100 bp (St-3077).

The Diversion of the River Ribble

3.4.12 The suggestion that the upper Ribble, above Hellifield, once flowed down the Aire valley has a long history. Its capture by the lower Ribble was ascribed by Raistrick (1930, 1933) to the Devensian Lateglacial *s.l.*, following the dumping of the Hellifield-Gargrave-Barnoldswick drumlin field and the blocking of the drainage system. He envisaged the captured Ribble draining through the gorge-like reach cut into Devensian drumlinised till between Swinden (NGR SD858543) and Paythorne (NGR SD833515). However, as noted above, the drumlin field is now seen not to be a feature of deglaciation, but dates to the glacial maximum and so this might imply capture of the upper Ribble earlier than Raistrick thought. Earp et al (1961) thought that they could detect a pre-glacial (pre-Devensian) route east of Wigglesworth (NGR SD810555) to Bolton-by-Bowland north of Clitheroe, though how is unclear. From deep boreholes, Johnson (1985) was able to reconstruct the rock-head contours of the Craven Lowlands, representing the pre-glacial landsurface, and could demonstrate that the present river course mirrors the subsurface route, and that if capture ever did occur, it occurred prior to the last glaciation.

3.4.13 However, the upper Ribble today has certainly incised through the Swinden-Paythorne gorge in post-Devensian times, after meandering over the surface of Lake Settle and incising through the remnants of the Arnford Lake. Precisely when this incision occurred is unknown; like Raistrick (1930, 1933), Johnson (1985) assumed the cutting of the gorge to have occurred as a final phase of deglaciation but Earp et al (1961) and Arthurton et al (1988) saw the gorge as a post-glacial feature.

Soil degradation and erosion

3.4.14 One assumption in the interpretation of late Holocene alluvial deposits is that the accelerated deposition of minerogenic fills, usually as floodplain or overbank sediments, can be linked to soil erosion on slopes supplying the river system (Smith 1986; Needham & Macklin 1992). The fluvial sequence can then be used as an indirect measure of the degree of soil erosion, and can on occasions be linked to evidence for deforestation, intensification of or a change in land use.

3.4.15 Pigott and Pigott (1963) examined the sediments of Malham Tarn, specifically to explore the degree of soil cover in former times on the extensive limestone pavements. They found no evidence for soil washing into the tarn, and concluded that the pavements had never had a significant soil cover. Yet this area contains early field systems (Smith 1975), and it is likely that late prehistoric soil losses were significant. One mechanism which marries these apparent contradictions concerns the emergence of pavements by vertical soil losses into evolving and widening grike systems (Smith 1986).

3.4.16 Soil losses are clearly inextricably linked to the development of field systems, and in this regard the Craven district has been better studied than many others (Smith 1975, 1986). Smith (1986) argues for soil losses to have reduced the Craven Uplands to a scrubby heath before Norse settlement revived the agricultural economy. Other studies of the effect of hillwash on cultivation systems are Smith's (1975) excavations through lynchet systems at Otterburn in the upper Aire valley.

Vegetation history

3.4.17 A strong association between increases in anthropogenic activity and accelerating geomorphological activity, such as reflected in phases of soil erosion and changing fluvial regimes, has been proposed by a number of workers (see Needham & Macklin 1992). This link cannot at present be made from the comparatively poorly dated fluvial stratigraphies of the lower Aire and tributaries. Little is confidently known of the cause or chronology of prehistoric and historic geomorphological changes in the Craven Lowlands. A little more is known of the vegetation history.

3.4.18 Five pollen sites were analysed by Jones (1977) from the Craven Lowlands; no other analyses are known to have been undertaken in this area. Pigott and Pigott's (1963) analyses at Malham Tarn, and

Smith's (1986) work at Great Close Pasture and Gordale Beck, all lie in the uplands above Malham Cove. The upland-lowland contrast in Craven is critical given the dramatic contrasts in topography, rock-type, soil quality and agricultural history. Linton Mires near Cracoe has already been mentioned, but this site is truncated above the elm decline, and the last 4,000 years are missing (Bartley et al 1990). Nearby Threshfield Moor, south-west of Grassington, is also truncated just above the elm decline, as is Martons Both south-west of Gargrave (NGR SD893518) (Bartley et al 1990).

3.4.19 Only two sites analysed by Jones (1977; Bartley et al 1990) are thought to contain a more-or-less full Holocene sediment and pollen stratigraphy. These are Eshton Tarn, north-west of Gargrave in the upper Aire valley (NGR SD918576), and White Moss, south of Wigglesworth (NGR SD792546). However, full records can only be obtained at both of these sites by patching together two separate pollen profiles, and this has proved to be a problematic approach (see 3.4.25 and 3.4.26 below).

3.4.20 The main Eshton Tarn pollen diagram has a high temporal resolution, in that pollen sub-samples are taken at comparatively close intervals from sediments *c.*700cm thick, but historic period sediments are missing. A second core (M; 180cm thick) is thought to provide data on the historic period land use history, but there are severe reservations concerning this (see 3.4.25 below). The White Moss sequence is also *c.*700cm thick and was similarly analysed at high temporal resolution. However, the chronological controls for this site are poor (see 4.2.26 below).

3.4.21 The first 5,000 years of the Holocene are understood in excellent detail. The number and quality of the pollen counts are good, and analyses are supported by several seemingly valid radiocarbon determinations (Bartley et al 1990). In summary, a treeless Late Devensian landscape was invaded first by birch (*Betula*), ubiquitously across the landscape. Pine (*Pinus*) colonised limestone soils by 9,400 bp, and Craven seems to have been a rare northerly outpost for pine trees. Hazel (*Corylus*) colonised at 8,800-9,000 bp. In wetter and less calcareous areas, a mixed deciduous woodland of oak (*Quercus*) and elm (*Ulmus*) developed, but these woods were prone to invasion by pine when edaphic or climatic conditions changed. Alder (*Alnus*) colonised in force after 7,600 bp, though they may have been present in low numbers before that time. Mid-Holocene forests included ash (*Fraxinus*), lime (*Tilia*) and on limestones, yew (*Taxus*).

3.4.22 A recurring feature in pollen diagrams from upland and lowland areas is the suggestion of mesolithic anthropogenic activity (Pigott

& Pigott 1963; Smith 1986; Bartley et al 1990), supported by abundant archaeological sites.

3.4.23 The last 5,000 years are much more poorly understood. Fewer sites are available because of the truncation or cessation of peat growth (Smith 1986). The full Holocene sequences in the uplands are not radiocarbon dated so that confident correlation with the archaeological record cannot be achieved. It should be noted that this is the period of greatest interest for most archaeologists.

3.4.24 Only the Eshton Tarn and White Moss records can be used to examine the later Holocene vegetation history of the Craven lowlands (Jones 1977; Bartley et al 1990). In both cases there are severe reservations, as these otherwise high quality pollen records are handicapped by inadequately constructed chronologies, and are a poor base for interpretations of the timing of human impacts.

3.4.25 The Eshton Tarn record is constructed from two partial diagrams (see above), but the presumed temporal overlap (Bartley et al 1990) is uncertain. One sediment sequence is truncated well before the historic period, with only two radiocarbon dates covering the later prehistoric period. The second, much shorter, sequence has only one radiocarbon date, of *c.*3,160 bp, 110cm below the ground surface. However, this date and thence the assumption of temporal correlation with the main core must be doubted. Jones (1977) argued that the complex sequence of peats and lake clays at and above 90cm in the second core (M) could be related to medieval and later periods but this is very dubious and, most importantly, the two independent chronologies cannot be squared. Interpretation of this second core is insecure, and although figure 9 of Bartley et al (1990) implies continuity of deposition, there is no textual interpretation of the period from the late Bronze Age to the medieval period.

3.4.26 The main White Moss sequence also has only two radiocarbon dates in the later Holocene. This is a very inadequate coverage and assumes too much in terms of age-interpolation, particularly in a stratigraphy which varies greatly in sediment types and probably in sedimentation rates also. But, even assuming a linear sedimentation rate between these two dated points, it is clear that sediments formed in the last *c.*700 years (0-100cm) have not been analysed, a point ignored in Bartley et al's (1990) synthesis. Also ignored is Jones' (1977) apparent uncertainty over the veracity of the basal radiocarbon date in the second White Moss core (core 6), of *c.*7,520 bp. This date is taken as correct by Bartley et al (1990) despite the sediments appearing to be of post-elm decline age. Finally, while Bartley et al (1990) assume the White Moss 6 record to be continuous from *c.*8,000 bp to the present, Jones (1977) argued for an hiatus to have occurred within the top *c*.40cm, such that a gap of unknown duration probably exists between *c*.3,500 and 1,200 bp.

3.4.27 The description provided by Bartley et al (1990) is most pertinent to the Craven lowlands, but the chronology should be treated with caution. The elm (*Ulmus*) decline is synchronous (within the error of the radiocarbon technique) at Eshton Tarn and White Moss at *c*.5,000 bp (Bartley et al 1990). Neolithic woodland interference is noted in both the uplands and lowlands, with cereals recorded at Eshton Tarn at a depth "roughly dated" at *c*.4,500 bp, and at White Moss at *c*.4,300 bp. The first major woodland clearance is argued to have occurred in the early Bronze Age (Jones 1977; Smith 1986; Bartley et al 1990), in common with other areas of the Pennines, initially apparently pastoral in character, but with cereals represented in the late Bronze Age (*c*.3,200 bp) at Eshton Tarn. The major clearance phase at White Moss does not occur until *c*.1,470 bp, though whether this diachroneity can be taken as real (eg. Bartley et al 1990) is very unclear.

4 LATE QUATERNARY SEDIMENTS ON THE ROUTE OF THE PROPOSED A65 BYPASS

4.1 Introduction

4.1.1 From the review of existing research, three particular priorities have been isolated for further study, namely:

(i) a much clearer elucidation of the later Holocene (post-5,000 bp) vegetation history of the area, with particular regard to human activity. This history must be accompanied by a comprehensive and secure independently-derived chronology;

(ii) an understanding of the record of periodically accelerated alluvial sedimentation, and of major phases of soil erosion and general geomorphic disturbance, within the Ribble valley. There is tantalising evidence from the lower Aire valley and from "Lake Settle" that the alluvial record can firstly be deduced from stratigraphic work, and secondly securely dated;

(iii) an understanding of the timing of the drainage of "Lake Settle", with its relevance to the mode and environment of deposition of artefacts, and the resolution of the debate concerning the period of first occupation of the Swinden-Paythorne gorge by the Ribble.

4.1.2 This section will discuss specific localities within the proposed construction corridor (as in May 1993; drawing no. 40013/10/100/01) which appear capable of resolving these issues. The data sources are:

(i) the literature search, notably the British Geological Survey Memoir (Arthurton et al 1988);

(ii) the extensive sets of borehole logs generated by Terresearch Foundation Engineers (1989), Geotechnical and Testing Services (1991) and Structural Soils Limited (1993), particularly those commented on by Anthony Walker and Partners (1994);

(iii) a limited programme of site visits carried out on 21 February 1995 by Dr Richard Tipping. Promising localities were re-investigated by the use of a hand-held 1m long Eijelkamp gouge-sampler (diameter 2.5cm) and extension rods.

4.1.3 A full exploration of certain sites proved to be impossible due to the exceptionally high floods, the highest in 65 years (pers comm Mr

Thwaite of Long Preston), across the Ribble valley floor and the high groundwater levels within isolated basins.

4.2 Goosemires Laithe (NGR SD824586)

4.2.1 Arthurton et al (1988) describe a low terrace surface developed in peat *c.*1-2m above the Ribble valley floor. A narrow strip of peat is mapped as extending a few hundred metres north-west of the farm at Goosemires Laithe, and a larger spread of peat on the valley floor across the River Ribble in front of Wigglesworth Farm (BGS 1:50,000 Settle Sheet (Drift)). All the boreholes sunk during the investigation of the superficial geology of the road alignment in this vicinity lie at too high an altitude to allow the depiction of the valley-fill, the present surface of which lies at *c.*124m OD.

4.2.2 This site could not be visited due to flooding. However, it is likely that this locality more than any others on the proposed road alignment provides an opportunity to reconstruct the alluvial stratigraphy of the Ribble in this area. It is hoped that, like Raistrick's (1933) section near Long Preston, the peat will be found to be intercalated with overbank "flood loam" sediments. There is no evidence of late Holocene river terraces occurring at different altitudes, and it is most likely that, if present, flood sediments will occur as stratified fills sandwiched between peats, the latter forming on floodplains at periods of relative quiescence. Former lake-basins elsewhere have proved to have superbly resolvable alluvial stratigraphies overlying lake muds (Tipping 1994), with the advantage that the interbedded nature of the deposits allows a radiocarbon chronology to be established.

4.3 Goosemires Laithe-Sour Dale Lane (NGR SD824585)

4.3.1 The possibility of archaeological artefacts being recovered from stratified valley-floor deposits in this locality are emphasised by Raistrick's (1933) discoveries; this area is suggested as being a likely place from which such artefacts, if not occupation deposits, might be recovered.

4.3.2 At and north-west of Goosemires Laithe, the till and fluvioglacial slopes descend steeply to the valley floor, but south-west of Goosemires Laithe the slopes are much more gentle as coarse gravel, probably Late Devensian in age and possibly reworked into a smoother slope (see below), descends gradually beneath the valley floor. Access to the floodplain is made easier down this slope, as it is today via Sour Dale Lane. This might be seen as a prime location for early prehistoric settlement. Further south-east, the proposed road alignment lies entirely on gravels, and the interface between the gently-sloping parts of the valley side and the valley floor deposits is not crossed by the proposed road.

4.4 **Sour Dale Lane** (NGR SD82625850)

4.4.1 Borehole 69B and test pit 24 (Terresearch Foundation Engineers 1989) record, beneath some 1.50m of peat, a further 1.20m of "white silt" overlying gravels. This sediment is a marl, a calcareous lacustrine mud produced by biogenic deposition of algae and plants, and typical of limestone areas, as seen in the sediment stratigraphies at Malham Tarn, Linton Mires, Eshton Tarn and parts of White Moss. Marl is typically an early Holocene deposit, indicative of a lack of sediment supply from surrounding slopes, and, as soil leaching increases, climatic conditions deteriorate and human impacts accelerate, marl deposition ceases. In borehole 69B the marl is then replaced by a non-calcareous silt and then by peat.

4.4.2 This site was investigated further by limited Eijelkamp gouge-corings. The topography of the area does not at first indicate a buried lacustrine sequence. The western slopes of the fluvioglacial mass of Borks Hill fall steeply to Sour Dale Lane. At its base at *c*.132m OD the ground appears to fall more gradually to the present floodplain at 124m OD.

4.4.3 Careful mapping, not least aided by the knowledge of the stratigraphy seen in boreholes (4.4.1 above) revealed a very subdued raised rim or lip to a small, broadly circular depression some 50m by 35m. Boreholes 68, 68B and 69A lie outside this, and show no evidence of lacustrine sediment. Boreholes 69B and trial pit TP24 do, and borehole 68A is probably at one margin of this very small pond. The basin was probably a kettle-hole or dead-ice depression within fluvioglacial gravels, deposited during the Late Devensian ice-retreat. As such, it is unlikely that the gravels are fan sediments as mapped by Arthurton et al (1988).

4.4.4 One core was logged immediately adjacent to borehole 69B. The sediment stratigraphy is:

0-133cm:	inorganic to weakly organic silty clay sand; sharp boundary to
133-285cm:	dark brown highly humified amorphous peat with rare sedge stems and, in basal c.10cm, rare wood fragments; sharp boundary to
285-316cm:	dark grey structureless coarse sandy grit with silt; gradual to

316-528cm: creamy marl with rare sedge stems, seemingly pure except for the topmost *c.*10 cm and a band of sandy grit between 488cm and 494cm.

Bottomed on stone at 528 cm.

4.4.5 This stratigraphy bears some resemblance to the sequence logged in borehole 69B, but it is considerably deeper (528cm compared to 450cm). In addition, the sediment separating the marl and peat (285-316cm here) is described as a silt in borehole 69B.

4.4.6 The marl was deposited in still and clear water. If the basin was a kettle-hole, the basal sediments should date to the Devensian Lateglacial. This phase may be represented by the band of grit at 488-494cm, but it is felt that this is more likely to be later in date. If this is so, the apparent absence of Devensian Lateglacial deposits may be explained by the solifluction of gravels across the floor of this small basin in the Loch Lomond Stadial. Marl is then replaced by coarse grits. Marl deposition may have ceased because of the commencement of coarse sediment supply, or the two events may be separated by an hiatus. The grit may have derived through soil erosion from the slopes above, but an intriguing possibility is that this represents erosion of the now subdued south-west rim of the basin by water from the Ribble valley (Lake Settle?); it is certainly a mid-Holocene event. The overlying peat is remarkably free of mineral grains, which gives way abruptly to the final minerogenic band, extending to the surface.

4.4.7 The stratigraphy is certainly interesting, and between 285cm and 133cm clearly resolvable by radiocarbon dating, given confirmation of a carbonate-free peat. The later Holocene record contains a final and unusually thick inwash of minerogenic sediment, in which only the onset can be dated. The source of this sediment is unknown at present, and also raises questions about the erosive power of the Ribble, since sediment inwashing of this coarseness and extent are totally lacking from the next site, at Borks Hill, very close to Sour Dale Lane but, perhaps critically, isolated from the valley floor.

4.5 **Borks Hill** (NGR SD82855835)

4.5.1 The fluvioglacial mound of Borks Hill was the subject of an earthwork survey by Northern Archaeological Associates, where a pre-enclosure field system was identified (Fraser & Simpson 1992). At a low point in the centre of the system a man-made depression, possibly a quarry, was recorded. This depression, measuring some 70m by 30m is, from the sediment stratigraphy, certainly a natural feature.

4.5.2 Borehole 137 (Structural Soils Limited 1993) records 2.70m of amorphous peat over 1.50m of silty clay, described as "alluvium" but likely to be lacustrine, being deposited in a closed depression readily identifiable as a kettle-hole. TP23 records a similar, perhaps more marginal stratigraphy in which marl can be recognised beneath peat.

4.5.3 This site was also investigated by hand-held corer. At a point in the centre of the basin, some 30m from borehole 137, the following stratigraphy was recorded:

0-84cm:	black highly humified amorphous peat, slightly friable in top *c.*14cm; gradual boundary to
84-177cm:	brown poorly humified fine fibrous peat with rare wood fragments, increasingly poorly humified down-unit, with increasing sedge component and change of colour to light brown; sharp boundary to
177-190cm:	black/dark brown amorphous/fine fibrous peat; gradual boundary to
190-198cm:	black amorphous peat; sharp boundary to
198-214cm:	dark brown fine fibrous peat; sharp boundary to
214-224cm:	greenish-brown gyttja (algal mud) or amorphous peat; sharp boundary to
224-254cm:	dark brown, changing to light brown down-unit, increasingly poorly humified fine fibrous peat with rare wood fragments; gradual boundary to
254-340cm:	dark grey structureless to very weakly laminated inorganic clay with silt, organic-rich between 318cm and 324cm; sharp (?) boundary to
340-349cm:	organic-rich clay; gradual boundary to
349-449cm:	organic-rich clays and gyttjas with fluctuating organic contents and common plant macro-remains; gradual boundary to
449-462cm:	impure organic-rich marl; gradual boundary to
462-476cm:	very compact increasingly pure laminated marl.
	Impenetrable by hand below 476cm.

4.5.4 This is in most respects similar to the sequence recovered in borehole 137, though this is much more detailed and considerably deeper (476cm compared to 420cm). But in addition, marl is not reported (or suggested by the phrase "creamy silt") in borehole 137, although it is present at TP23.

4.5.5 Three attempts were made to penetrate below 476cm. It is frustrating not to know the full depth of marl at this site, and motor-driven corers would be needed to examine this site. Marl is replaced by lacustrine sediment, much finer-grained than the grit seen at Sour Dale Lane. Marl may have ceased forming here because of a loss of carbonates by natural leaching of the well-drained soils on slopes around the basin. If so, then it is likely that the sequence above 449cm can be dated by radiocarbon techniques, but sedimentological analyses will be needed to confirm the non-carbonate nature of the lake muds that formed above 449cm. This lake mud seems to have varied in its organic content, most likely as sediment supply from slopes varied, probably induced either by climatic or land use changes. But again the minerogenic sediment being inwashed periodically was clay, and rarely silt, rather than coarse sand as at Sour Dale Lane.

4.5.6 Peat eventually replaces lacustrine muds at some time in the later Holocene period. The peat itself varies enormously, and the contrasts in colour and state of preservation are probably controlled by the mean level of the groundwater table in the basin: black and well humified peat is indicative of dry conditions and *vice versa*. Some or all of these changes could be determined in turn by the nature and intensity of land use on the slopes, controlling precipitation run-off. There is no evidence at all for minerogenic sediment inwashing in the peat, although a more marginal core might show this. Even now, the basin floods every winter and it is likely that peat is still forming, hopefully to provide a securely dated record of historic as well as prehistoric human activity.

4.6 **Long Preston Beck** (NGR SD834578)

4.6.1 At the point where the proposed road alignment crosses the Long Preston Beck, it is incised several metres below the surface of the fluvioglacial gravels. The most prominent river terrace surface is the highest of three incised terrace accumulations, and has been deposited following a phase of very active erosion, both vertically through the fluvioglacial gravels and laterally into them. This activity may be of Devensian Lateglacial (Loch Lomond Stadial) age, but this is very uncertain. Below this surface two minor terraces, almost certainly Holocene in age (and quite probably late Holocene), have been deposited.

4.6.2 Although gravel-rich from reworking of fluvioglacial deposits, these terraces may contain organic deposits within them or at their bases that might provide a chronology of geomorphic activity for this beck which could be compared with that from the Ribble (see 4.2 above). Although it is proposed to bridge the beck via a culvert, it would be of benefit to monitor any sections during construction.

4.7 Other localities evaluated

Cow Bridge feeder route

4.7.1 Boreholes 101 to 109 (Geotechnical and Testing Services 1991) were examined as they lay on a transect perpendicular to the River Ribble. However, although boreholes 101 to 103 lie on the present floodplain (*c*.124m OD), all others lie on elevated ground, on fluvioglacial and glacial sediments.

4.7.2 The transect is very close to the Cow Bridge "moraine", with little information on Holocene sediment sequences, and the borehole data suggests little value in investigating this particular road alignment further.

Bendgate peat/clay

4.7.3 At NGR SD84155720, a small patch of "alluvium" on the proposed road alignment is mapped on BGS 1:50,000 Sheet 60 (Drift) at the head of a small stream, Bend Gate Syke, draining towards Hellifield. Borehole 118 records 40cm of peat beneath the topsoil, while in test pit 18 organic and alluvial deposits appear mixed. The sediment is or has been accumulating in a fairly well-defined kettle-hole, one of several in this area.

4.7.4 There was no time to evaluate this site by coring. The record from borehole 118 does not suggest this site to be a great source of data, particularly when compared to Sour Dale Lane and Borks Hill, but this borehole is marginal to the basin. Since the proposed scheme will destroy the surficial stratigraphy at least, further reconnaissance may be worth-while.

5 RECOMMENDATIONS

5.1 Introduction

5.1.1 The recommendations outlined below fall into a number of phases, with the results of each phase influencing and setting the parameters for the next. Phases 1 to 2 deal with the assessment of individual sites and obtaining palaeoenvironmental information in advance of construction works, and phase 3 deals with the assimilation, publication and deposition of any results. It should be noted that not all phases are appropriate to each site. In summary, these phases comprise:

Phase 1 **Initial analysis and assessment:** fieldwork to collect stratigraphic data and collect suitable core samples; the assessment of potential for radiocarbon dating and/or artefact recovery; preliminary radiocarbon dating where appropriate.

Phase 2: **Detailed radiocarbon dating, palynological and sedimentological analyses:** if the presence of a datable sequence is established, phase 2 involves subsampling for detailed radiocarbon dating and detailed sedimentological and palynological analyses, and appropriate subsequent laboratory analyses.

Phase 3: **Publication of results:** report preparation and publication followed by deposition of the archive and artefacts and all other materials associated with the investigations with the appropriate institution for long term storage and curation.

5.1.2 While this assessment is primarily related to the palaeoenvironmental potential of the proposed road corridor, it has also produced new information relating to the archaeological potential of the corridor. Some work which is not strictly palaeoenvironmental in its aims is therefore also included below.

5.1.3 In addition to the above phases of palaeoenvironmental investigation, an archaeological watching brief would be undertaken along the whole of the proposed route corridor. This would incorporate the observation of construction work at a number of specific locations to sample and/or record any deposits of palaeoenvironmental interest which may be exposed. The results of this work would be included in the Phase 3 reporting.

5.1.4 Figure 2 provides an indication, as part as is possible at this stage, of the areas which would be investigated as part of these recommendations.

5.2 **Goosemires Laithe** (NGR SD824586)

5.2.1 This sequence is thought to provide the best opportunity to understand the lacustrine and alluvial stratigraphy of "Lake Settle" and the River Ribble. While this work is strictly tangential to the currently proposed road alignment, earlier and better opportunities to explore this aspect of late Holocene landscape evolution on the course of the A65 Settle bypass appear not to have been taken. The results of this work would improve the interpretations of the other recommended fieldwork, and therefore enhance its value.

Phase 1

5.2.2 This preliminary phase of fieldwork and analysis would obtain suitable stratigraphic data and enable a decision to be made on the potential for and the value of further work. There are three main elements to this phase:

(i) A series of borehole logs, obtained if possible by hand-held Eijelkamp gouge-sampler, would be laid out at right angles across the Ribble floodplain between the proposed road alignment and either to the present river or preferably to the right bank at Wigglesworth Farm. The locations of the boreholes would be surveyed in to establish their National Grid co-ordinates and height OD.

(ii) Correlation and interpretation of the sedimentary sequence.

(iii) Assessment of the potential for radiocarbon dating the alluvial sequence.

(iv) Sampling with a motorised peat corer to obtain material for radiocarbon dating and sedimentological analyses (only if a datable sequence is confirmed by the work described above).

Phase 2

5.2.3 This phase would involve obtaining suitable samples for detailed analysis with subsequent laboratory analyses. The work can be split into a number of elements:

(i) Subsampling for radiocarbon dates.

(ii) Radiocarbon dating.

(iii) Appropriate sedimentological analyses such as loss-on-ignition, carbonate content, magnetic susceptibility, and particle size analysis to establish the stratigraphy more objectively.

Phase 3

5.2.4 This phase would cover the reporting of any results to publication standard.

5.3 Goosemires Laithe-Sour Dale Lane (NGR SD824585)

5.3.1 Topographic and geomorphological factors suggest that this area has the potential to be a prime location for prehistoric settlement and activity. The possibility therefore exists that artefactual finds, or even occupation deposits, are present at the interface between the alluvium and the gravels. If present, these would be more easily located if more detailed information relating to the sediment sequence was available.

Phase 1

5.3.2 The phase 1 works would involve obtaining a detailed series of borehole logs across the gravel/alluvial boundary to determine the sequence of sediments at the edge of the floodplain and to assess the possibility of artefactual or site recovery. These logs would be obtained by hand-held Eijelkamp gouge-sampler or, if necessary, motor-driven peat-corer.

Phase 2

5.3.3 No phase 2 work is envisaged at this stage.

Phase 3

5.3.4 This phase would cover the reporting of any results to publication standard.

5.4 Sour Dale Lane (NGR SD82625850)

5.4.1 This sequence, though possibly containing a less complete Holocene sediment stratigraphy than that at Borks Hill, contains two layers of exceptionally coarse sediments that would prove critical to an understanding of geomorphic activity in the area, derived either from upslope erosion of fluvioglacial gravels or from the Ribble valley floor. The sequence may also prove complimentary to that at Borks Hill, and should be pollen-analysed.

Phase 1

5.4.2 The fieldwork and analysis undertaken during this phase of work would be designed to obtain suitable samples for subsequent analysis and to determine whether radiocarbon dating is likely to be successful. There are several elements to this work:

(i) Sampling the peat and clay sediments with small- and large-diameter Russian corers to obtain palynological and radiocarbon samples

(ii) Sedimentological tests on the peat to determine its carbonate content. If acidic, subsamples would be taken for radiocarbon dating.

(iii) Appropriate sedimentological analyses such as loss-on-ignition, carbonate content, magnetic susceptibility and particle size to establish more clearly the sediment stratigraphy.

5.4.3 Depending on the results of these elements, further work would take place, as follows:

(iv) Obtain "rangefinder" radiocarbon dates in order to check the time-depth of the stratigraphy.

Phase 2

5.4.4 Detailed laboratory analysis, which would take place only if the Phase 1 work had confirmed a more complete sequence than was present at either Eshton Moss or White Moss. If this work does proceed, it could be undertaken at one of two levels of detail; the choice would depend on a comparison of the relative quality of this sequence with that at Borks Hill, based on the Phase 1 results.

(i) Detailed radiocarbon dating in advance of palynological analysis.

(ii) Palynological analysis. If, as anticipated, the Borks Hill stratigraphy provides a better sequence for full-scale palynological analysis, palynological work at Sour Dale Lane would be limited to important stratigraphic boundaries. However, if the Borks Hill stratigraphy proves to be unsatisfactory, more detailed pollen analysis, together with additional radiocarbon dating, of the Sour Dale Lane sequence would be necessary. This would be carried out throughout the stratigraphy, at the following temporal frequencies:

10,000 bp-5,000 bp: one analysis every *c.*200 years
5,000 bp-0 bp: one analysis every *c.*75 years

Phase 3

5.4.5 This phase would cover the reporting of any results to publication standard.

5.5 Borks Hill (NGR SD82855835)

5.5.1 Without doubt, this site contains an exceptionally interesting sequence of sediments, and appears to provide the first single continuously forming peat stratigraphy for the later Holocene period in the area. The sedimentological changes also provide an insight into the effects on soils and groundwater hydrology of land use and (possibly) climatic changes. This is potentially a very significant stratigraphy.

Phase 1

5.5.2 The fieldwork and analysis undertaken during this phase of work would be designed to obtain suitable samples for subsequent analysis and determination whether radiocarbon dating is likely to be successful. There are several elements to this work:

(i) Sampling the peat and clay sediments with small- and large-diameter Russian corers to obtain palynological and radiocarbon samples

(ii) Sedimentological tests on the peat to determine its carbonate content. If acidic, subsamples would be taken for radiocarbon dating.

(iii) Appropriate sedimentological analyses such as loss-on-ignition, carbonate content, magnetic susceptibility and particle size to establish more clearly the sediment stratigraphy.

5.5.3 Depending on the results of these elements, further work would take place, as follows:

(iv) Obtain "rangefinder" radiocarbon dates in order to check the time-depth of the stratigraphy.

Phase 2

5.5.4 Detailed laboratory analysis, which would only take place if the Phase 1 work had confirmed a more complete sequence than was present at White Moss or Eshton Tarn.

(i) Detailed radiocarbon dating in advance of palynological analysis.

(ii) Detailed palynological analysis at the following temporal frequencies:

10,000 bp-5,000 bp: one analysis every *c.*200 years
5,000 bp-0 bp: one analysis every *c.*75 years

Phase 3

5.5.5 This phase would cover the reporting of any results to publication standard.

5.6 Long Preston Beck (NGR SD834578)

5.6.1 There is the possibility that organic deposits dating to the late Holocene phases of fluvial activity will emerge from the construction work in this area, and these could provide the basis for a chronology of geomorphic activity for the beck for comparison with that from the Ribble.

5.6.2 The likelihood of success is, however, relatively low and so the recommended fieldwork would be limited to the carrying out of a palaeoenvironmental watching brief during construction and landscaping works.

5.7 Bendgate (NGR SD84155720)

5.7.1 Less is currently known about the deposits here than those at the other sites discussed above. However, only the periphery of the site will be directly affected, and it appears unlikely that the sequence will be of equal value with those at Borks Hill or Sour Dale Lane. Some Phase 1 assessment work to confirm this view would, however, be of value.

Phase 1

5.7.2 This work would fall into

(i) Preliminary examination of the stratigraphic sequence by hand-held Eijelkamp gouge-sampler, to determine whether any further work would be of value. This decision would be based on a comparison with the sites at Borks Hill and Sour Dale Lane.

5.7.3 In the unlikely event that a sequence of equal potential than those at Borks Hill or Sour Dale Lane is identified, further Phase 1 work would proceed as at Sour Dale Lane.

5.8 Desk-based studies

5.8.1 The hundreds of commercial borehole logs and other geotechnical results arising from the planning of the scheme are an important sedimentological resource. Interpretation is for the main inhibited by imprecise description, or by the difficulties of inferring the nature of sediments from boreholes, but particular sediment associations can be identified, eg. the laminated silts and clays of Lake Settle.

5.8.2 This resource would be examined and analysed to identify recurring sediment suites, to allow a deeper reconstruction of the late Quaternary history of the area.

6 REFERENCES

Anthony Walker & Partners 1994 A65 Hellifield and Long Preston Bypass, North Yorkshire: Supplementary Archaeological Survey.

Arthurton, R S, Johnson, E W & Mundy, D J C 1988 Geology of the Country around Settle. British Geological Survey Memoir. London, HMSO.

Bartley, D D 1964 "Pollen Analysis of Organic Deposits in the Halifax Region. I. Deposits in the Cromwell Bottom gravel pit near Elland". The Naturalist 1964, 77-87.

Bartley, D D, Jones, I P & Smith, R T 1990 "Studies in the Flandrian Vegetational History of the Craven District of Yorkshire: the Lowlands". Journal of Ecology 78, 611-632.

Earp, J C et al 1961 Geology of the Country around Clitheroe and Nelson. Geological Survey of Great Britain Memoir. London, HMSO.

Fraser, R & Simpson, R 1992 Hellifield and Long Preston Bypass: Earthwork Survey for the Department of Transport (Northern Archaeological Associates Report 92/9)

Fraser, R & Speed, G 1992 A65 Hellifield and Long Preston Bypass: an Archaeological Evaluation for the Department of Transport (Northern Archaeological Associates Report 92/3)

Gaunt, G D, Coope, G R & Franks, J W 1970 "Quaternary Deposits at Oxbow Opencast Coal Site in the Aire Valley, Yorkshire". Proceedings of the Yorkshire Geological Society 38, 175-200.

Geotechnical and Testing Services 1991 A65 Trunk Road, Hellifield and Long Preston Bypass. Report on Supplementary Ground Investigations (Report 006/701/1213)

Johnson, R H 1985 "The Imprint of Glaciation on the West Pennine Uplands". In Johnson, R H (ed) The Geomorphology of North West England, 211-240. Manchester University Press, Manchester.

Jones, I P 1977 Studies in the Flandrian Vegetation History of the Craven District of Yorkshire (unpublished Ph.D Thesis, University of Leeds).

King, C A M 1976 Geomorphology of the British Isles: Northern England. Methuen, London.

Mitchell, W A 1991 Western Pennines: Field Guide. Quaternary Research Association, London.

Needham, S & Macklin, M G 1992 Alluvial Archaeology in Britain. Oxbow Monograph 27, Oxford.

Pennington, W 1970 "Vegetation History in the North-west of England: A Regional Synthesis". In Walker, D & West, R G (eds) Studies in the Vegetational History of the British Isles, 41-80. Cambridge University Press, Cambridge.

Pigott, C D & Pigott, M E 1963 "Late-glacial and Post-glacial Deposits at Malham, Yorkshire". New Phytologist 62, 317-334.

Raistrick, A 1926 "The Post-glacial Deposits of Airedale, Yorkshire". Geological Magazine 63, 555-557.

Raistrick, A 1927 "Periodicity in the Glacial Retreat in West Yorkshire". Proceedings of the Yorkshire Geological Society 21, 24-28.

Raistrick, A 1929 "Some Yorkshire Glacial Lakes". The Naturalist 1929, 209-212.

Raistrick, A 1930 "Some Glacial Features of the Settle District, Yorkshire". Proceedings of the University of Durham Philosophical Society 8, 239-251.

Raistrick, A 1933 "The Glacial and Post-glacial Periods in West Yorkshire". Proceedings of the Geologists Association 44, 263-269.

Raistrick, A & Blackburn, K B 1938 "Linton Mires, Wharfedale: Glacial and Post-glacial History". Proceedings of the University of Durham Philosophical Society 10, 22-37.

Raistrick, A & Woodhead, T W 1930 "Plant Remains in Post-glacial Gravels near Leeds". The Naturalist 1930, 39-46.

Rose, J & Letzer, J M 1977 "Superimposed Drumlins". Journal of Glaciology 18, 471-480.

Smith, R T 1975 "Early Agriculture and Soil Degradation". In Evans, J G, Limbrey, S & Cleere, H (eds) The Effect of Man on the Landscape: the Highland Zone, 27-36. Council for British Archaeology Research Report 11, London.

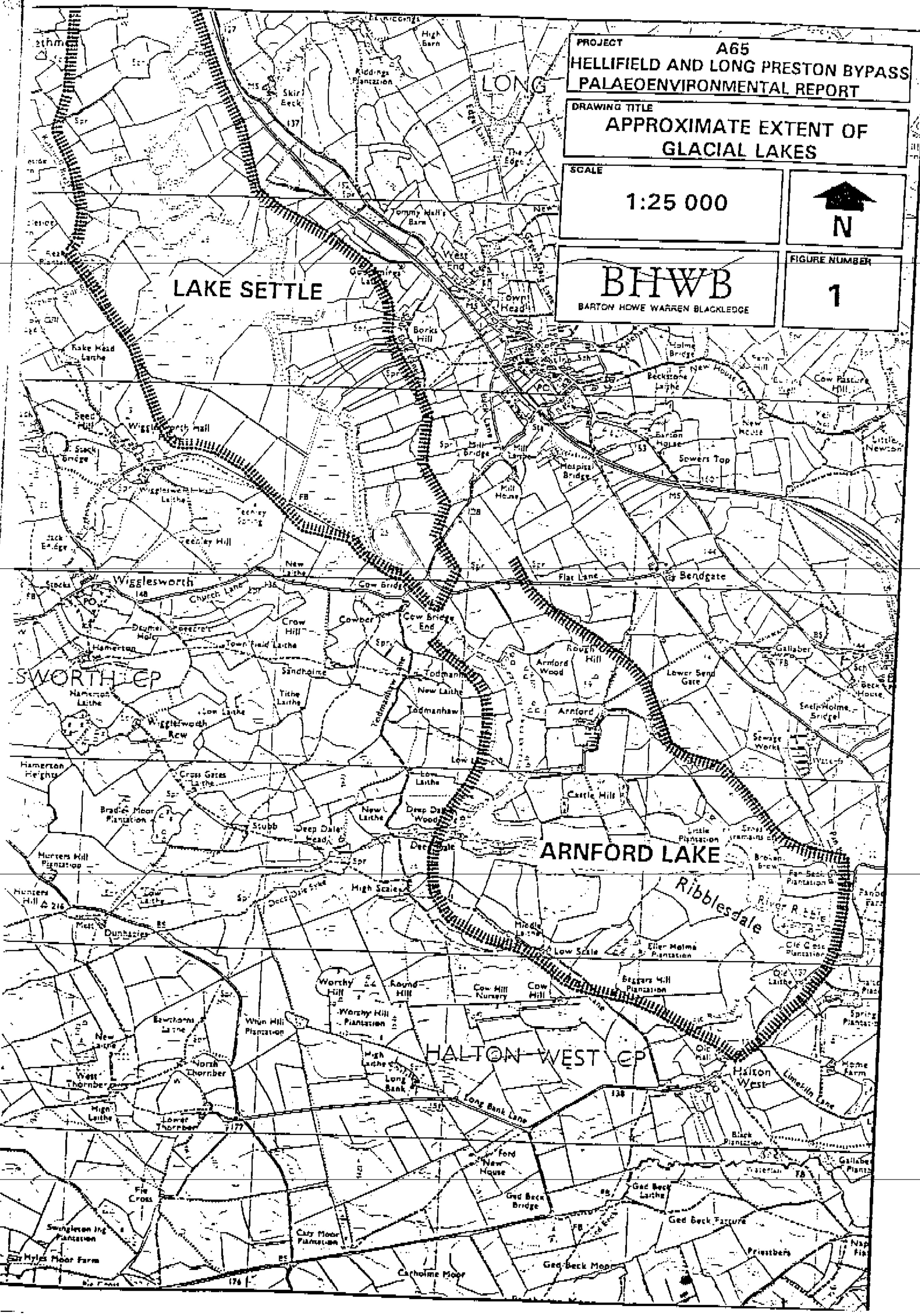
Smith, R T 1986 "Aspects of the Soil and Vegetation History of the Craven District of Yorkshire". In Manby, T G & Turnbull, P (eds) Archaeology in the Pennines, 3-28. British Archaeological Reports British Series 158, Oxford.

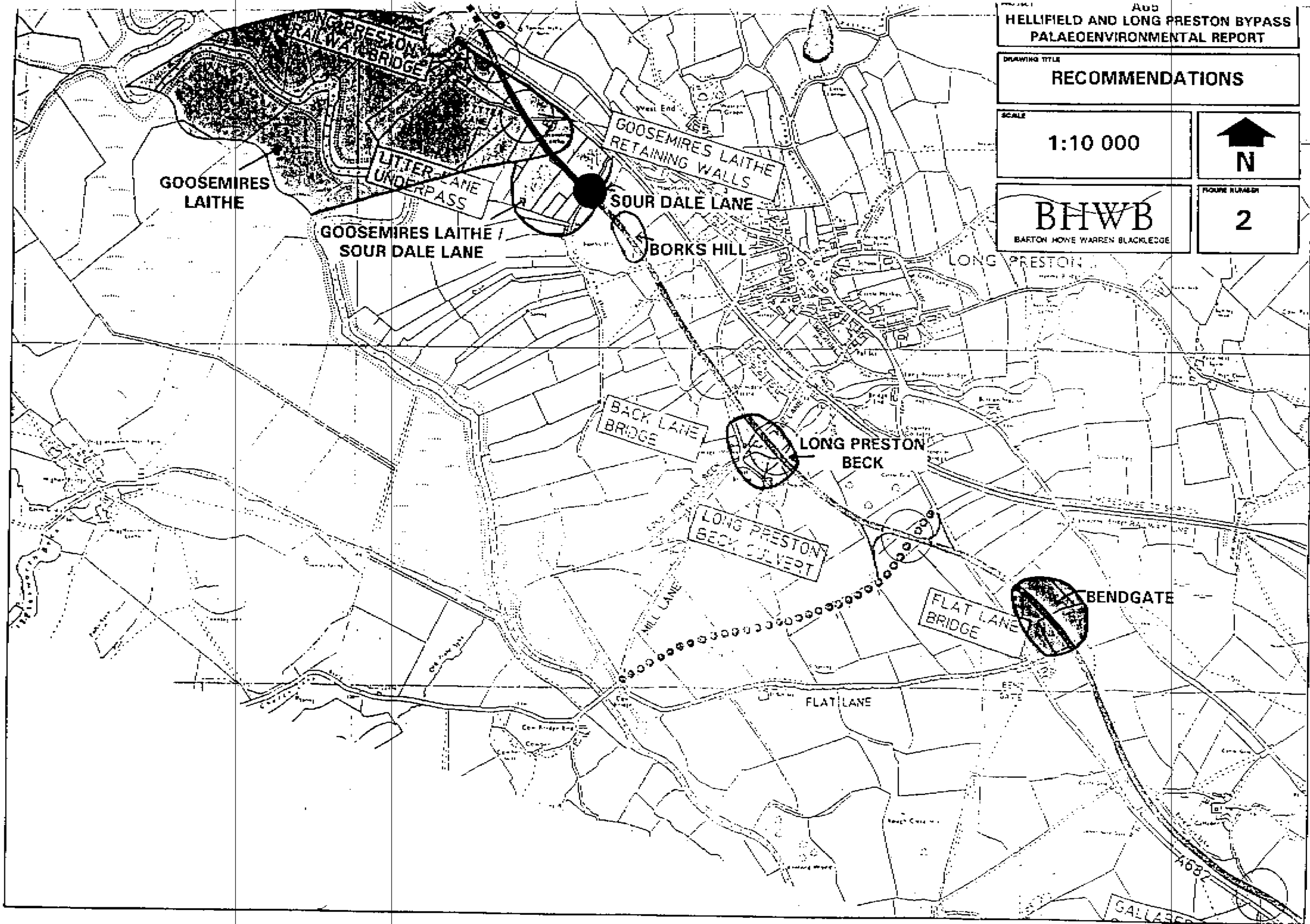
Structural Soils Limited 1993 A65 Hellifield and Long Preston Bypass, Factual Report on Additional Ground Investigations (Report 30756)

Terresearch Foundation Engineers 1989 Ground Investigation for A65 Hellifield and Long Preston Bypass (Report S.39/967)

Tipping, R 1994 "Akeld Steads and the Evolution of the Milfield Basin". In Harrison, S & Tipping, R (eds) The Geomorphology and Late Quaternary Evolution of the Cheviot Hills: Field Guide, 80-87. British Geomorphological Research Group, London.

Tipping, R 1995 A65 Long Preston - Hellifield Bypass: Report and Recommendations on the need for Palaeoenvironmental Anaylses.


PROJECT
A65
HELLIFIELD AND LONG PRESTON BYPASS
PALAEOENVIRONMENTAL REPORT
DRAWING TITLE
APPROXIMATE EXTENT OF
GLACIAL LAKES
SCALE
1:25 000
N
BHWB
BARTON HOWE WARREN BLACKLEDGE
FIGURE NUMBER
1
LAKE SETTLE
ARNFORD LAKE
LONG
Wigglesworth
Ribblesdale
HALTON WEST CP
Halton West
Long Bank Lane


PROJECT
A65
HELLIFIELD AND LONG PRESTON BYPASS
PALAEOENVIRONMENTAL REPORT
DRAWING TITLE
RECOMMENDATIONS
SCALE
1:10 000
N
FIGURE NUMBER
2
BHWB
BARTON HOWE WARREN BLACKLEDGE
LONG PRESTON RAILWAY BRIDGE
LITTER LANE UNDERPASS
GOOSEMIRES LAITHE
GOOSEMIRES LAITHE / SOUR DALE LANE
GOOSEMIRES LAITHE RETAINING WALLS
SOUR DALE LANE
BORKS HILL
LONG PRESTON
BACK LANE BRIDGE
LONG PRESTON BECK
LONG PRESTON BECK CULVERT
MILL LANE
FLAT LANE BRIDGE
BENDGATE
FLAT LANE
A682