4.

Interpretation

4.1 Chapter Structure

Using the lithostratigraphy and biostratigraphy presented in Chapter 3, the following section attempts to reconstruct the depositional regime of *The Lows.* In order to ascertain a more complete picture of both the local and regional conditions, and to add a relative dating framework to the stratigraphy, it has been necessary to correlate these results with previously published work in this area. For clarity, this chapter has again been separated into lithostratigraphy and biostratigraphy sections although the correspondence between the two has been allowed for. Having interpreted the results, Chapter 5 then reviews the available evidence in an attempt to answer the research questions proposed in section 1.5.

4.2 Interpretation of Lithostratigraphy

The deepening of *The Lows* sequence towards the northern end of the coring transect (away from the river channel) may be the result of sediment infilling of a topographic hollow. The wide lateral variation in the depth of each sediment unit may indicate that local (site-based) factors are dominant. Tallantire (1969) showed that there are isolated rather than continuous marl deposits in this area which may explain why marl is present at the southern end of *The Lows* transect, but not at the northern limit. This provides further evidence of the significance of local variations.

Further, the amorphous black peat layer, e.g. between 337cm and 260cm in LOW 0010 suggests that humification has occurred through localised lowering of the water table. Price (1979) comes to the same conclusion in his investigation of a similar peat unit at the nearby Redgrave and Lopham Fens.

There appears to be some evidence of sediment reworking towards the northern end of the transect in cores LOW 0008, 0009 and 0010. Isolated clumps of sandy deposits are poorly mixed within the *Cladium* fen peat, e.g. between 120cm and 200cm in LOW 0009. The exact cause of such sediment reworking is unclear, but possible explanations include bioturbation by small animals and some low intensity land use affecting the upper sediments. It seems that periodic flooding of the Little Ouse can be ruled out as the source of such deposits due to their absence near to the channel itself.

Sediment reworking may help to explain some of the obscure particle size results, as displayed in Figure 8, e.g. the very high sand component (99.75%) found at 200cm in the fibrous peat layer. Alternatively, it is possible that some of the organic content was not properly removed from the samples during processing, thus distorting the results.

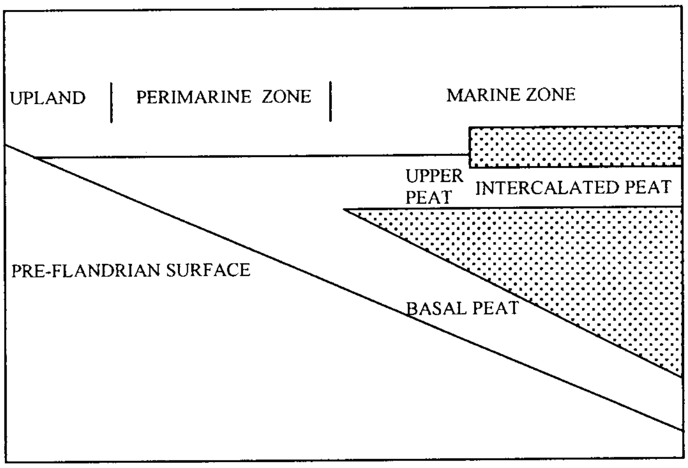
There does not appear to be any clear evidence at *The Lows* of the 'Upper Silt' layer described by Godwin (1978) and present in many Fenland sequences. However, there are relatively high silt proportions throughout LOW 0010, e.g. 68.97% at 390cm and 87.4% at 50cm. Tallantire (1953) suggests that during the lake phase stratigraphy, the relatively uniform distribution of silt and sand is a result of in blowing from the surrounding countryside at a time when plant cover was still discontinuous.

The pre-Flandrian surface appears to be the basal sand layer present in all of the cores at the study site and also described at nearby sites within the Little Ouse valley such as at Shippea Hill where Clark & Godwin (1962) conducted an investigation. The well-rounded nature of the sand particles may indicate that it is a fluvioglacial deposit. Tallantire (1969) adds weight to this theory, arguing that the sand outcrops that he found below Lopham Little nature of the sand particles may indicate that this is a fluvioglacial deposit. Tallantire (1969) adds weight to this theory, arguing that the sand outcrops that he found below Lopham Little Fen (see Figure 3) represent braided meltwater channels carrying outwash from a lobe of the Hunstanton ice sheet in north Fenland during deglaciation.

The stratigraphy that Tallantire (1953+1969) produced was of one to two metres of *Cladium* peat on a half metre of calcareous lake mud, resting on a variable layer of coarse sand. Moreover, Tallantire (1969) argues that in some places, the basal sand layer may actually cover a series of Late Glacial muds. He recognised nonetheless the difficulty in penetrating the sand layer using only a hand borer. Indeed, numerous attempts were made to bore through such densely packed deposits at *The Lows*, but this was beyond the capability of the manually operated equipment. Diatom analysis at *The Lows* just above the sand contact at 495cm found an assemblage of *Halophobous* and *Oligohalobous* types that seem to rule out any possibility that the sand deposits could be of marine origin.

Chapter 3 highlights the presence of a lower peat layer, e.g. in core LOW 0004 between 470cm and 495cm. Similarly, Tallantire (1969) described a basal peat layer in his investigations of meres in the Ouse-Waveney valley. It does not appear to occur everywhere, but he suggested that it is a Late Glacial deposit of zones II or III on Godwin's (1940a) chronology. Further, it may be an example of the pre-Flandrian 'Lower Peat' referred to in Godwin's four-part stratigraphic nomenclature, the modern version of which is displayed in Figure 14. However, Shennan's (1980) re-investigation of the sediments at Shippea Hill has provided a radiocarbon date of 8620 ± 160 BP from close to the basal sand, suggesting that the lower peat may in fact have been laid down in the early Holocene after all.

Figure 14- The four-fold stratigraphic division of the Flandrian deposits of Fenland (as adapted by Waller, 1994, p13)



The clay and marl layers present in the lower sections of *The Lows* transect may represent a postglacial lake phase in the sequence, as suggested by Tallantire (1953+1969). This is because in LOW 0010 between 480cm and 385cm, for example, there is a high minerogenic content (92%) and laminations indicative of lacustrine sedimentation. In LOW 0004, there are fine pink and grey laminations between 375cm and 380cm that resemble the settling out of particles from suspension in a lacustrine type environment.

The following section will now interpret the biostratigraphy of LOW 0010 in relationship to the aforementioned lithsostratigraphy. Authors such as Horton *et al.*, (2000) have recognised however that changes in these two components of the sediment record do not necessarily occur synchronously. Biostratigraphic assemblages are often capable of reacting more quickly to changes in a controlling variable such as RSL than lithostratigraphic indicators, which experience more of a lag time. In this way, any interpretation must take into account the fact that a proxy such as pollen may be more capable of recording the early stages of changes in the depositional environment than the lithostratigraphy.

4.3 Interpretation of Biostratigraphy

a) Diatoms and mollusc shells

The diatom assemblage at *The Lows* does not necessarily allow the pinpointing of any lake phase in time and space because as Figure 13 shows, there is a gap in diatom presence between 480cm and 390cm in what might be considered to be lacustrine sedimentation. Nevertheless, the presence of well preserved white mollusc shells, e.g. below 337cm in LOW 0010, and the fact that all the diatoms counted are either *Halophobous* or *Oligohalobous* allows the inference that low energy freshwater conditions were present when this sediment was laid down. (Kerney & Cameron, 1979).

It is particularly important to discern the salinity conditions of the clay layer found, for example, between 500cm and 385cm in LOW 0010. This is so as to avoid its confusion with the blue grey 'Fen Clay' of southern Fenland. In many studies, e.g. at Shippea Hill, the 'Fen Clay' has been interpreted as being deposited during the Wash III or IV (transgressive) phase (refer to Table 1). RSL rise is seen as having led to a rise in the water table and hence 'Fen Clay' formation (Waller, 1994). However, the author argues that the clay deposits at *The Lows* have formed under local hydrological conditions, as opposed to regional RSL rise. Indeed, there appears to be little or no evidence for marine sedimentation in the diatom or pollen assemblages at this site.

b) Pollen analysis

The unequivocal dominance of *Betula* pollen at the opening of *The Lows* sediment sequence (e.g. 69% TLP at 480cm in PAZ1) could represent the late Devensian to early Flandrian period. This is because Waller's (1994) synthesis of studies in Fenland has shown that Birch species of *Betula pubescens*, *Betula pendula* and *Betula nana* were present in eastern England during the late Devensian. Moreover, the fact that they are light demanding and short-lived trees meant that they were well adapted to the warming after the *Younger Dryas* stadial due to relatively little competition for nutrients, light and space. It is likely therefore, that Birch was the pioneer community at *The Lows* at the beginning of the present interglacial.

Indeed, Godwin (1940a) has attributed high *Betula* values to zone IV, the earliest of his Flandrian pollen zones (see Figure 15). This corresponds with the Pre-Boreal period c.10,250-9,450 BP (Goudie, 1992). *Pinus* pollen appears to accompany the high *Betula* values at the study site, especially in the lower clay layer. This accompaniment is common in many of the early Holocene diagrams in East Anglia (Waller, 1994).

However, Huntley & Birks (1983) maintain that *Pinus* is often over-represented in many pollen diagrams in this region due to its abundance and wide dispersal. They therefore suggest that *Pinus* should reach values greater than 25% TLP before its *in situ* presence is indicated. Since the *Pinus* values at *The Lows* fall far short of this level, (e.g. only 12% TLP at 480cm), it seems inappropriate to attribute too much significance to this particular taxon. Despite this recognition, *Pinus* is present at low frequencies throughout *The Lows* sequence suggesting a regular regional input of this pollen type during the Holocene.

Figure 15- Godwin's pollen zonation schemes and the corresponding Blytt-Sernander zones (Waller, 1994, p21)

ENGLAND & WALES (Godwin 1940b)	**FENLAND (Godwin 1940a)**	**BLYTT-SERNANDER UNITS**
VIII ALDER – OAK – ELM – BIRCH – (BEECH)	**VII-VIII** TRANSITIONAL	SUB - ATLANTIC
b **VII** ALDER – OAK ELM – LIME a	d ALDER DRY c OAK WET b ALDER DRY a OAK WET	SUB - BOREAL
		ATLANTIC
c **VI** b PINE - HAZEL a		BOREAL
V PINE		
IV BIRCH - PINE		PRE - BOREAL

Furthermore, Bennett (1986+1988) applied pollen analysis to several sites in Norfolk and recorded high *Betula* values until 9,250 BP, after which time *Betula* became excluded due to competition from other species. Indeed, at *The Lows*, the arrival of tree species such as *Alnus*, *Quercus* and *Tilia* as temperatures rose may have led to the decline of *Betula* at about this time with the establishment instead of Alder carr vegetation. The commencement of such a trend may be represented by PAZ2 and PAZ3 in the pollen diagrams.

Figures 11 and 12 of the pollen assemblage at *The Lows* correlate well with Tallantire's (1953) assertion that at the beginning of the Holocene, rising *Betula* values occurred at the same time as falling *Pinus* values. This feature can be seen between 480cm and 450cm (in

PAZ1) at the study site. Tallantire (1953+1969) interpreted this as marking the boundary between Late Glacial and post-glacial conditions.

The presence of *Salix* at values of between 2% and 4% in zones one to three is indicative of moist or wet soil conditions. Waller (1994) also suggests that consistent values as low as 3% to 5% TLP suggest that *Salix* was a significant element of the local vegetation community, given its under representation in the pollen rain. It appears that species such as *Salix cinerea* often cohabit areas colonised by *Alnus.* Thus, the presence of *Salix* even at low values in all but two of the samples may indicate a strong relationship between Alder and Willow carr vegetation, a feature that is perhaps underplayed in relative percentage diagrams such as Figures 11 and 12.

Within many sites in Britain, a useful marker for the correlation of assemblages is the *Ulmus* and *Tilia* declines c. 5,000 BP and often attributed to deforestation by humans (Waller, 1994). Yet at *The Lows*, these taxa are only present at low values normally below 10% and 9% TLP respectively, and so it is difficult to discern a discrete phase marking the decline of these genus's. What is more noticeable however, is the sharp decline in *Betula* from 51% TLP at 332cm to 5% TLP at 265cm. *Alnus* values also fall sharply from 16% TLP at 300cm to 7% TLP at 290cm. By contrast, there is a sharp rise in *Graminae* to a peak of 67% at 290cm in PAZ4.

This could indicate forest clearance of Alder and Birch trees by Neolithic people at about 5ka BP. Of the *Graminae* pollen counted at 300cm, there is a small rise in grains with large annulus diameters, and of *Plantago lanceolata* that is indicative of a more open type environment with lower tree density following clearance. Such human interruption is sometimes termed a 'plagioclimax' according to Clements's (1916) theory of plant succession. The vegetational development of an area is then deflected in another direction. However, this evidence is not conclusive and the author believes that it would be inappropriate to confirm that there was widespread human impact at this site without further more focused investigation.

The upper fibrous peat layer extending to 260cm depth in LOW 0010 contains arboreal pollen suggestive of Oak and Alder woodland. This explains the presence of wood macrofossil remains in this unit. They are most probably authochthonous deposits as it is unlikely that such large particles could be moved far in such a low energy environment. It appears however, that *Quercus* was established at this site well before *Alnus* became the dominant tree type, as shown by PAZ1 to PAZ4 in Figures 11 and 12. Indeed, at Hockham mere in Breckland, Waller, (1994) notes that *Quercus* values start to rise just after those of *Corylus* and *Ulmus* at about 9,300 BP.

The role of *Quercus* is difficult to establish in this sequence because it is often over-represented in the pollen rain (Andersen, 1970). This may mean that much of the Oak pollen is derived from the regional pollen rain rather than being locally sourced. Having said this, it seems plausible that Oak's ability to act as a pioneer in secondary woodland at the opening of the Holocene enabled it to colonise those areas previously occupied by Birch at this site (Waller, 1994). Godwin (1978) argues that fen Oak woodland stages often co-exist with *Filicales* spores due to the tendency of Fern to colonise areas beneath Oak trees. This would explain why *Filicales* becomes prominent as Oak frequencies increase at about 390cm.

Furthermore, the presence of *Filicales* in the upper peat acts as an indirect measure for the relative dryness of this layer, and in turn, a greater likelihood of oxidation. The periodic arrival of such aerobic conditions (e.g. at times when there was a local fall in the water table) may explain why pollen preservation is poorest in the upper peat layer, and why there are more unidentifiable grains here than lower down in the sequence. The moisture content results in Figure 10 show the present day hydrological conditions with fluctuating zones of dryness and wetness. It is clear that the relatively dry sediment at 200cm (with a water content of only

6.49%) would be more likely to undergo oxidation than at 390cm with a moisture content of 16.65%. It should not be assumed however, that the present day hydrological conditions are a good analogue for those in the past.

The drying out of the upper peat is probably a recent process (last few centuries), because the presence of Alder usually suggests wet and waterlogged conditions where the water table is consistently near to the surface (Waller, 1994). It is possible that *Alnus* first developed at this site as a constituent part of the Oak woodland (Godwin, 1940a). *Alnus* is also a reliable indicator of nutrient rich conditions, which in turn supports Bellamy & Rose's (1961, p369) argument that the fens in this region are fed by *"...base-rich waters from spring and seepage lines..."* (soligenous inputs).

It is possible that waterlogging at *The Lows* was partially an autogenic process, i.e. effected by the fen vegetation itself. A rise in the water table may have been brought about through an increase in capillarity as the litter accumulated (Moore *et al.*, 1991). Moreover, the gradual overshadowing of *Quercus* by *Alnus* above 350cm may suggest that conditions were becoming more waterlogged, and less favourable to Oak vegetation (Waller, 1994).

4.4 Chapter Summary

This chapter has attempted to interpret the lithostratigraphy and biostratigraphy of *The Lows* and correlate it with other nearby Fenland sites. Such interpretation has been kept separate from the discussion in Chapter 5 to allow important features of this sequence (other than those dealt with in the initial research questions) to be given due attention.

5.
Discussion

5.1 Discussion of Research Questions

Having interpreted the results in Chapter 4, the following section attempts to draw together the evidence and answer the research questions proposed in section 1.5. This hasallowed a summary model for the evolution of *The Lows* during the Holocene to be put forward in section 5.2. The limitations of the study and possibilities for future research are then considered in section 5.3.

1) What is the specific Holocene vegetational chronology at the site and what correlation can be made with other studies of the region?

Pollen analysis from the lower clay layers suggests that vegetation in the Pre-Boreal and early Boreal periods (10,250 to 8,450 BP) was an open Birch woodland complemented by Pine and Elm trees and some Hazel shrubs. Such taxa seem able to have colonised and began infilling a Late Glacial/ post-glacial lake. Table 3 shows many of the recognised Holocene periods in northwest Europe for correlation with the sequence at *The Lows*.

<u>**Table 3**</u>- The Classic European Holocene sequence (Goudie, 1992, p139)

Period	**Zone Number**	**Blytt- Sernander Zone name**	**Radiocarbon years BP**
Post Glacial	IX	*Sub-Atlantic*	Post 2450
	VIII	*Sub-Boreal*	2450-4450
	VII	*Atlantic*	4450-7450
	VI	*Late Boreal*	5450-8450
	V	*Early Boreal*	8450-9450
	IV	*Pre-Boreal*	9450-10,250
Late Glacial	III	*Younger Dryas*	10,250-11,350
	II	*Allerød*	11,350-12,150
	Ic	*Older Dryas*	12,150-12,350
	Ib	*Bölling*	12,350-12,750
	Ia	*Oldest Dryas*	

By about 8ka BP, it appears that competition firstly from Oak and then Alder trees caused an irreversible decline in Birch. The Oak and Alder mixed woodland continued the lake basin infilling allowing peat formation to commence over the clay and marl layers beneath. Moore (1986) argues that the commencement of peat accumulation is often an indication of increased water retention due to impeded drainage, possibly as a result of forest clearance by humans. Subsequently, it is likely that the peat accumulation rate speeded up during the warmer, wetter Atlantic period, approximately 7,500 BP to 5,200 BP when temperatures in Britain were 2°C to 3°C higher than at present, accompanied by the growth of mixed woodland.

Indeed, at *The Lows*, Local Pollen Assemblage Zones two to four show an increasing diversity of vegetation with tree species like Lime and Beech becoming more common, e.g. at 300cm. There also seems to have been an increase in herb vegetation with the more widespread development of grass and sedge communities. Deforestation by Neolithic people was earlier suggested as a possible cause of the declining dominance of trees apparent mid-sequence at *The Lows*.

Alternatively, the sudden rise in *Graminae* values and fall in *Alnus* values at 290cm could indicate the commencement of the Sub-Boreal period lasting from 4,450 BP to 2,450 BP (Goudie, 1992). It was characterised by cooler, drier conditions than the preceding Atlantic period. The drying out of the peat at this time was possibly less favourable to Alder vegetation and may have enhanced the spread of grasslands at *The Lows*

However, the transition to the Sub-Atlantic period in northwest Europe by 2,450 BP marked an increase in precipitation and helped the regeneration of peat in areas like *The Lows*. It coincides with zones VII to VIII in Godwin's (1940a+b) chronology of Fenland. This possibly explains why *Alnus* values are able to stabilise in the upper fibrous peat layer since Alder vegetation prefers wet or waterlogged conditions.

It is unclear whether or not the sediment sequence at *The Lows* extends right up to the present day. ^{14}C dating would be required to determine the age of the surface peat although it is likely that peat wastage due to drainage and desiccation during the industrial era has affected the surface layers. Field observations show that today, the site is occupied mainly by grass and reeds, and is enclosed by trees such as Alder.

2) Is Tallantire's (1953 +1969) stratigraphic model which suggests a Late-Glacial/ post-glacial lake, upheld by biostratigraphic and lithostratigraphic data collected from *The Lows*?

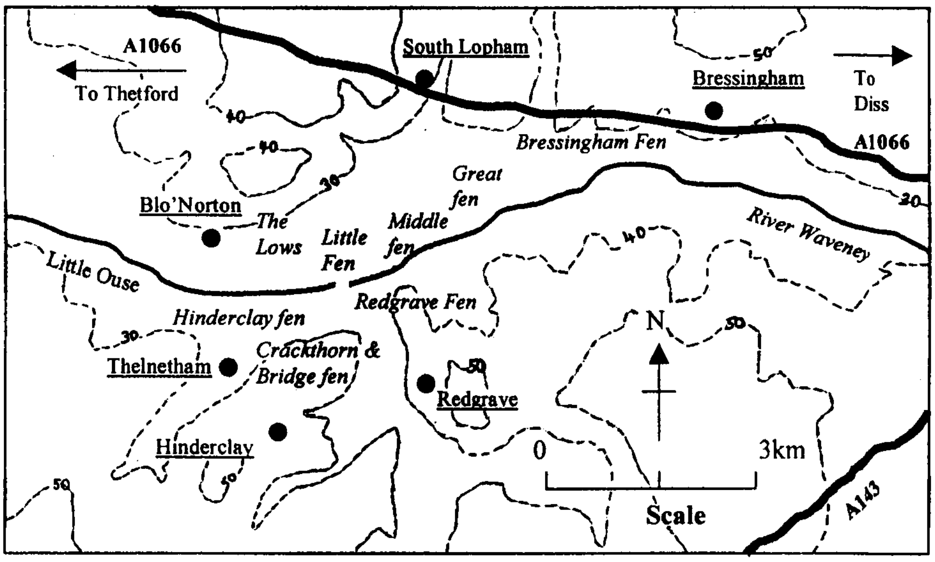
The clay or marl layers below 337cm in LOW 0010, for instance, seem to indicate the presence of a lake beneath the fen peat. The two layers of lake muds, the lower one with a high minerogenic content, the upper predominantly organics follows a pattern of lake sedimentation often seen in northwest Europe (Tallantire, 1969). The undulating lower sand layer found in all cores has been interpreted in both this study and by Tallantire (1969) as being fluvioglacial material laid down in the Late Glacial period. It has not been ruled out however, that there are Late Glacial muds beneath the sand contact and that we have bored through only the most recent phase of lake mud sedimentation.

Nonetheless, diatom analysis appears to confirm that the lake sediments above the sand contact are predominantly freshwater based. This is indicated by the strong presence of *Halophobous* species like *Navicula radiosa* and *Epithemia hyndmani* at 495cm. The question of why there is a lack of diatom preservation in the four samples between 495cm and 390cm remains unanswered since one would expect such water preferring organisms to be present as this lake mud and clay were laid down.

Battarbee (1986) provides a possible explanation with his recognition that valve preservation is sometimes poor in calcareous sediments. Indeed, the relatively low flora and fauna content preserved within the clay and marl units may indicate that the lake was oligotrophic (nutrient deficient) with low productivity at various times in its development (Faegri & Iversen, 1989). This would also explain the surprising lack of aquatic pollen in these layers except for *Nymphaea* and *Ilex* type taxas that are only picked up at very low frequencies, e.g. five *Nymphaea* grains at 420cm.

It has proved even more problematic to provide an estimate for the end of freshwater lake sedimentation and the development of fen peat due to the lack of an easily identifiable upper contact. Pollen stratigraphy suggests that the lake was gradually infilled as Oak, Alder and Grass became dominant, by about 8kaBP, over the Birch and Pine woodland which had mostly been present during the lake phase. Tallantire's (1969) pollen analysis has provided us with one relative date for the complete hydroseral succession of the lake however. He argues that at Bressingham Langfen (the location of which is shown in Figure 16), the lakes became filled up in the Late Boreal Period c. 6ka BP.

Figure 16- The situation of many of the valley fens in close proximity to *The Lows* and mentioned in the text (adapted from Tallantire, 1969, p263 incorporating modern contours from an OS map).



Plater *et al.,* (2000b) have investigated an analogous pro-glacial lake in the Tees estuary, which was impounded between the North York Moors and an ice mass to the north and northeast during the Late Glacial. It is characterized by highly resolved seasonal laminations (varves) of silt and clay. However, the laminations at *The Lows* are less well defined. The possibility of the lake at the study site being of the pro-glacial type needs further investigation, e.g. using techniques like sediment geochemistry. Tallantire (1953) suggests that the origin of the lake basin at Lopham Little Fen was from the thawing of a piece of buried ice, which subsequently created a depression.

On balance, there appears to be no evidence to falsify Tallantire's (1953+1969) lake theory. However, the evidence for such a lake is not unequivocal when taking into consideration the limited techniques used. Both this and Tallantire's (1953+1969) investigations lack a radiometric dating technique, and there is a need for more detailed chemical analysis of the marl and clay sediments. It is also unclear if these lower sediments derive from a single large lake or a series of smaller lakes, as suggested by Heathcote (1975) in her investigation of Redgrave and Lopham Little Fens, also in the Little Ouse valley.

3) What is the effect of valley topography on the stratigraphy across *The Lows*?

It appears that the flat topography of *The Lows* in the latter stages of sediment accumulation has produced a low energy but highly productive template of peat formation. The upper peat layer is indicative of rheotrophic (nutrient-rich) fen fed by both precipitation and base-rich water draining from the slight declivities of the surrounding land (Moore *et al.*, 1991). Heathcote (1975) maintains that water movement is slow due to the shallow valleys in this area. The decrease in depth of the cores from north to south may be a result of the undulating basal sand layer affecting accumulation rates, or perhaps due to infilling of a pre-existing topographic hollow. Again, Tallantire (1953) suggests that such a hollow may have resulted from the thawing of buried ice.

4) Does the stratigraphy support Shennan's (1986a+b) model of marine transgressions in Fenland?

There is not an intercalated sequence at *The Lows* and so this study does not really add to investigations carried out among others by Shennan (1986a+b). The freshwater-based assemblages found suggest that marine incursions did not reach this far inland during the Flandrian. It was important nevertheless in the research design not to ignore the possibility of evidence to support marine activity. Indeed, Hageman (1969) puts forward a 'perimarine' term to describe those areas that fall outside the limits of brackish or marine sedimentation, but which may have been influenced by RSL changes, particularly extreme events such as storm surges. Despite the lack of evidence for marine sedimentation, *The Lows* may have been such a perimarine zone at various stages during the Holocene.

5) What are the relative effects of regional factors (e.g. eustasy and glacio-isostasy) and local factors (e.g. sediment supply) on the study site?

The available evidence suggests that sediment genesis at *The Lows* has been dominated by local scale factors. These include the topography of the valley fen, local hydrological inputs from underground spring systems and competition among species of vegetation. The effects of sediment consolidation were not directly measurable, but seem likely especially given the extensive drainage of this area. The stratigraphy does not indicate any localised evidence of tectonic activity that could increase sediment consolidation. There appears to be no direct evidence of the aforementioned regional effects of RSL rise or fall, or indeed the compounding effect of isostatic subsidence of the Fenland basin by up to 2mm/yr during much of the Holocene (Shennan, 1989).

5.2 Summary Model

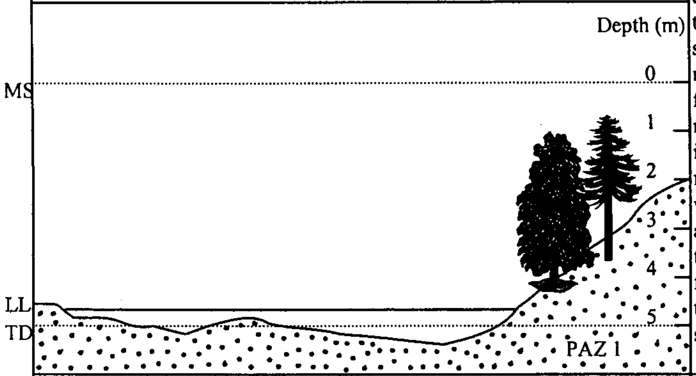
Having discussed the research questions, a summary model of the Holocene development of *The Lows* has been produced (Figure 17). It shows graphically how the site might have developed given the available evidence. There are six phases specifically related to pollen assemblage zones one to five and to Table 3 of the Classic European Holocene sequence. The author recognises that this model draws heavily on the Clementsian theory of succession and hence suffers from the assumption that vegetation changes are progressive, deterministic and follow a regular sequence. It also fails to recognise the dynamic nature of vegetation in time and space, and must assume that sedimentation rates have remained relatively constant. Nevertheless, Figure 17 helps to emphasise what appear to be thesalient features in the evolution of this site with climate and local water supply as the dominant controlling variables.

Figure 17- Summary Model of the Holocene evolution of *The Lows*

KEY

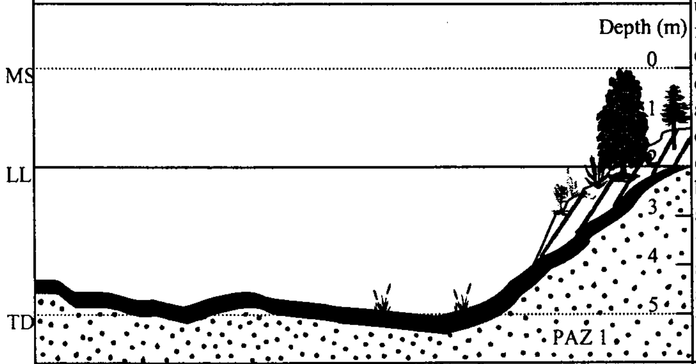
MS: Modern Surface   TD: Total Depth of sediment bored   LL: Lake Level   PAZ : Pollen Assemblage Zone (1-5)   ⁙ Sand   ▩ Marl   ■ Clay and lake mud   ▨ Peat   ▧ Surface vegetation

1) PRE-LAKE PHASE: (Pre c.11.5kaBP) Allerød to Younger Dryas



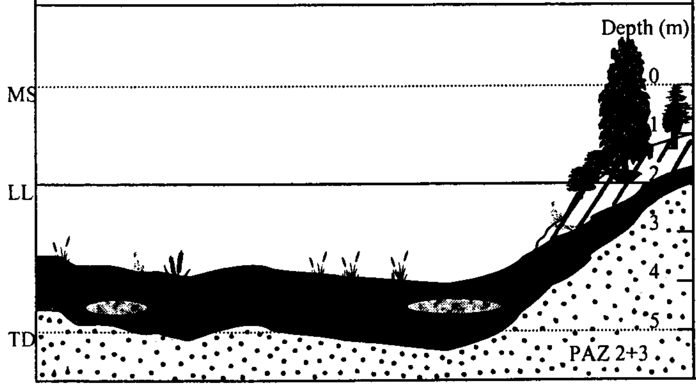
Light demanding Birch trees are the pioneer community. They are able to colonise fluvioglacial sands laid down by braided meltwater channels, e.g. from Hunstanton ice sheet melt. There is a regional influx of Pine. High minerogenic content with very little organics present as vegetation has not yet taken hold. Lake not yet formed, but rising water table leads to increase in surface water.

2) PRIMARY OPEN LAKE PHASE: (c. 11.5-9.5ka BP) Younger Dryas to Pre-Boreal



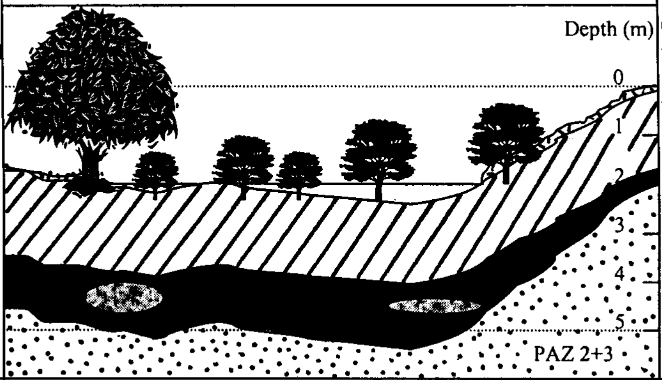
Rise in water level due to rejuvenation of underground springs following ice sheet melt. Commencement of deposition of silty muds and clays. Oligotrophic conditions so limited diatom growth, but lake becomes richer in nutrients as vegetation spreads over the lake. Lake sediment supply controlled by seasonal variations in runoff and melt water input.

3) LAKE IN FILLING PHASE 1: (c. 9.5-8.5ka BP) Pre-Boreal to Late Boreal



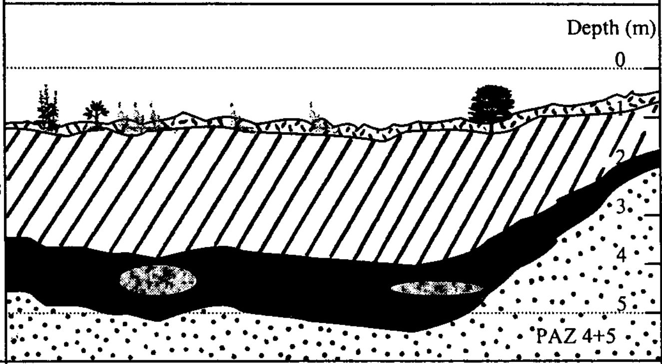
Contraction of the lake begins as vegetation rapidly colonises the lake fringes. This leads to the development of sedge peat. Alder, willow and Hazel shrubs become prominent. Nutrient enrichment allows organisms like diatoms to become more prominent. Low energy conditions still predominate. Localised marl deposits develop due to $CaCO_3$ input, aiding freshwater mollusc test development.

4) LAKE IN FILLING PHASE 2: (8.5ka-5.5ka BP) Early Boreal to Late Boreal



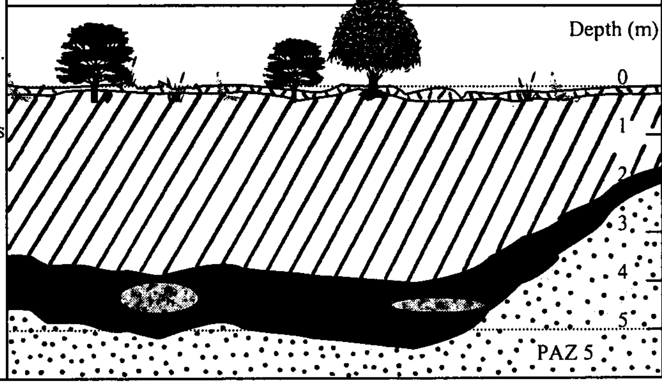
Alder flourishes in waterlogged conditions during the warmer, wetter period of the Climatic Optimum with temperatures 2°C to 3°C higher than at present. Lake sedimentation ceases, replaced instead by reed and sedge peat. Competition e.g. from Alder and Oak causes a decline in Birch and Pine. There is greater species diversity than in the opening stages. There is some surface water due to high precipitation, but sediment has filled up parts of the lake.

5) OPEN VEGETATION PHASE: (5.5ka-2.5ka BP) Sub-Boreal to Sub-Atlantic



The lake is completely in filled by sediment. Tree clearance by Neolithic people, e.g. for agriculture may have left a more open environment dominated by grasses and sedge. Industrialisation starting in the Bronze Age continued human alteration of the environment. Herbs challenge the dominance of the tree pollen during colder, drier conditions. Possible lowering of water table results in conditions less favourable to Alder vegetation.

6) MIXED VEGETATION PEAT DEVELOPMENT: (2.5ka BP to Present) Sub-Atlantic Period



Peat sedimentation raises ground level up to the Modern Surface (MS). Alder and Oak remain the dominant tree types with grasses, reeds and fern dominating the undercover. Local springs and seepages important in sustaining present day vegetation. It is likely that some compaction and oxidation has occurred in the industrial era due to human drainage. The modern path of the Little Ouse drains the fen surface, whilst soligenous inputs help to maintain a high water table.

5.3 Limitations and future research

Many of the drawbacks of this investigation have already been detailed, but it is necessary to emphasise certain factors. Firstly, there are practical limitations of coring including the possibility of sediment contamination from the overlying layers during core retrieval. In addition, the Troels-Smith (1955) stratigraphic technique is partly subjective, despite its aforementioned advantages, and so is open to misinterpretation.

There are statistical limitations, e.g. cluster analysis is effective in classifying like biological samples, but gives little information about variation between and within clusters. The interdependency of percentage counts also presents certain problems. Variations in the frequency of one particular taxon will affect the representation of all other types, irrespective of whether or not there has been a real change in their abundance (Waller, 1994). It is imperative therefore to refer back to the original raw data, as included in the Appendix.

Moreover, despite its quantitative counts and statistical techniques, this study has by necessity had to remain largely qualitative with generalisations such as ‘warm’, ‘moist’, and ‘cold’ being made (Birks, 1995). In the future, the development of pollen transfer functions may allow the value of an environmental variable such as temperature to be expressed quantitatively as a function of biological data (the pollen assemblage). The transfer function technique was pioneered by Imbrie & Kipp in 1971 and would allow greater precision in any future environmental reconstructions of *The Lows.*

Complications in the interpretation of pollen data arise due to factors such as the varying production of pollen by different taxa, e.g. productivity is greater for wind-pollinated taxa than for insect pollinated species (Lowe & Walker, 1997). Any future study could use statistical correction factors (R-Values) to establish a more accurate relationship between the actual vegetation and the count produced in the sample. Secondary transport of grains is also throughflow. This means that pollen can be moved both vertically and laterally within the sediment and hence introduce errors to the interpretation (Faegri & Iversen, 1989). Birks & Birks (1980) inform us of the problems of differential fossil destruction and preservation due to factors like grain morphology and oxidation. Roberts (1998) emphasises that ecological events may be time-transgressive, i.e. occurring earlier at one place than at another, which introduces further errors when trying to correlate regional pollen trends.

This is one of the reasons why ^{14}C dating has become so important in palaeoenvironmental reconstruction because it allows the chronostratigraphy to be accurately calculated. Without such a radiometric technique, it has not been possible to produce regional pollen zones incorporating data from *The Lows* or to adequately estimate the rates of sedimentation. Unfortunately, there is a lack of up-to-date research specifically in the Little Ouse valley fens, which incorporates a radiometric control. This means that correlation has often had to refer to older references.

There are also limitations of using diatoms, as outlined by Battarbee (1986). It is argued that there is differential diatom survival depending on factors such as the resilience of the individual frustules of different taxa to destruction. This may result in a bias in the assemblage towards certain types since not all valves present at the time of sediment formation will be incorporated within the sediment. Whilst diatoms are more reliable indicators of the local conditions than pollen (which suffers more from regional ‘noise’), there is still the possibility of contamination of the assemblage due to diatom transport from other sources, e.g. by throughflow or bioturbation.

Lastly, drainage modifications to the Little Ouse River since the seventeenth century may have disturbed the sediments at areas such as *The Lows*. The sources of the Little Ouse and Waveney rivers, for example, have most certainly been altered, but such man-made alterations have rarely been recorded. Fens such as *The Lows* should not be viewed as completely undisturbed ecosystems therefore because they have had some low intensity land use such as cattle grazing. The survival of such fens may only have occurred due to their designation as ‘Poor’s Land’, unfit for profitable peat cutting (Wheeler & Shaw, 1992).

There are several areas for future research at this site. It would be interesting to conduct a more detailed biostratigraphic investigation into the mollusc shells mainly preserved in the clay and marl layers. Their classification would help to advance our knowledge of what appears to be a Late Glacial to post-glacial lake. A multi-transect approach could also be employed for greater representation of the depositional environment. An east to west transect perpendicular to the present one might help not only to show changes in the upper peat layers parallel to the Little Ouse, but also to delimit the aforementioned lake. A multi-temporal investigation into the effects of changing water levels on these sediments would also be of practical management use to groups like English Nature.

6.

Conclusion

6.1 Conclusion

This study has produced an interesting, but limited Holocene palaeoenvironmental reconstruction of *The Lows*, and has hopefully achieved its two main research aims:

1) The Holocene environmental changes at the site have been examined using proxies like pollen and diatom analysis, which suggest a hydroseral succession from Late Glacial/ post-glacial lake to fen peat. The study appears to have yielded more detailed lithostratigraphic and biostratigraphic data than had previously been available at this site.

2) Tallantire's (1953+1969) lake theory has been investigated. There is some evidence to support his model of a Late Glacial/ post-glacial lake experiencing a hydroseral succession during the Holocene. However, further more focused research that includes a radiometric dating technique like radiocarbon is required to establish the exact date of the start and end of lake sedimentation. By contrast, there does not seem to be any marine influence atthis site indicative of Shennan's (1986a+b) marine transgressions.

There is a clear need for management of the fens at Blo'Norton and the surrounding areas in the Little Ouse valley if their international importance as sites of conservation is to be maintained. Dehydration of the sediments due to the depletion of groundwater reserves has already occurred due to the implementation of abstraction boreholes, e.g. at the southern boundary of Redgrave Fen in 1973 (Heathcote 1975). Wheeler & Shaw (1992, p34) emphasise the danger to these fens from desiccation, including deterioration in floristic composition:

"...dehydration has been, or threatens to be, a major threat to their botanical value."

What is required therefore is not only drainage and vegetation management (e.g. through periodic and careful cutting back of overgrowth), but also to record what has been done to aid future rehabilitation of these fens. There needs to be a move away from the anecdotal records of the past few centuries, which are often inaccurate and easily open to misinterpretation.

All things considered, this study has helped to emphasise the importance of wetlands for Holocene palaeoenvironmental reconstructions. Wetlands are under threat however, with the IPCC[4] predicting a 10% reduction in their worldwide surface area by 2050. There is therefore an urgent need in areas like Fenland for studies into both the freshwater sediments inland and the intercalated sequences nearer the coast. The past, in terms of Holocene timescales, is not necessarily the key to the future due to the unprecedented magnitude and rate of anthropogenic induced change of the earth's climate systems since industrialisation began. Nevertheless, the collection of palaeodata from areas such as the Fenlands is vital to help validate the models of future climate produced by the IPCC.

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[4] IPCC- Intergovernmental Panel on Climate Change predicts a global average temperature rise of between 1°C and 6°C by 2100 due to the Enhanced Greenhouse Effect, and a subsequent eustatic sea-level increase of between 20cm and 86cm. (Houghton *et al.,* 1995).

7.
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8.
Appendix

8 Appendix Structure

This chapter contains the stratigraphical field descriptions, raw pollen and diatom counts, levelling data and the standardised laboratory procedure, all of which were not considered appropriate in the main body of the text. Details of the College English Nature Links (CEL) scheme are also supplied.

Appendix 1- Pollen Analysis Preparation

Pollen analysis preparation followed standardised techniques described by Faegri & Iversen (1989).

i) Approximately 5g of sediment was measured out and placed into a testtube with 20mls of distilled water. As the samples came from a limestone rich area, 5mls of hydrochloric acid (HCl) were added to break down the Calcium Carbonate. In order to get rid of the alkali-soluble organic compounds, 5mls of 10% Potassium Hydroxide (KOH) were added to the test tubes. This is known as deflocculation and it helps to disperse the sediment (Berglund, 1986).

Heating took place for 30 to 45 minutes in a water bath. The samples were then washed through a 180µm sieve to remove the larger particles that might obscure the view of the pollen on the slide later on. Centrifuging at 4,000 RPM for four minutes followed and the process was repeated until the supernatant liquid became clear.

ii) The next stage involved the digestion of siliceous material. This is not always necessary for peat specimens, but some of the samples contained substantial minerogenic components that needed to be broken down. Hydrofluoric acid of 30% concentration was added and the samples were heated in the water bath until the sediment appeared to have dispersed and stratified. They were then stirred (using clean glass rods), centrifuged and the supernatant liquid decanted off. Hydrochloric acid (HCl) of 10% concentration was added to the samples and heating for a further three minutes took place. They were again centrifuged (4,000 RPM for four minutes), decanted and washed with distilled water. This was carried out twice; the samples were subsequently transferred to smaller tubes.

iii) The lignin and cellulose needed to be removed from the samples. Firstly, glacial acetic acid was added, the samples stirred, centrifuged and the supernatant decanted. It was then necessary to add 7mls of acetylation mixture (containing sulphuric acid and acetic anhydride in the proportion 1:9). Heating in boiling water for one minute took place, the samples were centrifuged, and the surface liquid consequently decanted. Next, a further 20mls of glacial acetic was added and stirred followed again by decantation and stirring. The samples were then 'washed' through twice by adding 20mls of distilled water and stirring, centrifuging and decanting the samples.

iv) Finally, it was necessary to stain the samples in preparation for their analysis using a light microscope. Washing twice with 20mls of ethanol took place to remove the water component, followed by centrifuging and decantation. 2mls of Tertiary Butyl Alcohol and two drops of safranin (a staining dye) were added and the samples transferred to small vials. After being centrifuged and decanted, the samples consisted of a pollen residue, which was then lubricated using Silicone fluid. It was then possible to mount a small amount of the contents of each vial onto the microscope slides for analysis.

Counting took place at magnifications of x400 along numerous linear slide traverses using the microscope's mechanical stage. Care was taken to ensure that each traverse covered a new (untouched) area of the slide. It was also important not to focus too much attention on the edges of the slide since evidence suggests that smaller grains may preferentially migrate to the edges under the cover slip weight (Moore *et al.,* 1991). The first three samples were re-counted once a greater level of classification expertise had been attained. In order to build up an accurate picture of the pollen spectrum, indeterminable grains were also included in the counts (see raw count data in Appendix 7). This provides information on factors such as the preservation quality of the pollen.

Appendix 2- Diatom Analysis Preparation

Diatom preparation followed a commonly used procedure for percentage counting, outlined among others by Berglund (1986). Approximately $0.5cm^3$ of sample was taken and 20mls of 30% hydrogen peroxide (H_2O_2) solution added. The test tubes were then placed in a boiling water bath for two hours to speed up the digestion of organic matter by the hydrogen peroxide. When all the organic matter had been removed, the sample was washed with water and centrifuged three times, as recommended by Battarbee (1986).

It was then possible to mount a small portion of each sample residue onto a microscope slide for identification. Approximately 0.2ml of the suspension was placed on to the cover slip using a clean polythene pipette. Evaporation of this suspension was allowed to take place and then cover slip was then placed sample side down onto a slide that had drops of naphrax on it. The slide was then heated on the hotplate for three seconds until all air had been forced out.

Diatom counting took place at magnifications of up to x1000 using oil immersion objectives and along continuous traverses for greater representation of the whole sample. The author made an informed decision not to include the broken valves in the final counts. This is because even though they can provide information on valve reworking and movement, such results are biased by each taxon's propensity to break (Alderton, 1994).

Appendix 3- Particle size preparation

This involved the collection of 12 samples covering each sediment unit, and focusing on the boundaries. 0.5g of sediment was allowed to dry and was then put through a 2mm sieve to get rid of the very large particles. The residue was emptied into a 50ml tube; the same chemical procedure as for diatom analysis was performed to remove the organic matter that could distort the particle size results. Following centrifuging, 20mls of Sodium hexametaphosphate solution was added. The samples could then be passed through the Coulter granulometer machine to produce a computer read out of the results.

Appendix 4- Loss-on-Ignition preparation

This required a nickel crucible to be weighed and approximately 3 to 5g of wet sample to be added. This was allowed to dry overnight and the weight of the crucible and oven dry sample subsequently recorded. Ignition of the organic material took place in the furnace at 550°C for four hours. Following cooling, the crucible and ignited sample were re-weighed and the LOI calculated using the following formula:

$$\textbf{\% loss on ignition} = \frac{F-G}{F-E} \times 100$$

Where:

E= Weight of crucible

F= Weight of crucible + oven dry sample

G= Weight of crucible + ignited sample

(Geog Dept Laboratory Book, 2000)

Appendix 5- Moisture loss preparation

The preparation involved the weighing of the sample, firstly when wet, and secondly after evaporation of all the H_2O had taken place overnight in the oven. The following formula was applied for the moisture loss calculation:

$$\frac{\mathbf{H_2O\ loss}}{\mathbf{Oven\ Dry\ Weight}} \times 100$$

(Geog Dept Laboratory Book, 2000)

Appendix 6- *The Lows* Stratigraphy according to Troels-Smith (1955)

Core reference	**Depth (cm)**	**Description & components**	***Nig***	***Strf***	***Sicc***	***Elas***	***Lim Sup***
LOW 0001	0-200	1 homogenous, dark brown, fibrous layer. Not well humified with several light brown roots present. No colour change on exposure to air. Red wood fragments present towards base. Th3, Tl1, Dh+, Dl+. Very diffuse boundary >1cm	3	0	3	1	0
	200-355	Homogenous light grey marl layer with white calcareous shells of varying size. Wetter than above layer, clayey texture with small silt component. Lc2[test.(moll.)2], As2 Ag+. Very diffuse boundary with layer below >1cm	2	0	2	0	0
	355- 372	Mixture of peat and marl. Diffuse laminations of peat and marl give a layered pattern. Peat well humified and unrecognisable. Sh2, Lc1, As1, Ag+. Sharp boundary with peat layer below <1mm and >0.5mm.	2	2	3	0	2
	372-389	Dark, well humified brown layer with silt present. Dryer than above layer with higher silt content. 1 homogenous horizon with a soft texture. Sh3, Ag1 As+. Very diffuse boundary with layer below >1cm.	3	0	3	0	0
	389-400	Homogenous sandy brown marl layer, feels gritty between the teeth, Ga3 Lc1. Not possible to bore deeper than this layer.	2+	0	3	0	0
LOW 0002	0-115	Dark brown homogenous peat layer. Wet with runny texture. Roots and stems and clearly visible especially at top. Wetness decreases towards base where texture becomes cumbly. Red wood chunks become more prominent towards base. Th2, Dh2, Dg+	3	0	2	1	0
	115-151	Heterogenous mixture of light grey marl and peat, but not clearly stratified. Some shells present. Decomposing woody fragments still present with small silt component. Lc2, Dl1, Tl1, Ag+. Very diffuse boundary with peat layer below > 1cm	2+	0	2+	1	0
	151-215	Dark brown peat layer- not very humified plant and tree remains. Some grass stems (phragmites) and tree fragments visible. Crumbly texture as in top layer. Tl2, Dh1, Dl1. Very diffuse boundary with marl layer below >1cm	3	0	2+	1	0
	215-400	Light grey marl with mollusc shells of varying sizes. Quite clayey texture at top but increasing silt component towards the base. Shells present in abundance at 348cm to 353cm and again at 378-381cm. Some decaying plant remains present but generally well humified. Lc2[test.(moll.)+], As 1, Ag1, Dh+. Very diffuse boundary with sand layer below > 1cm.	2	0	3	0	0
	400-405??	Light yellow/brown sand layer. Impossible to bore beyond depth shown. Ga3, Lc1	2+	0	3	0	0
LOW 0003	0-116	Homogenous very dark brown peat layer with lots of roots	3+	0	3	1	2

Core reference	Depth (cm)	Description & components	*Nig*	*Strf*	*Sicc*	*Elas*	*Lim Sup*
		present. Peat is crumbly and unconsolidated becoming wetter and darker towards the base. Th4, Dh+. Sharp boundary with layer below <1mm and >0.5mm					
	116-215	Transitional layer- mixture of marl and peat, but no discrete layers. Shells variously present and some orangey brown components. Large wood chunks at base. Very fine silt occurs at 150cm. Strong sulphur smell. Lc2[test.(moll)+] Tl1 Th1 Dl+ Very diffuse boundary with layer below >1cm	2+	0	3	0	0
	215-300	Light grey marl layer- peat phased out. Lighter colour at top than at base. Abundance of different white or yellow shells ranging from 1cm to 2mm^3 in size. Lc2[test.(moll)2]. Gradual transition to clay layer below >1cm.	2	0	2	0	0
	300-337	Grey clay layer with some marl present. One homogenous unit. Some small calcareous shells at top but none between 310-337cm. No visible organic remains. Lc1[test.(moll)+, As3. Gradual boundary with darker layer beneath (<2mm and >1mm)	2	0	3	0	0
	337-388	Darker grey marl and clay. Small white shells present. Some phragmites present. Lc2[test.(moll)+], As2, ThPhrag+. Very diffuse boundary with peat layer below >1cm	2+	0	2	0	0
	388-400	Dark brown woody peat- not well humified. Wood chunks up to 3cm long present- yellow/ red colour. Tl3, Th1 Sharp boundary with sand layer below (<1mm and >0.5mm)	3+	0	2	1	2
	400-410??	Introduction of dark yellow/ brown sand layer. Compaction meant that boring below this level could not take place. Relatively low water content. Ag4, As+	2++	0	1+	0	0
LOW 0004	0-195	Homogenous dark brown peat layer- crumbly texture and relatively dry. Many roots and monocot grass stems visble. Peat has a fairly high elastic response, but oozes clear water on sqeezing. Wetness increases towards base with red wood chunks becoming more prominent. Th3Phrag+, Tl1, Dl1. Very diffuse boundary with marl layer below >1cm	3+	0	1	1+	0
	195-223	Light grey marl layer with white calcareous shells. This is a transitional layer with some brown peaty components and a leathery clay texture. Lc2[test.(moll)+], As1, Th1. Sharp boundary with peat layer below	2	0	3	0	2
	223-230	Light brown peaty layer with small roots. Th3, As1. Gradual transition to clay/ marl layer below	2+	0	2+	0	0
	230-315	Light grey marl layer with big shells (up to 1cm^3) Big clay	2	0	2	0	0

Core reference	Depth (cm)	Description & components	*Nig*	*Strf*	*Sicc*	*Elas*	*Lim Sup*
		component with leathery texture. Lc2[test.(moll)1], As1+. Gradual transition to clay layer beneath.					
	315-380	Light grey clay layer with some small shells. Very fine clay laminations of grey and pink/grey clay, but too diffuse to detail as discrete units. Soft texture. As3, Lc1[test.(moll)+]. Gradual change to dark clay layer below <2cm	1++	3	2+	0	0
	380-470	Dark clay horizon- becomes siltier and lighter between 450-470cm. Fewer shells present than above layer and more evenly distributed. As3, Ag1. Sharp boundary with peat layer below.	2+	0	3	0	0
	470-485	Dark brown peat layer. Well humified with components unrecognisable to the naked eye. Sh4. Diffuse boundary with sand layer below >1cm.	3+	0	3	0	0
	485-500?	Dark yellow/brown sandy layer. Not possible to bore deeper than this. Ga4	3	0	3	0	0
LOW 0005	0-155	Dark brown homogenous peat layer. Not well humified and unconsolidated. Light brown roots and stems visible. Sediment is damp but yields very little moisture on squeezing. Becomes wetter further down. Red brown wood chunks between 100-155cm. Th2, Tl2. Very diffuse boundary with layer below >1cm.	3	0	3+	0	0
	155-205	Grey/ brown marl layer with mollusc shells ranging from 2mm to 1cm length- many of the shells are broken. Clay/ sludgey texture. Th1, Lc2[test(moll.)+], As1 Sharp boundary with dark grey marl layer beneath (<1mm and >0.5mm)	2+	0	2+	0	0
	205-237	Dark grey marl layer with shells (2-3mm). Silty component and some small roots present. Releases grey/ brown water on squeezing. Lc2[test.(moll)+], As1, Ag1, ThPhrag+. Sharp boundary with brown peat horizon below.	2+	0	3	0	1
	237-243	Mixture of peat and marl. Light brown colour, sulphur smell. Roots and some small mollusc shells present. Th3 Lc1[test.moll+] Diffuse boundary with lighter marl layer beneath > 1cm.	2+	0	2+	0	0
	243-412	Light grey marl layer- many shells at top with none at base. High muddy/ clay component and some phragmites still visible. Darker section between 340-360cm but not a discrete horizon. Lc2[test.(moll.)+] As2, Th+. Sharp transition to clay layer below (<1mm and >0.5mm).	2	0	3	0	1
	412-426	Grey clay with light brown tinge. No organic remains visible. As4. Diffuse boundary with layer below.	2	0	3	0	0
	426-450	Dark grey clay with some roots present-some layering. As4, Th+	2++	1	3	0	0

Core reference	Depth (cm)	Description & components	*Nig*	*Strf*	*Sicc*	*Elas*	*Lim Sup*
	450-500	Dark grey clay layer with generally broken mollusc tests. Silty texture, but no organic remains visible. Some diffuse layering Not possible to bore deeper than this as compacted sand was reached.	2++	1	3	0	0
LOW 0006	0-204	Dark brown homogenous peat layer, fibrous consistency. Some light brown wood chunks becoming larger and more common further down. Wood chunks up to 3cm^3. Below 150cm, yellow wood chunks become prominent. Phragmites also visible. Th2, Tl2, Dh+. Diffuse boundary with silty marl layer below >1cm	3	0	2	1	0
	204-220	Transition layer consisting of marl and peat, grey brown colour with some calcareous white shells present (2mm in length). Brown water oozes out on squeezing. Lc2[test.(moll.)+], Th2, Ag+. Gradual transition to lighter horizon below >1cm	2+	0	2	0	0
	220-283	Light grey silt/ marl layer. Various white shells well preserved. Silt/ sand texture and some roots still visible. Grey water oozes out on squeezing. Lc2[test.(moll.)+], Ag2, Ga+. Diffuse boundary with peat layer >1cm.	2	0	2+	0	0
	283-289	Dark peat layer- well humified sediment. Sh4. Very diffuse boundary with marl layer below >1cm	3	0	3	0	0
	289-300	Olive grey marl layer with no shells. Lc2, As1, Ag1. Gradual transition into clayey layer below.	2	0	3	0	0
	300-456	Clay/ marl layer. Very soft and dry texture. Scattered distribution of calcareous white shells becoming less frequent towards base. Some small well humified roots incorporated. This horizon has a pink tinge and grades to clay completely below 425cm. As3, Lc1[test.(moll.)+], Th+, (As4 below 425cm). Diffuse boundary with layer below > 1cm.	2+	0	3	0	0
	456-479	Brown coloured clay- very dry with fine particles. As4	2	0	3+	0	0
	479-500	Peaty clay layer- unrecognisable well humified organic components. Not possible to bore depper than this due to compact sand layer beneath. Sh2, As2.	3	0	3	0	0
LOW 0007	0-328	Very dark brown/ black peat layer. Fibrous texture with chunks of red brown wood. Below 200cm, traces of peat become more prominent with mollusc shells between 230 -328cm. Light brown streaks between 260cm and 270cm. Some diffuse layering between 320 and 328cm. Peat becomes more humified towards base. Sh1, Th2, Dl1, As1[test.(moll.)+]. Gradual transition to clay below.	3++	1	2+	0	0
	328-415	Grey/ brown clay layer with abundant white (CaCo^3) shells 2mm^3. Some brown horizontal layering present at top. As3, Lc1[test.(moll.)+]. Sharp boundary with clay layer below (<1mm and >0.5mm).	2	1	3	0	2

Core reference	Depth (cm)	Description & components	*Nig*	*Strf*	*Sicc*	*Elas*	*Lim Sup*
	415-474	Fine alternations of dark grey and pink grey clay. Appears to be no major structual differences, but noticeable colour changes. Each layer is approx. 2cm thick. No visible organic remains. Sharp boundary with lighter clay layer beneath (<1mm and >0.5mm).	2-2+	3	3	0	2
	474-500	Light yellow/ grey clay layer, soft, relatively dry texture. No noticeable organic components. Compact sand layer below means that boring beneath this layer not possible. As4.	2	0	3+	0	0
LOW 0008	0-80cm	Homogenous dark brown peat layer. Very fibrous consistency Large phragmites and leaves present- very little humification. Th3, Dh1. Diffuse boundary with sandy layer beneath >1cm.	3+	0	3	1	0
	80-150cm	Sandy peat horizon. Mineral component fines to silt towards the base. Some humification of peat but detrital matter including red wood chunks visible. Th3, Tl1, Ag+, Ga+. Diffuse boundary with sandy peat beneath >1cm.	3	0	3	0	0
	150-153	Thin horizon of peaty sand- very gritty texture with white quartz particles.	3	0	3	0	0
	153-184	Dark brown peat layer with many roots. Th3, Tl1. Very diffuse boundary with layer below.	3	0	3	1	0
	184-200	Layer of peat with sand traces and some small red wood chunks. Th1, Tl1, Ga2, Ag+.	3	0	3	0	0
	200-240	Turfa Herbaceous peat without sand, but many wood chunks. Transition to layer below marked by mollusc shells, Th2, Tl2.	3	0	3	1	0
	240-272	Very humified peat layer with white shells, becoming frequent towards base. This layer is very dark brown/ black with no recognisable organic remains. Sh4 [test.(moll.)+]. Sharp boudary to layer below (<1mm and >0.5mm).	3++	0	3	0	2
	272-279	Peat, clay and silt layer, organic remains well humified. Sh2, Ag1, As1. Diffuse boundary with layer below >1cm.	3	0	3	0	0
	279-308	Dark peat layer with white and grey mollusc shells. Sh3, Ag1[test.(moll.)+].	3	0	2+	0	0
	308-315	Light brown/ yellow layer of clay and silt- some small white shells (2mm-3mm length). Detrital matter not visible with naked eye. Sharp boundary with layer beneath (<1mm and >0.5mm). Ag2, As2[test.(moll.)+].	1++	0	2	0	1
	315-330	Substantia humosa peat, and clay layer. Black at top, becomes lighter towards base. Well humified organics. Some unevenly distibuted shells. Sh2, As2 {[test.(moll.)+]. Very gradual boundary with layer below (<1cm and >2mm).	3+/4	0	2	0	0
	330-419	Light grey clay with shells of varying shapes and sizes. Clay is relatively dry at this depth. Small peat trace. As3[test.(moll.)+], Sh1. Diffuse boundary with layer below (>0.75cm).	2	0	3	0	0

Core reference	Depth (cm)	Description & components	*Nig*	*Strf*	*Sicc*	*Elas*	*Lim Sup*
	419-428	Dark clay horizon with shells. As4[test.(moll.)+] Soft texture, but relatively dry.	2++	0	3	0	0
	428-490	Alternating layers of pink/ grey and grey clay approx. 0.5cm thick, but not recognisable as discrete units. Shells present at 430-435cm. As4[test.(moll.)+]. Sharp boundary with brown clay below (<1mm and >0.5mm).	2+-3	3	3+	0	1
	500-505	Light brown clay with some silt sized particles. As4, Ag+. Compact sand layer below made boring below this impossible.	2	0	3	0	0
LOW 0009	0-120	Homogenous dark brown, fibrous peat layer with some roots, phragmites and chunks of red wood. Traces of sand between 100-120cm. Th2, Dl1, Tl1 (Ga+ between 100-120cm). No clear boundary with layer beneath	3	0	2	0	0
	120-200	Sandy peat layer distinct from layer above by big increase in ratio of sand to peat. But sand is not fully mixed with peat and occurs in clumps. Red coloured wood chunks still visible. Th1, Ag2, Tl1.	2+	0	2+	0	0
	200-270	Dark brown woody peat detrital fragments of grass and rhizomes. No sand present in this layer and relatively dry. Th2, Tl2. Diffuse Boundary with black layer below >1cm.	3	0	3	0	0
	270-300	Very dark black, well humified peat horizon with no visible organic components. Some small (<3mm length) white shells present. Sh4[test.(moll.+]. As+- feels slightly silty between fingers. Not possible to bore below this due to unknown obstacle(s).	4	0	2	0	0
LOW 0010	0-260	Dark brown fibrous homogenous peat layer with phragmites and red wood chunks- some in excess of 3cm^3. Greater humification of organic remains towards base. Peat is very soft and wet at base. Th2, Tl2. Gradual boundary with layer beneath >1cm.	3	0	2+/3	0	0
	260-337	Black Substantia humosa peat layer with majority of organic components unrecognisable, but some isolated wood chunks. Sh3, Tl1.	4	0	2	0	0
	337-385	Transition layer of peat with clay. Isolated large shells up to 1cm^3. Clayey texture. Sh2, As2. Very diffuse boundary with layer below.	4	0	2+	0	0
	385-500	Homogenous clay layer with small white shells (generally <3mm^3). Clay is medium grey colour and relatively dry with some organics like roots are present, but well humified. Compacted sand at 500cm meant boring below this depth was impossible. As4[test.(moll.)+].	2++	0	3	0	0

Appendix 7- Absolute pollen counts (LOW 0010)

	Depth (cm)															
Family/ Genus	**50**	**100**	**150**	**200**	**255**	**265**	**290**	**300**	**315**	**332**	**342**	**380**	**390**	**420**	**450**	**480**
Total grains	222	221	203	209	207	215	218	207	204	217	220	218	221	215	206	221
Unidentified	12	3	8	10	2	10	1	4	3	2	3	1	0	0	3	1
Total Land Pollen	145	167	162	149	159	144	195	170	174	208	205	192	179	208	198	207
Trees																
Betula	0	1	1	1	1	7	17	16	52	106	58	68	35	144	143	143
Pinus	1	2	5	5	5	3	0	1	1	3	5	5	0	14	20	25
Populus	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Ulmus	5	7	2	3	10	6	3	5	5	17	24	15	11	16	14	13
Quercus	18	18	17	23	40	18	11	12	7	15	16	23	14	8	4	3
Tilia	0	1	8	6	9	13	2	3	3	8	4	3	5	0	0	0
Alnus	39	27	59	42	38	48	14	28	20	20	14	3	11	1	1	0
Fraxinus	0	0	1	2	1	0	1	0	0	0	0	2	1	0	0	1
Fagus	1	4	3	2	1	1	1	3	0	5	0	0	1	0	0	0
Acer	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0
Carpinus	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0
Abies	0	0	0	1	0	0	0	0	0	1	1	1	0	0	1	1
Larix type	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Total Trees	64	61	98	87	105	97	51	68	88	175	122	122	78	183	183	186
Shrubs																
Corylus	3	3	3	1	9	6	5	2	4	17	28	4	6	15	6	10
Prunus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Salix	0	1	1	1	3	0	4	1	2	0	9	8	5	7	4	2
Ericaceae- Calluna	11	2	1	3	2	0	2	2	7	1	3	3	1	0	1	1
Juniperus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Total Shrubs	14	6	5	6	14	6	11	5	13	18	40	16	12	22	11	13
Herbs																
Graminae	41	54	46	44	20	25	130	87	64	12	28	53	81	3	4	6
Cerealia	7	2	2	0	0	0	2	1	0	0	4	1	0	0	0	0
Cyperaceae	3	4	5	1	2	5	0	5	6	0	3	0	3	0	0	0
Malvaceae	14	34	3	4	11	4	0	1	0	0	5	0	0	0	0	0
Saxifragaceae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Taxodiaceae	1	4	3	3	0	0	0	0	0	0	0	0	0	0	0	0
Rumex	0	0	0	1	1	3	1	2	3	1	1	0	4	0	0	0
Liguliflorae	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Plantago lanceolata	1	1	0	2	0	1	0	1	0	0	2	0	0	0	0	0
Rubiaceae	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0
Littorella uniflora	0	0	0	0	4	3	0	0	0	0	0	0	1	0	0	0
Total Herbs	67	100	59	56	40	41	133	97	73	15	43	54	89	3	4	8
Aquatics																
Nymphaea	0	0	0	0	0	0	5	6	2	0	0	0	2	5	1	2
Ilex Aquifolium	0	0	0	0	0	0	0	3	1	0	0	0	1	0	0	0
Potamogeton	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0
Total aquatics	0	0	0	0	0	0	5	9	3	0	1	3	3	5	1	2
Spores																
Polypodium	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
Sphagnum	2	1	1	2	0	0	1	3	2	0	0	0	1	1	0	0
Filicales	58	47	25	37	43	55	15	16	21	7	11	20	34	1	4	0
Bryophyte spores	5	3	13	10	3	5	1	5	1	0	0	0	1	0	0	0
Total Spores	65	51	39	55	46	60	17	24	24	7	11	20	36	2	4	0

		Depth within core (cm)														
Family/ Genus	**Salinity (%)**	**50**	**100**	**150**	**200**	**255**	**265**	**332**	**342**	**380**	**390**	**405**	**420**	**450**	**480**	**495**
Amphora ovalis	O	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Cymbella turgida	O	0	0	0	0	0	0	6	0	4	1	0	0	0	0	1
Cymbella helvetica	O	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Cymbella *var. maculata*	H	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0
Cymbella *var. nonpunctata*	H	0	0	0	0	0	0	12	1	0	0	0	0	0	0	0
Cymbella brehmii	H	0	0	0	0	0	0	5	0	1	0	0	0	0	0	0
Cymbella cistula	O	0	0	0	0	0	0	10	2	14	19	0	0	0	0	35
Cymbella silesiacum	H	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Epithemia adnata	O	0	0	0	0	0	0	0	13	24	16	0	0	0	0	13
Epithemia hyndmani	H	0	0	0	0	0	0	34	50	33	30	0	0	0	0	44
Epithemia sorex	O	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Epithemia *var. granulata*	H	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Epithemia *var. gracilis*	H	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0
Epithemia turgida	O	0	0	0	0	0	0	0	0	4	17	0	0	0	0	2
Eunotia arcus	H	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0
Eunotia flexuosa	H	0	0	0	0	0	0	24	31	17	17	0	0	0	0	14
Eunotia fallax	H	0	0	0	0	0	0	0	0	10	4	0	0	0	0	6
Eunotia praerupta	H	0	0	0	0	0	0	10	9	7	8	0	0	0	0	0
Eunotia veneris	H	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Eunotia *var. ventricosa*	H	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Gomphonema accuminatum	O	0	0	0	0	0	0	9	14	0	0	0	0	0	0	0
Gomphonema angustum	O	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Gomphonema *var. capitatum*	H	0	0	0	0	0	0	0	0	8	3	0	0	0	0	0
Gomphonema vibrio	O	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0
Gomphonema *var. elongatum*	H	0	0	0	0	0	0	1	6	5	0	0	0	0	0	0
Gomphonema minutum	H	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Gomphonema constrictum	H	0	0	0	0	0	0	0	3	6	5	0	0	0	0	9
Gomphonema *var. brebissonii*	H	0	0	0	0	0	0	0	2	1	1	0	0	0	0	1
Gomphonema parvulum	O	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1
Gomphonema *var. trigonocephalum*	H	0	0	0	0	0	0	0	0	2	2	0	0	0	0	1
Gomphonema tergestinum	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Navicula angusta	O	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Navicula radiosa	H	0	0	0	0	0	0	49	45	46	52	0	0	0	0	59
Navicula completa	H	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Navicula contenta	H	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Navicula concentrica	H	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Navicula scutelloides	H	0	0	0	0	0	0	0	2	2	2	0	0	0	0	2
Navicula placentula	O	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Navicula cincta	H	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Rhopalodia gibba	O	0	0	0	0	0	0	11	6	9	17	0	0	0	0	19
Rhopalodia rupestris	H	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Total Diatom Valves (TDV)		**0**	**0**	**0**	**0**	**0**	**0**	**200**	**207**	**206**	**203**	**0**	**0**	**0**	**0**	**209**

Salinity Key

H = *Halophobous* types

O = *Oligohalobous* types

Appendix 8- Absolute Diatom Counts (LOW 0010)

Sample Depth (cm)	% Clay	%Silt	% Sand
50	11.5	87.4	1.1
100	12.1	65	22.9
150	57.1	42.9	0
200	0	0.25	99.75
255	57.7	42.3	0
265	57.1	42.9	0
332	3.8	69.4	26.8
342	2.77	47.93	49.3
380	3.76	53.74	42.5
390	8.03	68.97	23
420	14.8	81.9	3.3
480	16.3	78.6	5.1

<u>Appendix 9 (above)</u>- Particle Size Results (LOW 0010)

Depth (cm)	Crucible Weight (g)	Dry Weight (g)	Ignited Weight (g)	Loss-on-Ignition (%)
50	16.2875	16.7383	16.3843	78.53
100	17.2439	17.9327	17.5716	52.42
150	17.146	17.5934	17.2811	69.8
200	16.8553	19.1537	19.0529	4.39
255	17.032	17.3631	17.1107	76.23
265	17.2998	17.6336	17.3984	70.46
332	16.3564	17.1106	16.9181	25.52
342	16.5338	17.2922	17.1462	19.25
380	16.0564	16.5702	16.4218	28.88
390	15.2021	16.0066	15.7602	30.63
420	17.5286	18.383	18.315	7.96
480	17.4355	18.3451	18.2688	8.39

<u>Appendix 10</u>- (above) Loss-on-Ignition results (LOW 0010)

Sample Depth (cm)	Wet Weight (g)	Oven Dry Weight (g)	$H_2$0 loss (g)	% Moisture Loss
50	18.3497	16.7383	1.6114	9.63
100	19.9537	17.9327	2.021	11.27
150	19.6592	17.5934	2.0658	11.74
200	20.3962	19.1537	1.2425	6.49
255	19.5452	17.3631	2.1821	12.57
265	19.3641	17.6336	1.7305	9.81
332	19.5859	17.1106	2.4753	14.47
342	19.0854	17.2922	1.7932	10.37
380	18.1188	16.5702	1.5486	9.35
390	18.6722	16.0066	2.6656	16.65
420	19.5236	18.383	1.1406	6.2
480	19.4953	18.3451	1.1502	6.27

<u>Appendix 11 (above)</u>- Moisture Loss Results (LOW 0010)

Core Number	Height (mOD)
LOW0001	23.64
LOW0002	23.59
LOW0003	23.6
LOW0004	23.61
LOW0005	23.61
LOW0006	23.59
LOW0007	23.52
LOW0008	23.55
LOW0009	23.5
LOW0010	23.49

Appendix 12- Levelling data from *The Lows* transect