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Report on the Assessment of Alluvium Deposits on the Route of the Upper Forth Crossing.

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INTRODUCTION

The majority of the proposed route of the new Upper Forth Crossing (i.e. all except the extreme north-east end) lies on Holocene alluvium. The presence of alluvium raises a number of archaeological issues peculiar to this environment that will affect the scope and structure of the archaeological programme that the construction of the road will entail:

- The potential for waterlogged sediments (and therefore exceptional archaeological preservation);
- The potential for archaeological deposits and structures well-below modern ground level;
- The potential for significant palaeoenvironmental data (both local environment and whole-catchment data).

The extent to which this potential may be realised is primarily controlled by the depositional regime, the date of deposition of the alluvial sediments and the emergence of these sediments to terrestrial conditions. There are a variety of pre-existing sources of evidence that allow an assessment of this potential through a primarily desk-based approach. This report presents a model of the deposition and emergence of the alluvial sediments. The area of the crossing has been well studied by geologists and Quaternary scientists and it is on the basis of this work that the model has been generated. The report then presents the results of the application of other forms of evidence, primarily data from the engineering borehole logs, to the model, and the consequent conclusions concerning the archaeological potential of the alluvium.

METHODS

A number of types of evidence have been used in this assessment. The most important forms of evidence have been expert opinion, primarily in the form of published research, but also in personal communication, and the engineering core logs. Additional evidence has been sought in aerial photographs, maps and site visits.

Review of Quaternary Science Literature

A review of the relevant published literature has been undertaken. Relevant experts have been contacted for advice where appropriate. On this basis a model of environment of deposition, sea-level change, and emergence of surfaces has been generated.

Core Logs

A set of transects depicting the Holocene and Late Glacial deposits have been prepared to allow the application of the evidence derived from the core logs to be applied to the model derived from the published literature to explain the sedimentary history estuary along the route in terms of the depositional regimes of the sediments and the effects of landscape change due to relative sea level rise. The route of the bridge and the associated road was split into two transects, one south of the river Forth and one north of the river. Within the transect routes borehole records were selected on considerations of data quality, e.g. completeness of record, detail of core recording.

The deposits recorded in each borehole were classified into units belonging to one of six categories: made ground, clay and silt, peat, sand and gravel, till, bedrock. Made ground includes any definitely human formed deposits, primarily roads and embankments, excluding the soft sediment deposits that constitute reclaimed land, which are classified as clay and silt.

Boreholes were positioned on the basis of chainage measurements along the length of each transect. The appropriate units were placed in each borehole to scale. After all the borehole records in a transect had been depicted in this way a series of correlations were made. These are the current land surface, the late Pleistocene erosion surface/Bothkennar Gravel and the top of the bedrock. Dashed lines for the bedrock correlation indicate where a borehole has not reached bedrock. For the late Pleistocene erosion surface/Bothkennar Gravel correlation a dashed line indicates where a borehole has not reached the late Pleistocene erosion surface/Bothkennar Gravel. Overall depths of Holocene deposits, i.e. those overlying the late Pleistocene erosion surface/Bothkennar Gravel, have been interpolated between boreholes.

Aerial Photographs and Maps

All aerial photographs consulted were in the RCAHMS air photograph collection. Details of the photographs used are given in Appendix 1. Ordnance Survey maps back to the First Edition were consulted to check for evidence for change of position or infilling of channels. Earlier maps available digitally through the National Library of Scotland were also examined (see Appendix 2).

Site Visits

The walkover along the route of the road and the site visits were conducted during evaluation trenching. The geomorphology of the route was recorded during the walkover, in particular evidence for the former position of creeks and recent sediment deposition and erosion was sought. Evaluation trenches and sondages were inspected during evaluation to compare the sediments uncovered with both borehole data and the published lithostratigraphy.

RESULTS

Review of Quaternary Science Literature

The three main aspects relating to the understanding of the formation of the Forth carseland with respect to archaeological potential are the depositional regime, the dates of deposition and the emergence of the sediments to terrestrial conditions. The depositional regime includes the environments of primary deposition, re-working and erosion of deposits.

Depositional Regime

The Quaternary deposits of the Forth Estuary have been described and systematised into a formal lithostratigraphy, most fully in a British Geological Survey Report (Browne, Graham and Gregory 1984), and subsequently modified by Paul, Peacock and Barras (1995). More cursory treatments of these deposits have added little to these reports (Browne 1987, Browne, Mendum and Monro 1993). More specialist reports have refined certain aspects of the depositional sequence (Barras and Paul 1999, Barras and Paul 2000). The lithostratigraphy comprises a number of formations. Those of relevance to this report are tabulated in Table 1.

Lithostratigraphy		Dominant Lithology	Interpretation
Grangemouth Formation	Saltgreen Member	Very dark greyish-brown clayey silt usually lacking visible stratification.	Lagoonal deposits formed by impounding during foreshore reclamation.
	Skinflats Member	Greyish brown clayey silt with lenses and thin layers of marine shells.	Intertidal estuarine deposits.
Claret Formation	Members not formally defined	Black to very dark grey clayey silt and silty clay, sandier towards base, becoming dark grey at top. Bioturbation common.	Offshore shallow subtidal marine to intertidal estuarine deposits.
Bothkennar Gravel Formation	Members not formally defined	Fine to coarse gravel with sand and clayey silt. Locally cobbles.	Intertidal to shallow water marine deposits.
Loanhead	Members not formally defined	Brown to brownish grey to reddish brown silty clay.	Glaciomarine.

Table 1: Summary of relevant lithostratigraphic units in the Forth estuary area (Browne *et al.* 1984, Paul *et al.* 1995).

Although of Pleistocene date the Loanhead Formation has been included as deposits of this formation are common throughout the area and in places form a significant part of the sedimentary succession: as such they will be discussed in consideration of the overall archaeological potential of the estuarine deposits. The primary depositional regimes of the Holocene deposits should be noted: that of the Claret Formation is sub-tidal to intertidal estuarine. The Grangemouth Formation Skinflats Member also formed in an intertidal estuarine setting. The Saltgreen Member of the Grangemouth Formation belongs to the historic period, being the result of reclamation through warping (see below). The attribution of environment of deposition is based on faunal analyses, a combination of gastropods, bivalves, ostracods and foramanifera. Analysis of these assemblages has indicated regions of material reworked from earlier deposits at various points in the sedimentary succession.

The main impact of the sedimentary processes since the Holocene maximum transgression (see below) has been to infill the till-lined bedrock basin in which the Forth estuary is seated (Browne 1987). The gradual infilling of the basin would mean that the deposits are younging from the basin margins toward the channel (Paul *et al.* 1995). The depositional situation would also change from the basin margin, with deposition occurring primarily during marine transgression and the centre of the basin, where deposition occurred primarily during the marine regression (Paul *et al.* 1995).

Although the main trend has been infilling, the sequence of sedimentation has also had periods of erosion. The later Pleistocene glaciomarine deposits of the Loanhead Formation are overlain by the Bothkennar Gravel, which marks the end of a period of erosion in the late Devensian: even where the Gravel is not detected, an erosion surface at the top of the Loanhead Formation is observable (Browne *et al.* 1984). The deposition of the Claret Formation resumes the infilling trend: the volume of sediment deposited was sufficiently great to contribute to a change in depositional environment from sub-tidal to intertidal through reducing water depth (Barras and Paul 1999). The top of the Claret Formation also shows evidence of erosion, with *Cerastoderma edule* beds on top of an erosion surface, associated with a sea-level oscillation (Browne *et al.* 1984).

The erosion surface is overlain by the sediments of the Grangemouth formation, primarily the Skinflats Member. Knowledge of the deposition through reclamation, resulting in the Saltgreen Member of the Grangemouth Formation, is primarily derived from Cadell (1929), a landowner who had undertaken reclamation at his own estate in the early twentieth century. Issues concerning the validity of this account will be addressed in the relevant borehole results. Reclamation around Higgins' Neuk (centred on NS921 872) occurred between 1784 and 1787, corresponding to the 600 m of the proposed route closest to the southern bank of the Forth. Reclamation on the northern bank of the estuary was undertaken for the Tulliallan estate between Kincardine and Kennet Pans during 1821 and 1822. This area corresponds to the current boundaries of Kincardine Power Station. In both cases the method used was warping, that is embanking an area and allowing flooding during high tide, creating a lagoon which clay and silt will settle out from, raising the ground level (Cadell 1929, Barras and Paul 2000).

Chronology of Deposition

The chronology of the deposition of the sediments has been investigated by radiocarbon dating of shells. The relevant dates are tabulated below. With regard to the radiocarbon determinations it should be noted that SRR-1483 is problematic: it does not agree with the other dates, and appears to have some problems relating to the borehole (Paul *et al.* 1995). Given the proximity of the date to an overlying erosion surface the possibility of reworking cannot be ignored. If this date is excluded, the Claret Formation dates from 7015± 76 BP- 3825 ± 130 BP, although the uppermost extant Claret Formation is effectively undated, so the upper part of the formation can be assumed to be of a younger date. The overlying Grangemouth

Formation is dated to 3045 ± 80 BP to 4025± 85 BP. The depositional regime of the area near the channel therefore was a low intertidal estuarine mudflat setting by c. 4000 BP uncal. Significant net accumulation of sediment by natural processes had ceased by c. 3000 BP uncal. The younging of the deposits towards the channel should be noted: the cessation of net accumulation would be earlier further away from the channel. Although precise dates cannot be put on this, following the figures suggested in the literature, net accumulation may have ceased on the edges of the carseland c. 6-7000 BP uncal.

Sample Location	Laboratory Reference	Elevation (m. O.D.)	Lithostratigraphic Position	Species Dated	Adjusted Age ^{14}C yrs BP ±1σ
Kinneil Kerse No. 4 NS 9630 8121	SRR-1483	-1.86	Top: Claret Formation	*Corbula gibba*	7750±126
Bothkennar D1 NS 9209 8586	OxA-3388	-4.2	Middle: Claret Formation	*Saxicavella jeffreysi*	3825±130
Bothkennar HW3 NS 9206 8585	OxA-3389	-16.5	Base: Claret formation	*Spisula subtruncata*	5075±90
Grangemouth Docks 021 NS 9252 8353	SRR-1344	-24.15	Base: Claret formation	*Ostrea edulis*	7015±76
Kinneil Kerse No. 4 NS 9630 8121	SRR-1345	-4.36	Base: Claret formation	*Ostrea edulis*	6075±64
Bothkennar S111 NS 9207 8590	OxA-3507	+1.8	Base of Skinflats member	*Cerastoderma edule*	3045±80
Bothkennar 22 NS 9142 8283	SRR-1343	-1.44	Base: Grangemouth formation	*Ostrea edulis*	4025±85

Table 2: Radiocarbon dates for the Holocene sediments in the Forth estuary (adapted from Paul *et al.* 1995). Adjusted age refers to a correction for an apparent age of 405±50 years for seawater.

Sea-level Change and Emergence

The knowledge of the depositional regimes needs to be placed in the context of the research published on relative sea-level change in the Forth estuary. The initial work on this subject was undertaken by Sissons and Smith (e.g. Sissons 1974, Sissons and Smith 1965), but has largely been superseded for the Holocene by Robinson (1993), whose sea-level curve, supplemented by Barras and Paul's work on relative sea-depth changes (Barras and Paul 1999), forms the basis of this discussion.

The beginning of the Main Postglacial rise of sea level has been dated to c. 8500 Bp uncal., with the culmination of the Main Postglacial Transgression occurring c. 6400 BP uncal. (Robinson 1993). It is during the period between these dates that, under Barras and Paul's model, the deposition of the Claret Formation largely occurred at the margins of the Forth basin (Paul *et al.* 1995). From c. 6400 BP uncal. relative sea-level has fallen, during which period the deposition of the Claret Formation towards the centre of the Forth basin would have occurred. The fall of relative sea-level has broadly continued until recently, although there have been minor sea-level oscillations, for example that thought to have eroded the upper Claret Formation at c. 4000 BP (Browne *et al.* 1984). The main point to emerge is that the area of the Upper Forth Crossing is now at it's highest point on the estuary since the end of the last glacial i.e. marine influences have been important throughout the Holocene depositional history of the Forth in the area of the proposed crossing.

The regression probably occurred in stages (Barras and Paul 1999, Robinson 1993). Such a process would form a succession of planation surfaces as regression proceeded (Browne *et al.* 1984). The succession of surfaces would be from the relatively older and higher surfaces further from the channel to the relatively younger and lower surfaces closer the channel of the river.

The sea-level curves reconstruct mean sea-level, and therefore when trying to estimate dates that surfaces emerge the depth of the tidal range should be taken into account. The role of the tidal range in determining the nature of environments should also be noted: a greater range will mean a larger area of mudflat and high salt marsh. Most of the studies use a tidal range based on the modern range of 5.2-5.5 m, and Robinson provides evidence in terms of the relative position of shell beds used for dating to confirm the validity of this assumption (Robinson 1993). This information will be referred to in the discussion of the emergence of the current land surfaces.

From the published literature the following model has been derived. The basin of the Forth has undergone net infilling with sediment from the late Pleistocene until the mid to late Holocene. From at least 7000 BP the environment of deposition would have been sub- tidal until between 5200 BP (at the basin margins) and 3400 BP (near the river channel), when the depositional environment would have changed to intertidal conditions. The change in deposition environment reflects the effects in changes in sea-level and water depth resulting from sea-level regression and sediment accumulation. The regression of sea-level continued from the Holocene Main Transgression (c. 6400 BP uncal.) until recent times. The regression occurred in stages, resulting in a succession of planation surfaces. As sea-level regression occurred in stages, so did the emergence of the sediments to the succession of mud flats, high salt marsh and fully terrestrialised surfaces, with the date of these changes varying with the height of the planation surfaces and the rate of relative sea-level regression. With the emergence of the surfaces above mud flat conditions significant sediment deposition through estuarine processes ceased.

Borehole Transects

Transect 1 (ch. 0-2220 m) (Figure 1)
Distances are chainage measurements in metres from the first borehole, moving from the southwest to the northeast. The transect can be divided into three sections:
Section One: (ch. 0-470 m) , from the western end of the route to Bowtrees,
Section Two: (ch. 470-1780 m) from Bowtrees to the edge of Higgins' Neuk,
Section Three: (ch. 1780-2220m) Higgins' Neuk.

Section One: western end of route to Bowtrees (ch. 0 –470 m).
This area has an altitude of 6.2 to 6.8 m O.D. The relatively consistent level suggests the area has formed as a planation surface associated with sea-level regression. This contrasts with

the dips and ridges in the bedrock, which are draped with till. The gravels depicted in the transect correspond to the Bothkennar Gravel (Browne *et al.* 1984). The lowest clay and silt deposits correspond to the Loanhead Formation, deposits of glaciomarine origin (Browne *et al.* 1984). The late Pleistocene erosion surface/Bothkennar Gravel varies in depth from between 0.5 to 4 m below O.D. The sediments that overlie these correspond to the Claret Formation, deposits of subtidal to low intertidal origin (Paul *et al.*1995). The upper two metres of these deposits have undergone a degree of oxidation and drainage.

Section Two: Bowtrees to Higgins' Neuk (ch.470-1780m)
This area has an altitude of 5.3 to 5.8 m O.D., with the relatively consistent level suggesting a planation surface, associated with sea-level regression, presumably of a later period than that associated with the more westerly section of the transect. This level surface contrasts with the bedrock, which has two significant depressions (at ch. 1200 & 1700 m). These are till draped and infilled by the Pleistocene deposits (Loanhead Formation overlain by Bothkennar Gravel). The overlying Holocene deposits are identifiable as the Claret Formation, with the last borehole (BH623) containing a possible deposit belonging to the Skinflats Member of the Grangemouth Formation.

Section Three: Higgins' Neuk (ch. 1780-2220m)
This area has an altitude of 3.5-4.0 m O.D, excluding the sea-defence embankments. This part of the transect conforms to the area of land mapped as reclaimed in the later eighteenth century and mid twentieth century (Cadell 1929). The borehole evidence suggests that the twentieth century reclamation was carried out through raising the ground level through dumping material (BH625, 626, 627). Although mapped as an area of reclamation through warping, the current ground level is above the High Water Spring Tide level, making warping unlikely to have succeeded (Cadell 1929). In two of the Boreholes (BH624 and 625) sediments that correspond to the Skinflats Member of the Grangemouth Formation have been identified. These deposits are found to a depth of 1-2m O.D. Over the rest of the area of Twentieth century reclamation no deposits corresponding to the Skinflats Member is found. Whether this is a result of natural erosion or due to truncation by the made ground deposits, the lower boundary of which reaches 0.5-2m O.D. in this area, is unclear. The rest of the soft sediments in the boreholes in this area correspond to the Claret Formation.

Transect 2 (ch. 0-1650 m) (Figure 1)
The transect can be divided into four sections. These sections run from the north bank of the estuary northwards to the area of Garlet:
Section One: (ch. 0-440 m) Kincardine Power Station,
Section Two: (ch. 440-1270 m) Kincardine Power Station to Kilbagie,
Section Three: (ch. 1270-1500 m) Kilbagie to the foot of Lady's Brae,
Section Four: (ch. 1500-1650m) Lady's Brae.

Kincardine Power Station (ch. 0-440 m)
This area was reclaimed in the early nineteenth century, between 1821 and 1822 (Cadell 1929). This area is currently quite level with an altitude of c. 1.1 m. This contrasts with the underlying bedrock, which descends in a series of ridges and depressions from around –4.2 m O.D. at the landwards end of the section to –20 m O.D. at the banks of the estuary. The bedrock is draped by till of varying thickness. Over most of this section of the transect this is overlain by soft sediments that correspond to the Loanhead Formation. The late Pleistocene erosion surface/Bothkennar Gravel overlies these deposits, over most of this section, but at some points overlies the till. Overlying these are deposits corresponding to the Claret

Formation. The uppermost soft sediments, from a depth of 1 m to –1 m O.D. correspond to the Saltgreen Member of the Grangemouth Formation, being the deposits laid during the reclamation of the area through warping.

Kincardine Power Station to Kilbagie (ch. 440-1270 m)
This section of the transect runs across a level area with an altitude of c. 5 m O.D. The underlying bedrock is uneven, with the rock trending down from both north and south to a depression with a depth of –16.4 m O.D. at ch. 980 m. This depression is infilled with Pleistocene deposits: primarily till in the southern part of the depression and gravel to the north. This is overlain by deposits that correspond to the Loanhead Beds Formation, with the late Pleistocene erosion surface/Bothkennar Gravel overlying these deposits at 0 to – 2 m O.D. The overlying Holocene deposits correspond to the Claret Beds Formation, which have developed a characteristic yellowish firm 'crust' of between 0.6 and 1.3 m thickness (Browne *et al.* 1984).

Kilbagie to the foot of Lady's Brae (ch. 1270-1500 m)
This shorter section of the transect rises from 5.2 m O.D. to 7.0 m O.D. , with a break of slope between ch. 1270 and 1350 m (6.3 m O.D.), with the rest of the rise being more gentle. This rise is less pronounced than that in the bedrock, which rises from – 5.0 m O.D. to 3.9 m O.D., with the most pronounced rise (from –5.0 m O.D. to 1.5 m O.D.) occurring in the same region as the break of slope at the ground surface. The soft sediments correspond to the Claret Formation: no stratigraphy corresponding to the Loanhead Beds or late Pleistocene erosion surface/Bothkennar Gravel has been noted in this area.

Lady's Brae (ch. 1500-1650m)
This final short section of the transect contains another rise in ground level, from 7.0 to 9.6 m O.D., the beginning of Lady's Brae. The deposits are of a different character to all those noted in the rest of the transect, with a thin (0.2 m) peat deposit noted at 4.8 m O.D. This deposit is overlain by a sand deposit. Neither this sand nor the gravel deposit at the end of the transect can be correlated with the Bothkennar Gravel.

Aerial Photographs

No palaeochannels or related features were noted in the route corridor south of the estuary. An infilled loop of the Pow Burn was noted to the west of the route. Between where the proposed route leaves the Higgins' Neuk Roundabout as an embanked road to the end of the proposed embankment there appears to have been additional reclamation in the post-war era, forming the area which projects out into the mudflats of the estuary. North of the estuary the only feature that strongly resembled a palaeochannel was noted in the post-war aerial photographs in the area now occupied by Kincardine Power Station. A possible palaeochannel was noted in the region of the intersection of the route corridor and the Canal Burn, however this feature may also be the remains of a field boundary.

Maps

No changes in the watercourses were noted in the Ordnance Survey 1st and 2nd Edition maps. Of the maps digitally available from the National Library of Scotland, the majority of these were insufficiently precise to allow reliable checking of watercourse changes, the exception being John Grassom's map of 1817, which depicts no changes of watercourses.

Site Visits

The walkover of the route confirmed the delineation of a series of flat areas, corresponding to the divisions of the transects described (see above). No evidence of former creeks was noted. The section of the Pow Burn nearest the route is in an environmentally sensitive area and could not be visited: the Canal Burn, which crosses the route, could be visited. The stream is relatively deeply incised for a relatively small channel, from 1.4 to 1.8 m moving downstream in the accessible areas of the route. The depth of incision corresponds with the stability of the route of the stream noted from the maps. Through the site visits is was possible to confirm the correspondence of the upper part of the borehole logs with the published lithostratigraphy on both sides of the Forth. The raised beach at the foot of Lady's Brae was also identified.

DISCUSSION

Lithostratigraphy and Chronology

It has proved possible to correlate the deposits observed in the borehole logs with known lithostratigraphic formations, which are of sub-tidal and intertidal estuarine origin. This has demonstrated that north of the Forth there are up to 15m of Pleistocene deposits (Loanhead Formation and Bothkennar Gravel) and that south of the Forth this depth varies between 0-14 m. These are overlain by Holocene deposits. North of the Forth the Holocene deposits vary between 3 and 6 m in depth, to the south of the Forth there are 7-14 m of Holocene deposits. The majority of these deposits belong to the Claret Formation. No palaeochannels were noted from maps or aerial photographs, or detected in the borehole data transects, nor were any observed in the trial trenches during site visits.

The gravels noted at the northern end of Transect 2 form a raised beach. If the height of the beach (c. 2m O.D.), is compared to the relative sea-level curve and the relatively high position of such a sediment in the tidal range is taken into account, it seems likely that the beach dates to the early Holocene or possibly late Pleistocene. The underlying peat, therefore, while of potential palaeoenvironmental interest, it is unlikely to be of archaeological interest.

The dates of deposition of the Holocene sediments have been presented above, and date range for the end of deposition is between 3000 BP and 7000 BP (Paul *et al.* 1995). It should be noted that the dates relate to sites close to the channel of the river. The sediments trend of younging towards the channel should be noted: the dates represent the more recent dates of deposition across the estuary (Paul *et al.*1995). On the basis of the published dates and the younging trend the most recent deposition of Holocene deposits would have been around 3000 BP.

Emergence of surfaces

The transects have been divided into a series of sections. These sections are of different ground levels. The relatively flat ground surface of each section indicates an erosional planation surface, each emerging at different stages of sea-level regression. As noted above, in an estuarine setting the tidal range is important in establishing the areas of different environments as surfaces emerge, and in conjunction with the rate of emergence, the rate of terrestrialisation. The influence of the tidal range means that initial emergence does not equate with full terrestrialisation of a ground surface. If a ground surface is between the mean low water spring tide and mean sea-level it is a mud-flat, being submerged twice a day, between mean sea-level and the mean high water spring tide it is a high salt marsh environment, flooding on a frequent basis. Table 3 gives approximate dates of emergence to these two envirionments in radiocarbon years derived from Robinson (1993) and Barras and Paul's (1999) sea-level curves.

Transect	Transect Section (chainage in metres)	Height (m. O.D.)	Date of emergence to mud flat radiocarbon years)	Date of emergence to high salt marsh (radiocarbon years)
1	0-470	c. 6.2	c. 5100 BP uncal.	c. 4350 BP uncal.
1	470-1780	c. 5.3	c. 4900 BP uncal.	c. 3900 BP uncal.
1	1780-2220	c. 3.5	Reclaimed 1784-1787	
2	0-440	c. 1.1	Reclaimed 1821-1822	
2	440-1270	c. 5	c. 4850 BP uncal.	c. 3850 BP uncal.
2	1270-1500	c. av. 6.3	c. 5100 BP uncal.	c. 4350 BP uncal.
2	1500-1650	c.7	c. 5300 BP uncal.	c. 4650 BP uncal.

Table 3. Dates of emergence of ground surfaces

This gives dates of emergence of land surfaces to form high salt marsh in the later Neolithic to early Bronze Age, excluding the reclaimed areas. Only sea-level regression so that a surface is above the high water spring tide will result in the full terrestrialisation of a ground surface. The sea-level curve is does not extend far enough to allow a fully reliable date for terrestrialisation to be given. Taking into account the tidal range and continued regression a speculative date range for full terrestrialisation can, however, be offered and this lies between the middle Bronze Age to early Iron Age.

The carseland higher on the Forth estuary was noted for its extensive peat deposits. Although no peat deposits have been noted that are likely to relate to the emergence and terrestrialisation of the current ground surfaces, the possibility that peat growth occurred, particularly given the relatively poor surface drainage of the carseland, and that peat was subsequently removed, cannot be ruled out.

Archaeological Potential

In the introduction it was noted that the archaeological potential of the alluvial deposits were as follows:

- The potential for waterlogged sediments (and therefore exceptional archaeological preservation);
- The potential for archaeological deposits and structures well-below modern ground level;
- The potential for significant palaeoenvironmental data (both local environment and whole-catchment data).

The potential for waterlogging of the sediments and therefore exceptional preservation in the sediments can be assessed by reference to the original environment of deposition and the subsequent post-depositional changes which the sediments have undergone. The sub-tidal and low intertidal environments of deposition of the Holocene sediments would favour the preservation of some organic materials, particularly wood. The subsequent land use of the carse has affected this position. Although the surface drainage of the carseland is relatively poor, extensive drainage has been in place long enough to cause considerable oxidation of the upper part of the sediments (see transect descriptions). The oxidised zone extends to 0.5 to 1.5 m from the ground surface, with the zone tending to be deepen away from the channel. In the deposits below this zone there would be scope for exceptional preservation, through waterlogging, of archaeological materials.

The potential for significant archaeological deposits and structures below modern ground level depends on both the environment and date of deposition of the sediments, in that these determine the possible range of activities that could be carried out in an area and the types of archaeological remains likely to be found. The environment of deposition of the uppermost 2-5 m of sediment across the carse is intertidal. The date range for the end of sediment accumulation is between 3000 BP uncal. and 7000 BP uncal., that is the uppermost deposits date from the middle of the Bronze Age to the Mesolithic. Across this period the remains associated with the intertidal zone would be likely to be fish traps and boats. Both would relate to low intensity activity in the landscape, and thus have a relatively low frequency of occurrence in large volumes of sediment. The deeper Holocene deposits, below 2 – 5 m from the current surface, are of subtidal origin, and as such deposited in conditions of near permanent submersion. These deposits are therefore less likely produce archaeological remains resulting from deliberate human exploitation of the environment, although exceptional situations, e.g. the sinking of a boat, might produce a deposit. Moreover, the deeper deposits, particularly those further from the channel, are likely to date from the early Holocene, which would also limit the potential for evidence of human activity. It should be noted that no buried terrestrialised surfaces were recorded in the Holocene sediments, which also accords with the findings of the Quaternary science literature, which suggest a relatively steady rate of sea-level regression from the mid Holocene.

With respect to the potential of palaeoenvironmental data, that pertaining to the local environment has high potential for the reconstruction of changes in the estuarine setting. The sediments are known to preserve macro and microfossils, e.g. gastropods, bivalves and ostrocods and foramanifera that would relate to local conditions. The tendency for reworking of sediments, noted in the review of the Quaternary science literature, would make reconstructions more difficult, though by no means impossible.

With respect to palaeoenvironmental data relating to the wider environment, it should be noted that the Forth at the point of the proposed route is a brackish, estuarine environment, as should the point that this region of the Forth is higher up the estuarine setting than at any time since the late Pleistocene, i.e. there has been no period of predominantly riverine influence. As such the sediment sources of the estuarine deposits are varied, with a significant coastal/off shore component. This component has been significant throughout the Holocene. This component would make whole-catchment analyses for chemical signatures of activities in the catchment unworkable, as such analyses rely on the transport of terrestrially derived riverine sediments. The reworking of sediments would also be a problem, with reworking probably more difficult to detect than would be the case in faunal analyses.

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APPENDIX 1

Aerial Photographs

Sortie	Frames	Date
106G/Scot/UK 85	4388 – 4381, 3388 – 3382, 3290 – 3295, 4290 – 4295	10.5.1946
540/RAF/1645	F21: 0262 – 0256, F21: 0364 – 0369, F22: 0364 – 0369	17.6.1955
58/RAF/1955	F22: 0228 – 0233	14.3.56
Meridian 114/71	087 – 089, 061 – 063	10.7.71
51488	074 – 072	14.6.1988
51988	027 – 029	7.6.1988

APPENDIX 2

Map Sources

Ordnance Survey First Edition

Clackmannanshire and Perthshire	Sheet CXL	Surveyed 1861-63	Published 1866
Stirlingshire	Sheet XXV	Surveyed 1860	Published 1864
Stirlingshire	Sheet XXIV	Surveyed 1861	Published 1865

Ordnance Survey Second Edition

Stirlingshire	Sheet XXV NW	Revised1895	Published 1899
Stirlingshire	Sheet XXIV NE	Revised 1895	Published 1899
Stirlingshire	Sheet XVIII SE	Revised 1895	Published 1899
Fifeshire	Sheet XXXVII	Revised 1895	Published 1897

Digital Maps Held By the National Library of Scotland

A Mape of the Countries About Stirling, Adair, John, 168?
The Shires of Stirlingshire and Clackmannanshire, Moll, Herman, 1745, London
To the Nobility and Gentry of the County of Stirlingshire, Grassom, John, 1817, Stirling
'Stirlingshire', from An Atlas of Scotland, Thomson, John, 1820, Edinburgh

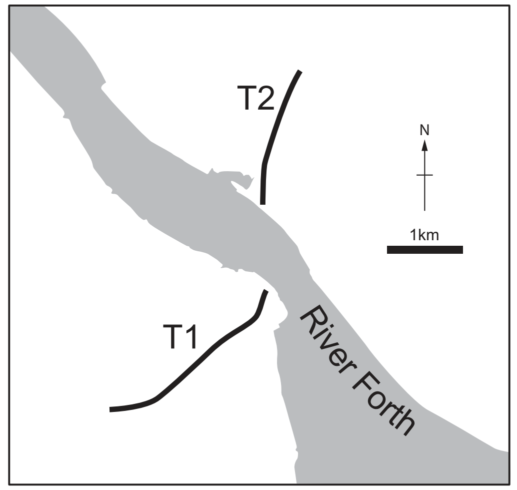


Figure 1: Route of Transect

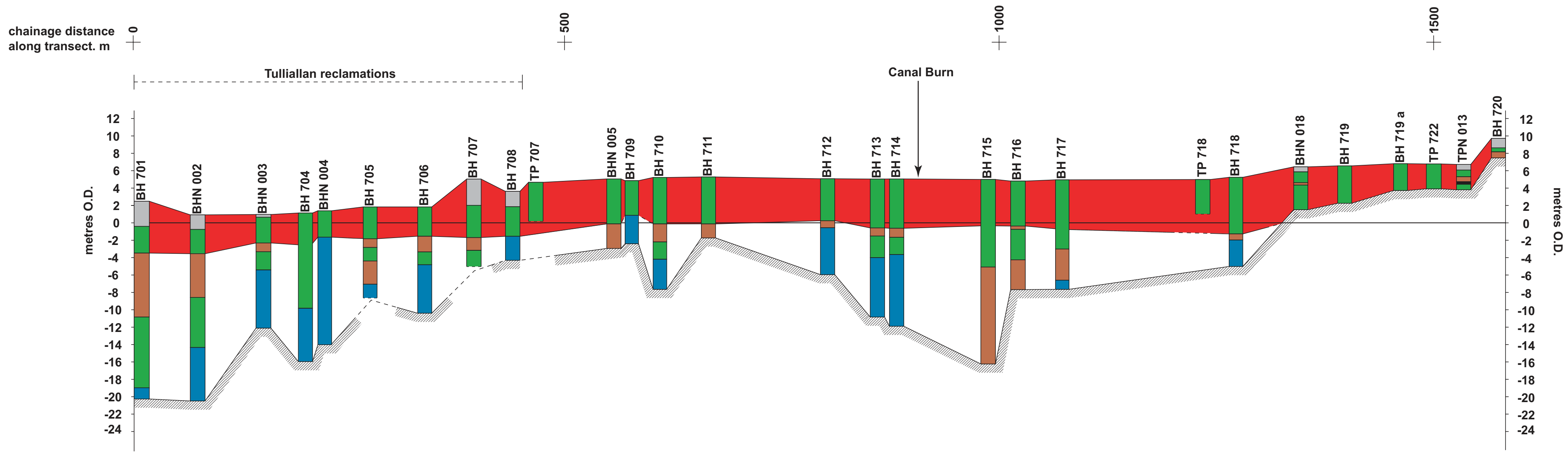
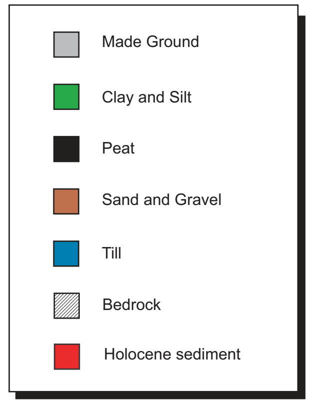


Figure 2: Transect 2: Quaternary deposits north of the Forth Estuary.



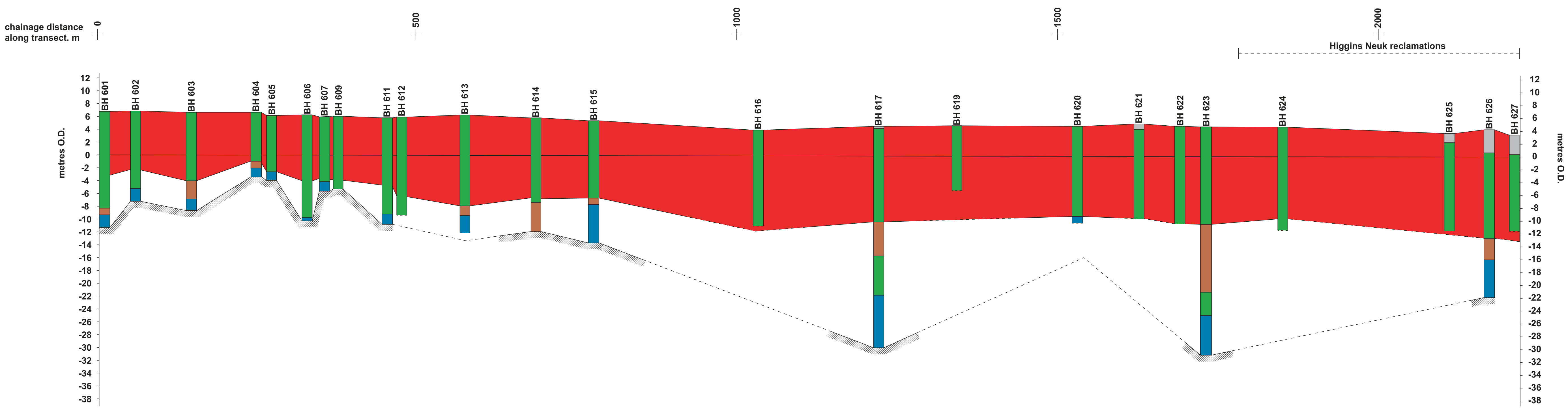


Figure 3: Transect 1: Quaternary deposits south of the Forth Estuary.