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Flag Fen, Cambridgeshire

Tree-ring Analysis of Oak Timbers (FFB21)

Ian Tyers

Scientific Dating

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Summary

Dendrochronological analysis of oak timbers excavated at Flag Fen, near Peterborough, Cambridgeshire was undertaken. This material was excavated as part of an investigative project "*Flag Fen: Investigating the survival and preservation of the archaeological remains to inform a management strategy. HE Project No: 7902*" under site code FFB21 by Cambridge Archaeological Unit. The dated timbers were from the late Bronze Age and replicate tree-ring chronologies originally constructed in the 1990's.

This report archives the newest dendrochronological results and integrates them with previous studies on this important site.

Contributor

Ian Tyers

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Front cover image

Trench 3 paired piles (© Cambridge Archaeological Unit)

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Tree-ring analysis of oak timbers from Flag Fen

This document is a technical archive report on the tree-ring analysis of oak timbers from Flag Fen, Cambridgeshire excavated in 2021. Elements of this report may be combined with detailed descriptions, drawings, and other technical reports at some point in the future to form either a comprehensive publication or an archive deposition on the material.

Flag Fen lies *c*. 3km east of Peterborough in Cambridgeshire (Fig. 1). The internationally significant site at Flag Fen is a Bronze Age monument, consisting of a kilometre-long post alignment constructed from five rows of posts, along with a timber platform, located towards its eastern end. First identified in 1982 by Francis Pryor (Pryor 2001), there have been a number of subsequent excavations across the site. A full Gazetteer of the interventions is provided in Brittain et al. (2020). Their Gazetteer map is reproduced here as Figure 2.

Timbers from Flag Fen, and Fengate at its western end, were subject to an extensive programme of dendrochronological analyses during the late 1980's up to 1994, culminating in the publication in 1999 of results for *c*. 250 dated timbers identified from the analysis of *c.* 690 timbers (Neve 1992; 1999; 2001). A single composite sequence, called, FFB_T225, which was dated 1406 to 937 BC was produced from these studies. This chronology was amongst the first Bronze Age tree-ring data sets produced from English excavations and formed a core block within the prehistoric tree-ring chronology. The Flag Fen sequence has been used subsequently to date a number of Bronze Age timber features from the nearby area, particularly the Must Farm and Horsey Bridge sites. Timbers from contemporary features further afield also cross-match well with these datasets; including sites from Essex, Kent, Nottinghamshire and Somerset.

The analysed timbers for the 1999 report were the most suitable candidates from amongst a much larger total number of excavated or exposed timbers. For example, the westernmost end, Fengate, comprised 154 dated samples from 350 analysed, selected from *c.* 1500 exposed timbers.

The chronology published in 1999 covered the period 1406–937 BC. The material was worked on at Flag Fen by Janet Neve and the analysis and dating of this material was undertaken in collaboration with dendrochronologists from Sheffield University, Queens University Belfast and the Museum of London. Sapwood survival was poor, and bark-edge survival was extremely rare with only ten examples. The dated assemblage indicated a

long period of activity throughout the alignment and platform from the thirteenth century BC through to mid tenth century BC.

The only additional tree-ring samples analysed from Flag Fen between the 1999 report and the present report comprised a small number of samples from a *Time Team* excavation (*Time Team* is a British television series where a team of archaeologists and experts conduct intensive, three-day excavations to uncover and explore archaeological sites), located in Gazetteer Area 34, which yielded a single datable timber (Tyers 1999).

The nearby excavations at Must Farm, and Horsey Bridge have both yielded two composite tree-ring sequences that are broadly contemporary with the beginning and end sections of the Flag Fen 1999 datasets. Using this newer material to re-assess the older Flag Fen material has slightly changed the chronologies used here compared to the published version, several tenth century BC timbers have been identified and a mistake was identified in the first two decades of the original sequence where it was reliant on a single timber. The 2022 version of this dataset as used here is two separate long replicated tree-ring chronologies. One of these, called FF91, is combined from 103 timbers, representing 91 trees excavated from Gazetteer Areas 2, 4, 6 and 13 and dates from 1390–955 BC inclusive, whilst the other is called FG139, and is combined from 157 timbers representing 139 trees excavated from Gazetteer Area 16, the Fengate Power Station, which marks the currently known western extent of the alignment. This sequence dates from 1364–918 BC inclusive. There has been no change to the absolute dating of the chronology since 1999, but there has been an amendment at the beginning and some additions at the end.

The new FFB21 excavations in 2021 comprised a series of three transects across the alignment, Tr. 2, Tr. 3 and Tr. 4, and two investigations into the extent of the platform, Tr. 5 and Tr. 6. Their locations are illustrated in Figure 2, Tr. 1 was abandoned due to the presence of a gas pipeline. This material was excavated as part of a project titled "*Flag Fen: Investigating the survival and preservation of the archaeological remains to inform a management strategy*". Flag Fen is an internationally significant post-alignment which is now degrading *in situ*. Historic England wishes to address this risk and remove the site from the Heritage at Risk register. Excavations were undertaken to enable scientific analysis of preserved remains in order to provide objective information on the survival and state of preservation of parts of the site and the extent of the platform.

At this stage none of the material from the site extends into the ninth century BC. As a result we cannot currently identify a tree-ring date for the pile dwelling at Must Farm, dated *c. 860–835 cal BC* (*68% probability*) by radiocarbon wiggle-matching of the tree-ring

sequences (Tyers et al. 2020). The radiocarbon evidence suggests the inner end of the short-lived trees used for the pile dwelling at Must Farm must be tantalisingly close to overlapping the latest absolutely dated material from Flag Fen, Horsey Bridge and Must Farm.

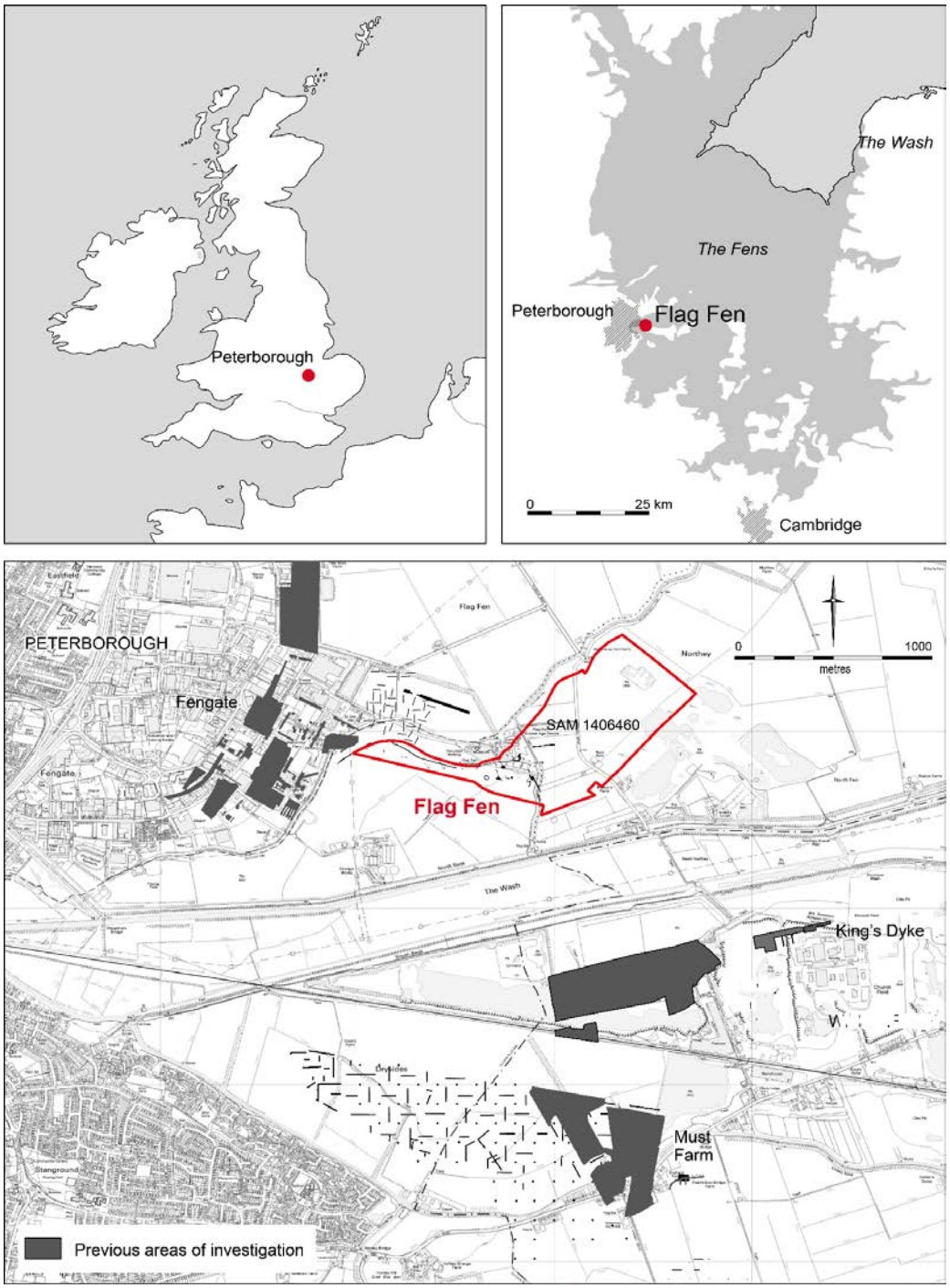

Figure 1: Location of Flag Fen (SAM 1406460) and distribution of archaeological investigations in the Flag Fen Basin. (© Cambridge Archaeological Unit)

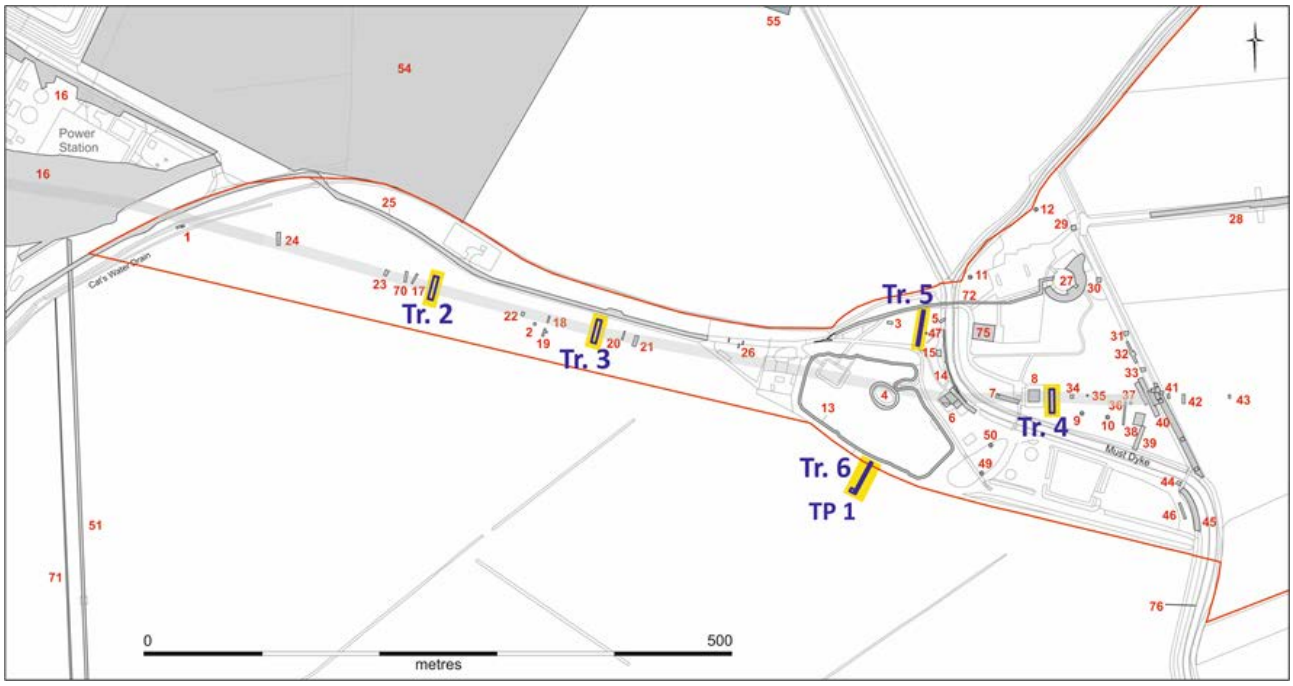

Figure 2: The location of FFB21 trenches (Tr.2 to Tr. 6) and gazetteer entries for previous excavations (red numbers 1–80). Gazetteer entries cross-reference to Brittain et al. (2020). Gazetteer entries 2, 4, 6, 13 and 16 contained wood discussed in Neve 1999 and entry 34 contained wood from a *Time Team* excavation. Samples from the FFB21 excavations, bold labels Tr. 2 to Tr. 6, are discussed. (© Cambridge Archaeological Unit)

Methodology

The timbers were sampled by the removal of cross-sectional slices by handsaw at locations that provided a combination of the maximum numbers of rings, and/or retained likely original outer surfaces. Each sample was subsequently placed in a deep-freeze for at least 48 hours in order to consolidate the timber. A surface equivalent to the original horizontal plane of the parent tree was then prepared with a variety of bladed tools. This preparation revealed the width of each successive annual tree ring. Each prepared sample could then be accurately assessed for the number of rings it contained, and at this stage it was also possible to determine whether the sequence of ring widths within it could be reliably resolved.

Tree-ring dating employs the patterns of tree-growth to determine the calendar dates for the period during which the sampled trees were alive. The amount of wood laid down in any one year by most trees is determined by the climate and other environmental factors. Trees over relatively wide geographical areas can exhibit similar patterns of growth, and this enables dendrochronologists to assign dates to some samples by matching the growth pattern with other ring-sequences that have already been linked together to form reference chronologies.

Timbers intended for dendrochronological analysis need to be free of aberrant anatomical features such as those caused by physical damage to the tree, which may prevent or significantly reduce the chances of successful dating.

Standard dendrochronological analysis methods (see eg English Heritage 1998) were applied to each suitable sample from the site. Complete or partial sequences of the annual growth rings were measured to an accuracy of 0.01mm using a micro-computer based travelling stage. Cross-correlation algorithms (eg Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated. The ring sequences with highly correlated positions were, in addition, plotted on the computer screen, or onto semi-log graph paper, to allow visual comparisons to be made, this providing a measure of quality control identifying any potential errors in the measurements. Where such matching positions were satisfactory, new composite sequences were constructed from the synchronised sequences. Any *t*-values reported below were derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position need to have been obtained from a range of independent sequences, and that these positions were supported by satisfactory visual matching.

Not every tree can be correlated by the statistical tools or the visual examination of the graphs. There are thought to be a number of reasons for this: genetic variations; site-specific issues (for example a tree growing in a stream bed will be less responsive to rainfall); or some traumatic experience in the tree's lifetime, such as injury by pollarding, defoliation events by caterpillars, or similar. These could each produce a sequence dominated by a non-climatic signal. Experimental work with modern trees shows that 5–20% of all oak trees, even when enough rings are obtained, cannot be reliably cross-matched.

Converting the date obtained for a tree-ring sequence into a useful date requires a record of the nature of the outermost rings of the sample. If bark or bark-edge survives, a felling date precise to the year or season can be obtained. If no sapwood survives, the date obtained from the sample gives a *terminus post quem* for its use. If some sapwood survives, an estimate for the number of missing rings can be applied to the end-date of the heartwood. This estimate is quite broad and varies by region. This report uses a range of 10–46 rings for the local English material from Flag Fen (English Heritage 1998, 11; Arnold et al. 2019, fig 9). The BC scale used by dendrochronologists, and as used in this report, has no year zero, the year 1 BC immediately precedes the year AD 1.

Results

Samples from 66 excavated timbers were supplied for dendrochronological analysis (Table 1). These timbers were assessed to contain 30 or more rings. All the selected dendrochronological samples were oak (*Quercus* spp.). The three alignment transects provided very similar numbers of samples; 23 samples from Tr. 2, 23 samples from Tr. 3, and 19 samples from Tr. 4. The platform area provided only one sample, no samples were selected from Tr. 5, and only one sample from Tr. 6. All the submitted material was analysed. Sapwood was exceedingly rare with only eight samples retaining measurable sapwood rings, and only one of these was complete to bark-edge. One further sample is complete to the heartwood/sapwood transition, and another nine samples were probably complete to the heartwood/sapwood transition. Some of the material was long lived, with the two longest sequences containing 192 years and 166 years, at the other end of the scale three of the samples contained less than 30 rings. The material was quite de-lignified, with some of the samples resembling sponges.

The sequences were compared with each other and with the other Flag Fen Basin composite and individual datasets. Three pairings were identified that comprise same-tree pairs (Figs. 3–5) all from Tr. 3. These were combined for Table 2. Another strongly matched pair was identified between one of these samples and a sample from the 1990's analyses (Fig. 6), Three further pairings were identified that also may be same-tree pairs (Figs. 7–9), but which are treated separately in Tables 3–4. In total 40 of the new sequences were directly cross-matched to each other and/or directly matched to the various Flag Fen composite series (Tables 2–8, Fig. 10). The FFB21 composite data comprises 39 samples covering the period 1336–990 BC (FFB21_T39, Table 8) with a single later outlier of 970–938 BC (Sample 216, Table 5). The site therefore provides a similar sequence to the earlier series though with less samples it perhaps unsurprisingly starts later and ends earlier. It does provide a further useful replicate sequence for dating other contemporaneous material across the Basin area (Fig. 11, Table 8).

Table 1: Details of the analysed *Quercus* spp. (oak) dendrochronological samples from Flag Fen, sitecode FFB21.

WD	TR	Cross-section (mm)	Rings	Sapwood	AGR (mm)	Date of measured sequence	Interpreted result
13	TR2	85 x 30	83	-	0.94	1120–1038 BC	after 1028 BC
15	TR2	140 x 25	58	-	2.39	1072–1015 BC	after 1005 BC
25	TR2	135 x 60	52	-	1.64	–	–
41	TR2	75 x 15	50	-	1.11	–	–
45	TR2	65 x 65	76	-	0.71	–	–
46	TR2	55 x 5	59	-	0.88	1125–1067 BC	after 1057 BC
59	TR2	85 x 15	51	-	1.66	1102–1052 BC	after 1042 BC
67	TR2	40 x 10	47	-	0.64	–	–
76	TR2	145 x 140	53	-	2.85	1109–1057 BC	after 1047 BC
79	TR2	160 x 25	128	-	1.24	1279–1152 BC	after 1142 BC
81	TR2	90 x 20	110	4	0.71	1142–1033 BC	1027–991 BC
92	TR2	180 x 105	23	H/S	3.89	-	-
93	TR2	180 x 160	36	12	2.33	-	-
106	TR2	105 x 50	52	-	1.88	1095–1044 BC	after 1034 BC
113	TR2	185 x 105	113	?H/S	0.91	1131–1019 BC	1009–973 BC?
145	TR2	160 x 110	52	-	3.10	1099–1048 BC	after 1038 BC
216	TR2	75 x 60	33	-	1.75	970–938 BC	after 928 BC
272	TR2	55 x 30	44	-	1.08	1050–1007 BC	after 997 BC
297	TR2	110 x 80	72	-	1.32	1336–1265 BC	after 1255 BC
299	TR2	110 x 45	30	?H/S	1.50	–	–
325	TR3	155 x 150	59	-	1.99	1137–1079 BC	after 1069 BC
326	TR3	95 x 65	50	-	1.10	–	–
327	TR3	150 x 120	58	-	2.04	1071–1014 BC	after 1004 BC
330	TR3	125 x 115	122	?H/S	1.00	1161–1040 BC	1030–994 BC?
331	TR3	110 x 70	65	-	0.87	–	–
333	TR3	110 x 90	24	5	4.65	–	–
334	TR3	110 x 75	63	-	1.61	1180–1118 BC	after 1108 BC
337	TR3	185 x 145	40	11+Bw	3.16	1070–1031 BC	1031 BC winter
340	TR3	55 x 55	44	-	1.23	–	–
341	TR3	145 x 120	64	?H/S	1.99	–	–
342	TR3	150 x 140	166	-	0.90	1326–1161 BC	after 1151 BC
343	TR3	165 x 110	85	-	1.95	1094–1010 BC	after 1000 BC
346	TR3	120 x 120	32	3	1.70	–	–
348	TR3	40 x 40	52	-	0.76	1132–1081 BC	after 1071 BC

WD	TR	Cross-section (mm)	Rings	Sapwood	AGR (mm)	Date of measured sequence	Interpreted result
359	TR3	170 x 40	192	-	0.84	1235–1044 BC	after 1034 BC
363	TR3	60 x 50	31	-	1.66	–	–
375	TR3	120 x 45	163	-	0.69	1288–1126 BC	after 1116 BC
381	TR4	215 x 40	54	-	2.07	1124–1071 BC	after 1061 BC
382	TR3	165 x 50	83	-	1.88	1162–1080 BC	after 1070 BC
384	TR4	210 x 60	46	-	2.01	1156–1111 BC	after 1101 BC
387	TR4	80 x 70	43	-	1.88	1147–1105 BC	after 1095 BC
390	TR4	190 x 85	81	3	2.22	1157–1077 BC	1070–34 BC
393	TR4	150 x 140	58	?H/S	1.23	–	–
394	TR4	235 x 190	56	-	2.08	–	–
395	TR4	135 x 65	38	-	1.72	–	–
397	TR4	130 x 125	35	-	1.43	1198–1164 BC	after 1154 BC
399	TR4	200 x 110	67	?H/S	1.56	–	–
400	TR4	215 x 115	77	?H/S	1.43	–	–
402	TR4	175 x 165	60	13+Bw	2.01	–	–
404	TR4	160 x 150	86	-	1.67	1187–1102 BC	after 1092 BC
406	TR4	125 x 125	23	?H/S	2.38	–	–
408	TR4	125 x 45	34	-	3.26	–	–
411	TR4	150 x 95	110	-	1.33	1114–1005 BC	after 995 BC
412	TR4	145 x 75	114	-	1.17	1116–1003 BC	after 993 BC
416	TR4	50 x 20	43	-	1.35	1148–1106 BC	after 1096 BC
441	TR4	70 x 45	36	-	1.22	1025–990 BC	after 980 BC
453	TR4	140 x 60	85	?H/S	1.51	1144–1060 BC	1050–14 BC?
455	TR3	85 x 60	36	-	2.13	–	–
456	TR3	70 x 10	33	-	1.91	1158–1126 BC	after 1116 BC
458	TR3	80 x 50	70	-	1.09	1104–1035 BC	after 1025 BC
459	TR3	100 x 50	66	-	1.37	1117–1052 BC	after 1042 BC
604	TR2	130 x 50	106	-	0.51	–	–
676	TR2	240 x 200	99	-	1.98	–	–
690	TR4	240 x 130	42	10+?B	3.46	–	–
694	TR2	155 x 140	54	-	1.71	1166–1113 BC	after 1103 BC
697	TR6	190 x 50	92	-	1.91	1108–1017 BC	after 1007 BC

KEY: WD wood number; TR trench number; Cross-section dimensions to nearest 5mm; H/S onset of sapwood; ?H/S possible onset of sapwood; +Bw bark edge winter felled; +?B possible bark edge; - no sapwood; AGR = average growth rate per year.

Table 2: Showing *t*-values (Baillie and Pilcher 1973) between a) the FFB21 Flag Fen Tr. 3 sequences, and b) their *t*-values to the FFB21 Tr. 2 and Tr. 4 composites, and the Flag Fen Areas 2, 4, 6 and 13, and Flag Fen Area 16 composites. – *t*-values less than 3.0, \ overlap less than 15 years. Tr. 2 is the FFB21 Tr. 2 T13 composite 1336–1007 BC, Tr. 4 is the FFB21 Tr. 4 T11 composite 1198–990 BC, FF91 is the Flag Fen Areas 2, 4, 6 and 13 composite (Neve 1999, T91/S103 2022 version) 1390–955 BC, and FG139 is the Flag Fen Area 16 Fengate composite (Neve 1999, T139/S157 2022 version) 1364–918 BC

a)	**325**	**327+ 343**	**330+ 334**	**337**	**342**	**348**	**359**	**375**	**382+ 456**	**458**	**459**
325		-	-	\	\	3.05	-	\	-	-	4.35
327+343			-	-	\	\	-	\	4.21	-	-
330+334				-	-	-	3.25	-	-	-	-
337					\	\	-	\	\	-	-
342						\	3.12	5.24	\	\	\
348							-	\	4.96	-	-
359								3.07	-	-	-
375									-	\	\
382+456										-	3.13
458											-
b)											
Tr. 2	4.62	6.05	5.12	4.52	6.14	4.67	5.81	-	3.40	4.35	3.79
Tr. 4	3.98	6.82	5.30	3.84	4.61	4.70	4.93	-	5.04	4.27	-
FF91	5.45	8.24	5.87	5.08	8.48	4.91	9.55*	6.70	8.41	6.14	3.67
FG139	6.04	7.48	7.68	4.35	9.77	4.59	10.72	5.41	6.21	4.96	4.78

* This appears to be the same tree as timber A3182 from Flag Fen Area 6A (see Fig. 6), this *t*-value will be raised by this pairing.

Table 3: Showing *t*-values (Baillie and Pilcher 1973) between a) the FFB21 Flag Fen Tr. 2 sequences, and b) their *t*-values to the FFB21 Tr. 3 and Tr. 4 composites, and the Flag Fen Areas 2, 4, 6 and 13, and Flag Fen Area 16 composites. – *t*-values less than 3.0, \ overlap less than 15 years. Tr. 3 is the FFB21 Tr. 3 T14 composite 1326-1010BC, Tr. 4 is the FFB21 Tr. 4 T11 composite 1198–990BC, FF91 is the Flag Fen Areas 2, 4, 6 and 13 composite (Neve 1999, T91/S103 2022 version) 1390–955 BC, and FG139 is the Flag Fen Area 16 Fengate composite (Neve 1999, T139/S157 2022 version) 1364–918 BC

a)	**13**	**15**	**46**	**59**	**76**	**79**	**81**	**106**	**113**	**145**	**272**	**297**	**694**
13		-	3.75	-	-	\	5.00	-	-	3.55	\	\	\
15			\	-	-	\	3.44	-	-	-	-	\	\
46				-	-	\	9.34	-	4.01	-	\	\	\
59					3.17	\	3.15	-	4.40	4.09	\	\	\
76						\	3.71	-	-	7.70	\	\	\
79							\	\	\	\	\	-	-
81								3.42	4.90	3.15	-	\	-
106									-	-	\	\	\
113										-	3.10	\	-
145											\	\	\
272												\	\
297													\
b)													
Tr.3	5.97	-	4.41	7.63	3.85	7.16	7.70	7.77	7.84	5.46	4.92	3.27	3.11
Tr.4	4.91	4.33	3.57	3.47	4.37	-	6.85	5.38	4.83	3.61	6.46	\	5.74
FF	6.08	4.48	4.32	6.26	4.99	10.49	8.63	6.04	6.77	7.05	5.63	7.70	5.02
FG	6.51	5.52	3.98	6.29	5.04	9.14	8.78	7.49	6.39	6.83	6.17	9.06	4.80

Table 4: Showing *t*-values (Baillie and Pilcher 1973) between a) the FFB21 Flag Fen Tr. 4 sequences, and b) their *t*-values to the FFB21 Tr. 2 and Tr. 3 composites, and the Flag Fen Areas 2, 4, 6 and 13, and Flag Fen Area 16 composites. – *t*-values less than 3.0, \ overlap less than 15 years. Tr. 2 is the FFB21 Tr. 2 T13 composite 1336–1007 BC, Tr. 3 is the FFB21 Tr. 3 T14 composite 1326–1010 BC, FF91 is the Flag Fen Areas 2, 4, 6 and 13 (Neve 1999, T91/S103 2022 version) composite 1390–955 BC, and FG139 is the Flag Fen Area 16 Fengate (Neve 1999, T139/S157 2022 version) composite 1364–918 BC

a)	**381**	**384**	**387**	**390**	**397**	**404**	**411**	**412**	**416**	**441**	**453**
381		\	-	-	\	-	-	-	-	\	-
384			-	4.87	\	3.11	\	\	-	\	-
387				-	\	4.01	\	\	3.80	\	3.30
390					\	-	5.97	4.43	-	\	6.66
397						5.78	\	\	\	\	\
404							\	-	4.65	\	-
411								7.66	\	3.52	5.02
412									\	-	4.77
416										\	-
441											\
b)											
Tr.2	-	3.04	4.73	5.65	-	4.74	7.97	8.25	3.94	4.68	6.30
Tr.3	-	-	-	6.31	3.54	6.04	6.60	7.53	3.27	3.07	6.35
FF91	3.35	5.30	5.25	8.49	4.60	8.12	8.94	7.47	5.09	6.37	7.55
FG139	3.57	3.51	5.13	6.68	5.96	8.79	9.35	8.68	5.53	5.89	6.31

Table 5: Showing example *t*-values (Baillie and Pilcher 1973) between FFB21 sample 216 from Tr. 2 and contemporaneous reference data

	FFB 216: 970–938 BC)
Flag Fen Areas 2, 4, 6, and 13 (Neve 1999, T91/S103 2022 version) 1390–955 BC	3.40
Flag Fen Area 16 Fengate (Neve 1999, T139/S157 2022 version) 1364–918 BC	4.80
Horsey Bridge HOB22 #17 (Tyers 2022) 971–902 BC	3.25
Magna Park MAP08 #100 (Tyers 2022) 1004–924 BC	3.58
Must Farm MUS11 #1769 (Tyers et al. 2020) 990–933 BC	4.32
Must Farm MUS15 #7325 (Tyers et al. 2020) 1032–907 BC	7.10

Table 6: Showing example *t*-values (Baillie and Pilcher 1973) between FFB21 sample 697 from Tr. 6 and contemporaneous reference data

	FFB 697: 1108–1017 BC
Flag Fen Areas 2, 4, 6, and 13 (Neve 1999, T91/S103 2022 version) 1390–955 BC	6.40
Flag Fen Area 16 Fengate (Neve 1999, T139/S157 2022 version) 1364–918 BC	6.45
Flag Fen FFB21 Tr. 2 T13 (this report) 1336–1007 BC	5.49
Flag Fen FFB21 Tr. 3 T14 (this report) 1326–1010 BC	5.25
Flag Fen FFB21 Tr. 4 T11 (this report) 1198–990 BC	3.58
Horsey Bridge HOB22 & MAP08 T5 (Tyers 2022) 1094–902 BC	4.89
Must Farm MUS11 & MUS15 settlement T5 (Tyers et al. 2020) 1065–907 BC	5.61

Table 7: Showing *t*-values (Baillie and Pilcher 1973) between the FFB21 Flag Fen Trench composites. Tr. 2 is the Tr. 2 T13 composite 1336–1007 BC, Tr. 3 is the Tr. 3 T14 composite 1326–1010 BC, Tr. 4 is the Tr. 4 T11 composite 1198–990 BC. These were combined with single timber 697 from Tr. 6 to form the site composite FFB21 T39 used in Table 8.

	Tr. 3 T14	**Tr. 4 T11**
Tr. 2 T13	10.38	10.28
Tr. 3 T14		10.46

Table 8: Showing *t*-values (Baillie and Pilcher 1973) between the composite FFB21 T39 sequence and contemporaneous reference data

	FFB21 T39: 1336-990 BC
Flag Fen Areas 2 4 6 & 13 (Neve 1999, T91/S103 2022 version) 1390–955 BC	21.57
Flag Fen Area 16 Fengate (Neve 1999, T139/S157 2022 version) 1364–918 BC	22.55
Flag Fen Area 34 Time–Team D4 (Tyers 1999) 1293–1116 BC	8.36
Horsey Bridge HOB22 #3+4 (Tyers 2022) 1268–1200 BC	5.12
Horsey Bridge HOB22 #38 (Tyers 2022) 1431–1232 BC	6.23
Horsey Bridge HOB22 & MAP08 T5 (Tyers 2022) 1094–902 BC	6.29
Must Farm MUS06 & MUS15 causeway T12 (Tyers et al. 2020) 1400–1285 BC	7.11
Must Farm MUS11 & MUS15 settlement T5 (Tyers et al. 2020) 1065–907 BC	7.58
Cambridge St Clements Garden SCG15 (Tyers 2016a; b) 1257–948 BC	7.04
Kent, Swalecliffe (Masefield et al. 2003) 1432–1085 BC	8.99
Notts, Newington Quarry nr Misson NQ02 (Tyers 2003) 1580–954 BC	7.33

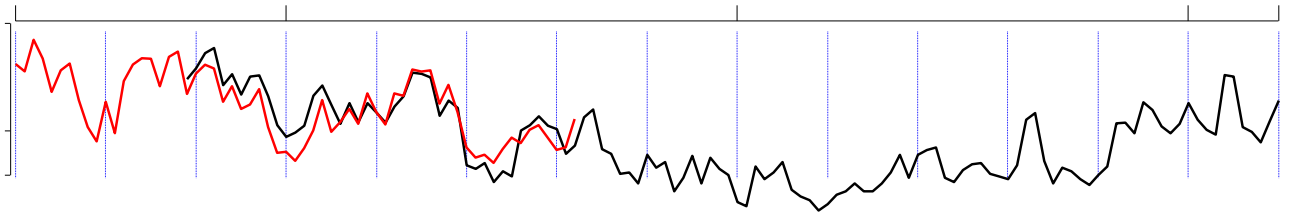

Figure 3: Diagram showing the tree-ring sequences from FFB21 Tr. 3 330 (black) and FFB21 TR. 3 334 (red), *t*-value 7.14. These appear likely to be from a single tree. These are combined as 330+334 in Table 2.
x-axis = Relative years and y-axis = tree-ring width in mm.

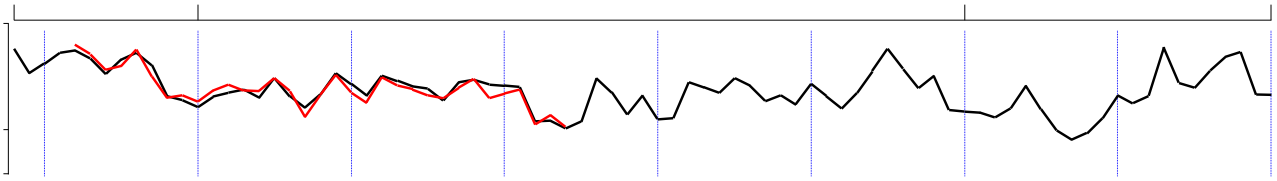

Figure 4: Diagram showing the tree-ring sequences from FFB21 Tr. 3 382 (black) and FFB21 Tr. 3 456 (red), *t*-value 13.38. These appear likely to be from a single tree. These are combined as 382+456 in Table 2.
x-axis = Relative years and y-axis = tree-ring width in mm.

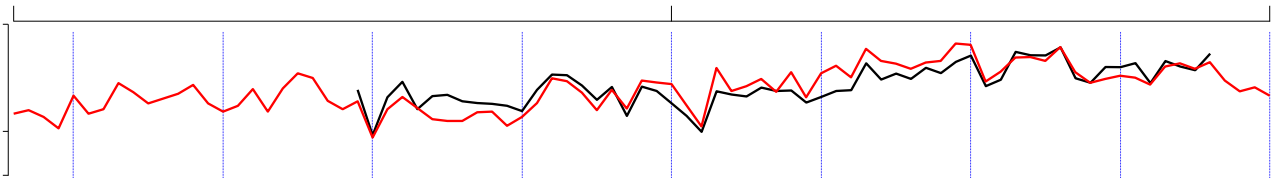

Figure 5: Diagram showing the tree-ring sequences from FFB21 Tr. 3 327 (black) and FFB21 Tr. 3 343 (red), *t*-value 11.50. These appear likely to be from a single tree. These are combined as 327+343 in Table 2.
x-axis = Relative years and y-axis = tree-ring width in mm.

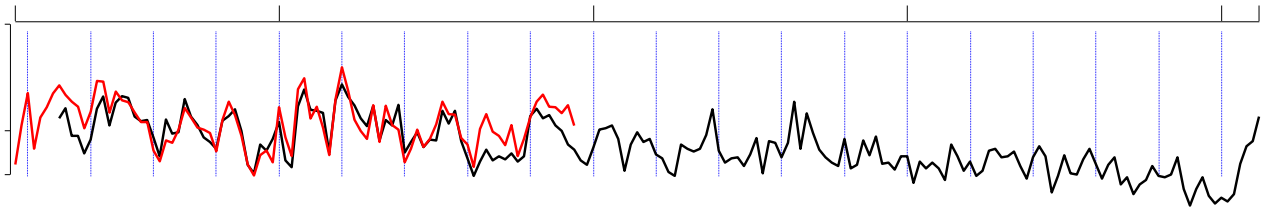

Figure 6: Diagram showing the tree-ring sequences from FFB21 Tr. 3 359 (black) and A3182 (red) from Area 6A of Flag Fen (Neve 1999), *t*-value 15.21. These appear likely to be from a single tree.
x-axis = Relative years and y-axis = tree-ring width in mm.

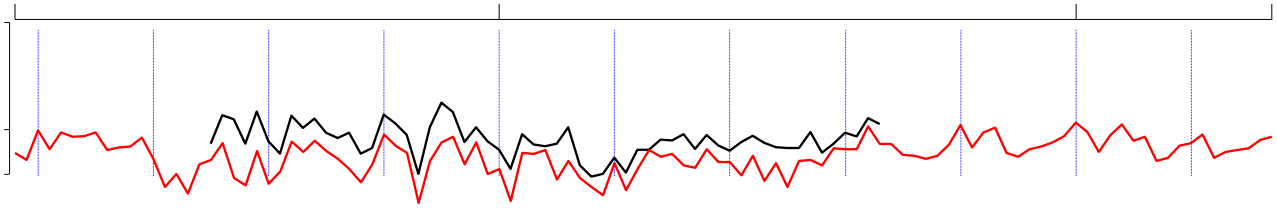

Figure 7: Diagram showing the tree-ring sequences from FFB21 Tr. 2 46 (black) and FFB21 Tr. 2 81 (red), *t*-value 9.34. Despite this high correlation they have quite different growth rates and appear less likely to be from a single tree, though they could be from opposite radii or different heights in a distorted tree. These are kept separate in Table 3.
x-axis = Relative years and y-axis = tree-ring width in mm.

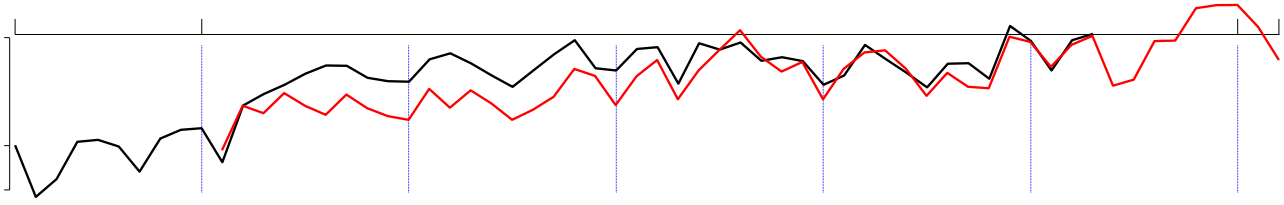

Figure 8: Diagram showing the tree-ring sequences from FFB21 Tr. 2 76 (black) and FFB21 Tr. 2 145 (red), *t*-value 7.70. Despite this lower correlation (compared to the pairings in Figs 3–7) they have a very similar growth trend; they grew much faster as they got older. These may be from a single tree, but they are kept separate in Table 3.
x-axis = Relative years and y-axis = tree-ring width in mm.

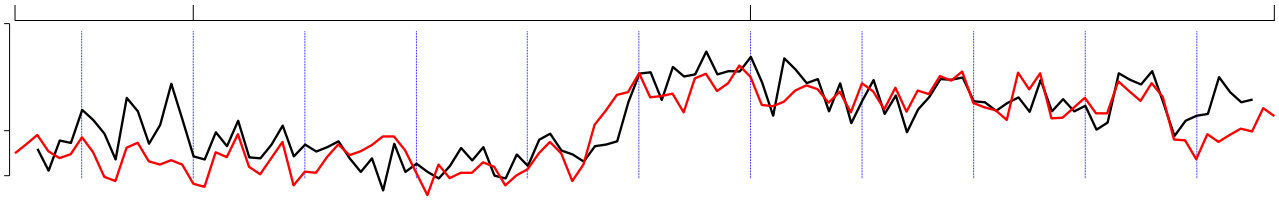

Figure 9: Diagram showing the tree-ring sequences from FFB21 Tr. 4 411 (black) and FFB21 Tr. 4 412 (red), *t*-value 7.66. Despite this lower correlation (compared to the pairings in Figs 3–7) they have a very similar growth trend, particularly the marked step in growth in the middle of the graph. These may be from a single tree, but they are kept separate in Table 4.
x-axis = Relative years and y-axis = tree-ring width in mm.

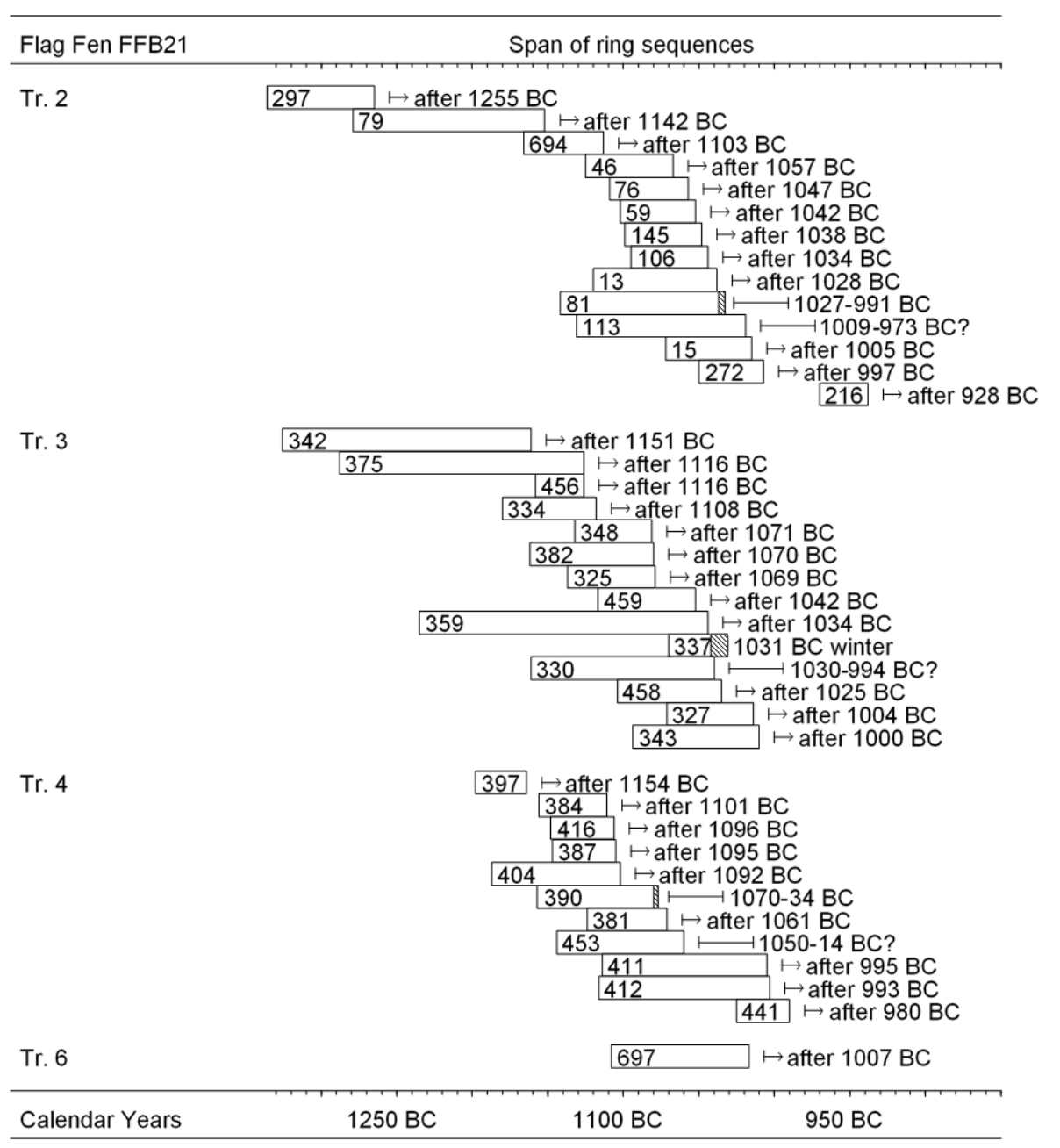

Figure 10: Bar diagram showing the absolute dating positions of the dated tree-ring sequences obtained from Flag Fen FFB21. The interpreted *terminus post quem* date, felling date range, or felling date is also shown for each sample. White bars are oak heartwood, hatched bars are oak sapwood.

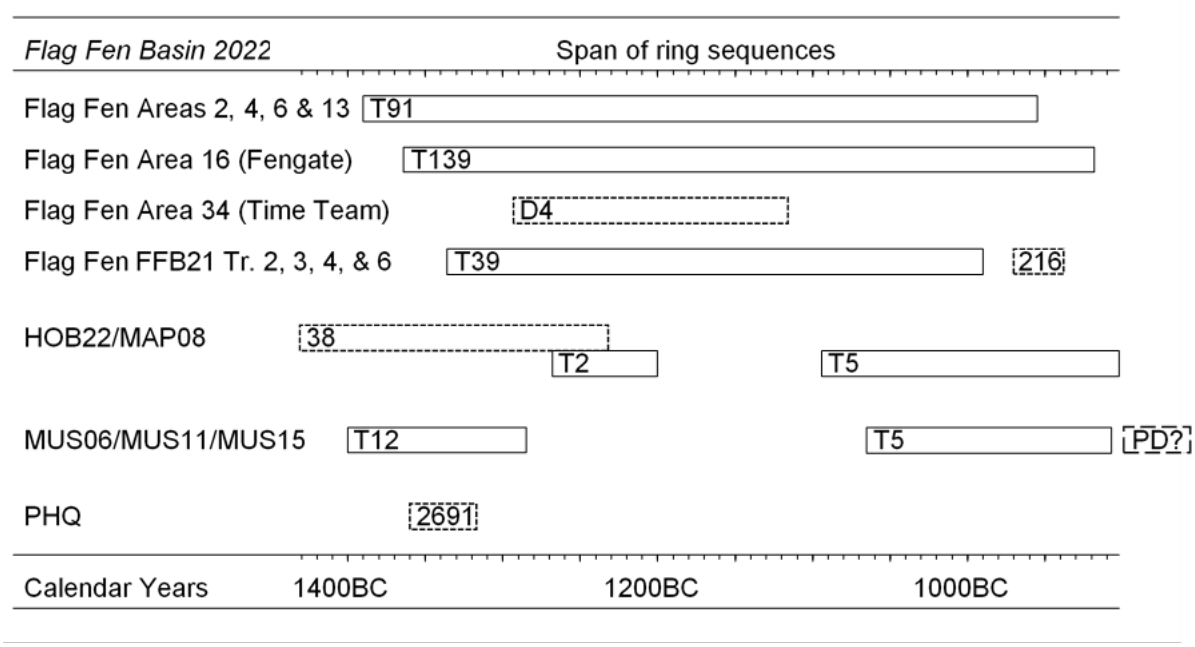

Figure 11: Bar diagram showing the current state of the Flag Fen Basin tree-ring chronologies. The top 3 refer to the Gazetteer Area's in Figure 2. The FFB21 material is from Trenches as marked on Figure 2. The composite data sets (solid line bars) are labelled with T2, T5 etc, the number of samples in the composite. The single timber sequences (dotted line bars) are marked with their reference numbers. D4 is a single timber from Northey Island a few meters east of the Flag Fen platform in Gazetteer Area 34 (Fig. 2), 216 is the outlier late timber from the FFB21 excavations, 38 is a single long lived timber from Horsey Bridge, 2691 is a single short lived sequence from Pode Hole Quarry, *c.* 5km north-east of Flag Fen. Horsey Bridge (HOB22 and MAP08) and Must Farm (MUS06, MUS11 and MUS15) are *c*. 2.8km south and *c*. 2.3km south-east of Flag Fen respectively. Site names and report references are in Table 8. The dashed line bar marked PD is the estimated position of the Must Farm pile dwelling sequence. This has an end-date of *c*. *860–835 cal BC* (*68% probability*) by radiocarbon wiggle-matching of the tree-ring sequences (Tyers et al. 2020).

Discussion

These excavations were undertaken to enable scientific analysis of the preserved remains in order to provide objective information on the survival and state of preservation of parts of the site and the extent of the platform. The dendrochronological analyses have confirmed that at present the material on the alignment is still capable of producing viable tree-ring samples, and that the data from them provides replicates of the data produced in the 1990's. Sapwood survival is poor, and the oak heartwood is in some instances approaching a condition where dendrochronology would no longer be possible. We can use the new data to review the previous work and suggest some approaches to future analysis on the site. It is not clear whether there will be any further systematic excavations on the site.

One notable feature of the site bar-diagram (Fig. 10) is that the three FFB21 alignment transects have provided very similar numbers of dated samples, 14, 14 and 11 respectively. There are very similar distributions of tree-ring data from each transect. FFB21 Tr. 4 provides the first major group of data from east of the platform, and it is slightly shorter as well as being less well replicated than FFB21 Tr. 2 and Tr. 3. This overall similarity might suggest that there is a relatively uniform survival of timbers of different periods along much the alignment. These excavations provide a baseline that suggests sampling further transects, of the same size, most likely will yield similar numbers of datable timbers. The excavations around the platform, FFB21 Tr. 5 and Tr 6, have yielded much less timber.

A characteristic of each transect, and also from each of the previously excavated areas is that the dates of the bark-edges, and the dates of the samples with some sapwood are all different. Both types of survival yield dates of some interpretable value in the context of the alignment. However, at present these mostly appear to be randomly distributed across the centuries. The FFB21 sequences include one datable sample with bark-edge, sample 337 from Tr. 3 which was felled in winter 1031 BC. The earlier analyses identified no bark-edge dates from the western, Fengate, end, and just 10 from the various interventions along the alignment and the platform area. None of these felling events are found in more than a single sample (contrasting with both multi-phase Fiskerton, and single phase Must Farm where multiple samples have been identified for each felling event). The present pattern may suggest this is a multi-phase structure with innumerable repairs or additions. However, the almost complete absence of bark-edge and sapwood bearing samples may be hiding any evidence for periodic activity.

FFB21 Tr. 2, Tr. 3 and Tr. 4 were 1.4m wide transects. If they are representative of the tree-ring data recoverable from the rest of the alignment then each 100m of alignment is likely to include *c.* 1500 timbers suitable for analysis, with *c.* 1000 of those likely to yield dates. The present Basin chronology is already sufficiently strong for most dendrochronological purposes. Opportunities to extend the sequence backwards or forwards appear to be small. If there is a hiatus between Flag Fen and the Must Farm pile dwelling, then only samples with sapwood from the latest phases of Flag Fen activity have any potential to cross the gap present in the local data set. Focussing any future analyses on samples with sapwood and bark potentially provides a more targeted opportunity for aiding the archaeological interpretation of the Flag Fen monument, and it could also potentially narrow the gap to Must Farm. If FFB21 Tr. 2, Tr. 3 and Tr. 4 are representative of the wider monument this would perhaps limit analysis to *c.* 25–50 samples per 100m of alignment. Rapid on-site assessment of timbers using the working practises at CAU have proven capable of dealing with large numbers of timbers at the various Basin excavations. The Flag Fen 'platform' area may be markedly different in character, though the earlier work from Area 6 suggests that the same approach could be taken here too. Because of its heavily degraded condition the material from the site is perhaps not really suitable for use in training, on the other hand anybody that could be taught to analyse this material would be well suited to handle almost any other archaeological assemblage.

The earlier work had focussed on material with 50 or more rings, with only a handful of samples with 40–50 rings analysed. Using the shorter material from FFB21 has not identified any previously unknown phases of activity. None of the new sequences assists with dating any earlier undated sequences, and none of the new material advances the Basin chronologies any closer towards the date of the Must Farm pile dwelling.

The 1999 report divided the then available dendrochronological data into horizontal and vertical elements, and also divided them into the different post rows. Here we will present a slightly different way of looking at the bulk data, dividing it into four linear groupings or zones along the alignment. This is made possible by FFB21 Tr. 4, the first reasonably large group of samples analysed from east of the platform. We can also now use the Must Farm and Horsey Bridge material, both excavated long after 1999, as comparators for the Flag Fen material. Figure 12 uses the histograms of the replication data from the various composite chronologies. Histograms are another way of looking at a sites bar diagram, they occasionally reveal subtleties that are not evident from inspection of the bar diagram itself. The histogram for an assemblage of data is produced by adding up how many individual timbers are present for each year of data. Each single sample has a weighting of one for each ring in it, where there are two samples that have the same year in them the composite sequence has a histogram value of two for that year, where 100 samples have

the same tree-ring in them the histogram value is 100 for that year. The end result is that each composite sequence can be weighted by the number of components for each ring.

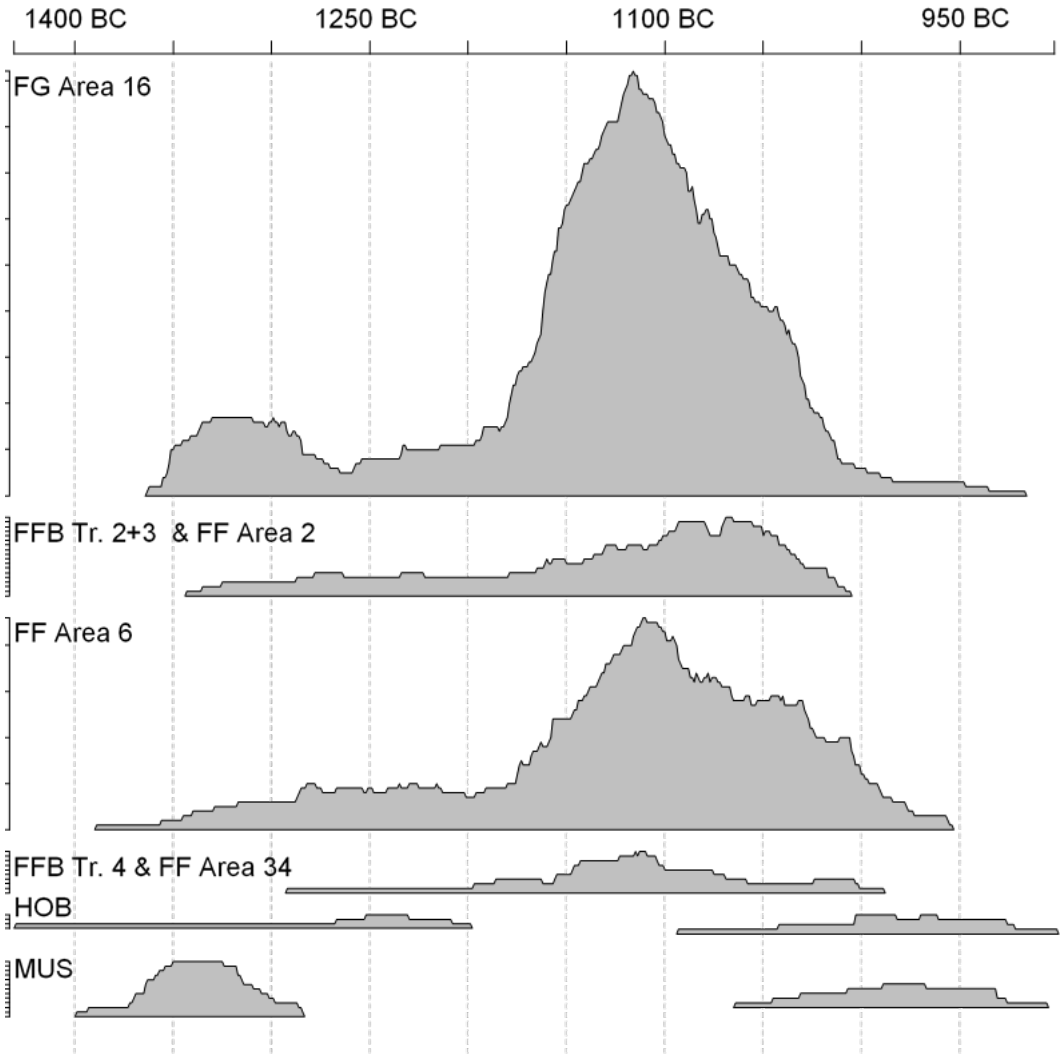

Figure 12: Diagram illustrating the histograms of data replication for the chronologies from the Flag Fen alignment. The upper four histograms are in west to east order across the alignment. HOB and MUS are the Horsey Bridge and Must Farm histograms for comparison.

There is no straightforward connection between these data weightings and actual archaeological events for a multi-phase, multi-period dataset, with poor sapwood survival, like those derived from the Flag Fen alignment. For most well replicated data sets the histograms have a variety of shapes; lumps, peaks, troughs, plateaus and cliff-faces. Figure 13 illustrates a typical single-phase histogram where bark-edge survival is good, the Must Farm pile-dwelling has a plateau and a single very precipitous cliff-face. The histogram from Fiskerton is typical of a multi-phase structure, it has a peak followed by a series of smaller cliff-faces with steps between. There are a lot of caveats to the use of these diagrams in an interpretative way. There will be numerous non-random events

affecting the taphonomy and survival of the timbers on these sites, there will be events that have left no archaeological traces, and timber usages that have left no traces in the dendrochronological data. For a site like Flag Fen where only the hardiest of materials, oak heartwood, is surviving at all there must be many of the less hardy wood types that have entirely disappeared. The general absence of sapwood tells us that timber survival is not complete across the monument. It is equally important to recognise that there will have been differences in the age distribution of the trees that were exploited for different parts of its construction. The surrounding woodland will have been non-uniform and selecting materials from these will affect the weighting diagrams even for contemporaneous events at different parts of the alignment. Nevertheless, comparing like-for-like histograms of the weightings from four different zones of the alignment suggests some systematic differences in the timber assemblages recovered along the length of the alignment. Similarly, it is very clear that there are profound differences between the assemblages recovered along the alignment and those from the nearby structures at Must Farm and Horsey Bridge. For Figure 12 the Fengate/Area 16 material is the single composite previously mentioned, FG139. Combining FFB21 Tr. 2 and Tr. 3 with two earlier samples from Area 2, which lies between them, provides a data set from halfway between Fengate and the platform. Removing Area's 2, 4 and 13 from the FF91 composite, leaves just Area 6 data, which is the major assemblage from the platform. Combining the single Area 34/*Time Team* sample with FFB21 Tr. 4, which is nearly adjacent, provides a data set from east of the platform. Eight series from Flag Fen Areas 4 and 13, the short and later outlier from FFB21 Tr. 2, sample 0216, the single timber from FFB21 Tr.6, sample 0697, and the single timber from Pode Hole are the only Flag Fen Basin data not included in this diagram. The chronological positions of some of these can be seen in Figure 10. The earlier data has 'same trees' combined into single series, adding these as separate series would subtly change these histograms, but not change their overall shapes. The four Flag Fen zonal histograms are placed in order with the westernmost at the top to easternmost at the bottom. The Horsey Bridge and Must Farm datasets are both in two sections, these sites are *c*. 2.8km south and *c*. 2.3km south-east of Flag Fen respectively on the edge of the same mere, both these sites have timbers with better preservation than Flag Fen.

These four combined zones of Area 16, Tr.2–3, Area 6 and Tr.4 for Fengate, Flag Fen, and FFB21 have peak replication of recovered and datable tree-ring data in the decades either side of 1100 BC, three of those groupings peak at 1119–1115 BC, 1113–1105 BC and 1124–1106 BC, whilst Tr. 2–3 peaks slightly later than the others, at 1070–1067 BC.

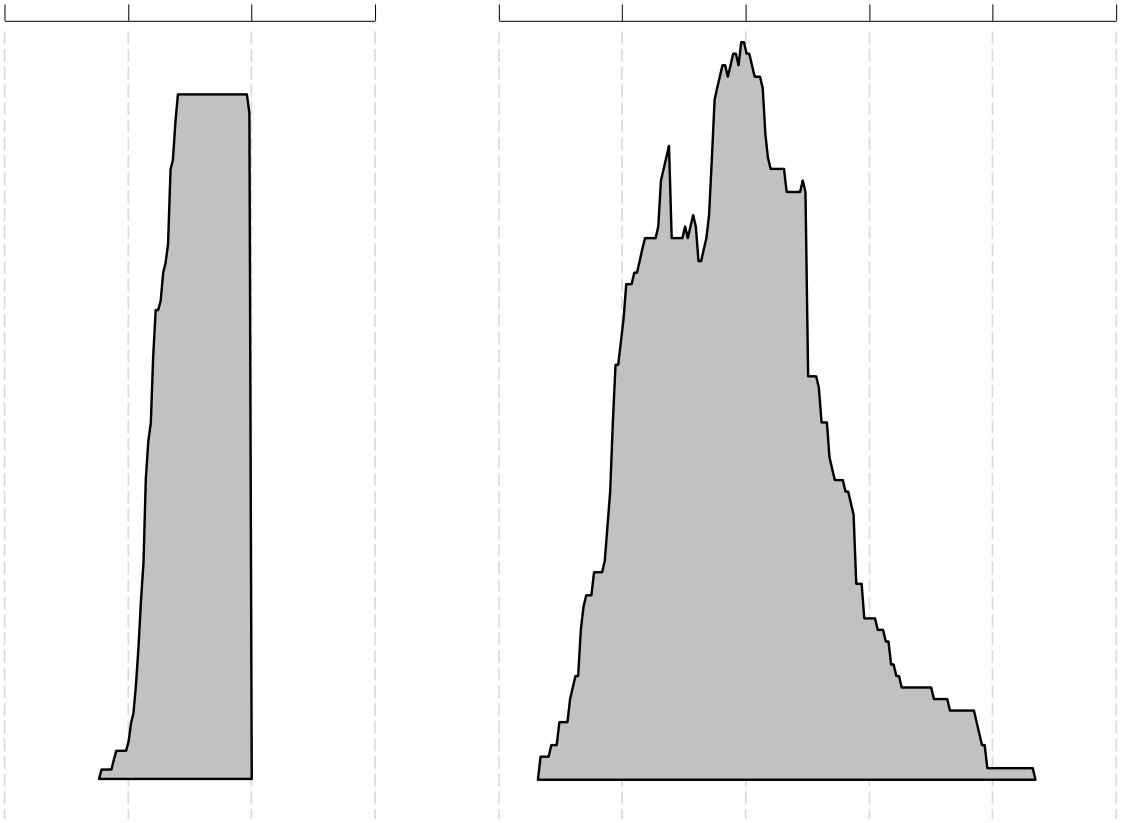

Figure 13: Diagram illustrating the kind of histogram shapes that should be produced by either a one-phase structure or a structure with a series of major felling events. Left; Must Farm late Bronze Age pile-dwelling, single phase, an undated 60-year sequence of 73 oak and ash samples. Right; Fiskerton Iron-Age structure with intermittent construction events, a dated 185-year sequence of 85 oak samples. Horizontal scaling the same as Figure 12, but neither are using absolute dates. Both sites have abundant bark-edge survival and the longer vertical drops on the right-hand side of each histogram identify the construction event at Must Farm, and several construction events at Fiskerton. Flag Fen is clearly not a single phase structure, if 50–100 bark-edge samples could be obtained and dated from the Flag Fen alignment it may begin to identify whether it also has intermittent irregular multi-phase construction events, like Fiskerton, or if it instead represents a type of continuously amended structure.

All four of these zones have long tails both backwards and forwards, where the data replication falls away until these composite tree-ring sequences end. These tails also appear to have patterns within them. For example, both Area 16 and Area 6 appear to have a shoulder on the right flank of their peaks, this may potentially indicate a drop off in the rate of deposition of datable timbers around 1000 BC. This pattern is not obvious in the other two zones, but since they are much less replicated it is perhaps not yet visible.

There is a lump of data at the oldest/left end of the Area 16 data set, i.e. the Fengate/western extreme end of the alignment. This lump has a broad plateau of tree-rings covering 1336–1294 BC. Inspection of the 1999 bar diagrams suggests this is a group of 15 trees in 17 vertical piles, with Y1007 ending at 1311 BC, through to Y0119

ending at 1267 BC. Y0138 is the only one with any sapwood, ending at 1294 BC. This group looks like it may be a mid-thirteenth century BC pile structure. If they represent a single phase, they potentially were all felled between *c.* 1255 and 1245 BC. If the location records survive, and if they have been digitised, it ought to be possible to pull this group out on a GIS diagram. There is no similar early group present in the data from the other three zones of the alignment. There is a very similar early group produced by material from a causeway that underlies the pile dwelling at Must Farm, it has a plateau 1361–1325 BC, which might suggest the Must Farm causeway is slightly earlier than the feature at Fengate.

Returning to the zonal histograms, their long level sections between *c.* 1300 and *c.* 1200 BC from all four zones along the alignment could imply little activity across the site from the mid-thirteenth through to the mid twelfth century. Alternatively, it may indicate that the activity during this period did not involve inserting large oak timbers into the structure, or that this activity was not at levels where they have survived. The steep rises from these to their peaks were potentially periods of similar or little activity, as these tree-rings are mostly the inner rings of the larger trees used from *c.* 1100 BC onwards.

Another tentative suggestion derived from these diagrams is whether there may be an east-west trend in latest rings along the alignment. This pattern may be due to less replication in some areas, but the latest rings currently from the western end are more than half a century later than the latest rings from the eastern end. Fengate/Area 16 ends at 918 BC, FFB21 Tr.2–3 ends at 938 BC (this from the outlier late timber from Tr. 2 not on Fig. 12, but seen in Fig. 11), the platform/Area 6 ends at 955 BC, and FFB21 Tr. 4 ends at 990 BC.

The replication strength of the Flag Fen data at this point ensures most decent samples from this period recovered from the vicinity would include datable sequences. This allows us to compare Flag Fen with sites from the immediate area. We have already noted the early group within the Fengate material and its similarity to the early causeway underlying Must Farm. Comparing the rest of Flag Fen histograms with those from Horsey Bridge and Must Farm it is evident that neither Horsey Bridge nor Must Farm have any tree-ring data from 1200–1100 BC, which is the peak period for data along most of the Flag Fen alignment. Whilst there may be activity on both sites, of course, it evidently does not involve datable oak timbers ending up in preserved locations. Both sites contain much smaller assemblages but they both produced later tree-rings than any so far recovered from the Flag Fen alignment, 902 BC from Horsey, and 907 BC from Must, compared to 918 BC from Fengate/Area 16. This may be due to better sapwood and outer heartwood survival, but it may indicate later structural activity is happening off the alignment rather

than on it. The same thing occurs at the older end, with a single long-lived tree from Horsey extending several decades beyond the oldest data recovered from the Flag Fen platform.

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Appendix 1: Data of Measured Samples

Measurements in 0.01mm units

Flag Fen FFB21 WD13 TR2

91	94	139	124	139	118	132	121	105	108
138	104	78	55	88	106	101	95	88	71
70	79	93	97	92	63	67	78	87	80
87	98	84	83	94	90	84	110	113	99
98	91	108	86	102	103	110	104	71	104
90	91	89	114	89	78	106	78	82	85
115	111	109	95	97	74	86	86	90	105
90	79	64	79	81	94	86	94	99	77
90	81	85							

Flag Fen FFB21 WD15 TR2

146	150	177	233	311	231	215	196	212	177
140	211	193	253	301	268	282	293	369	270
276	252	312	325	213	224	225	250	323	166
200	194	222	281	150	240	233	305	323	274
325	299	125	192	172	281	349	249	343	153
184	182	196	194	250	299	245	184		

Flag Fen FFB21 WD25 TR2

154	179	172	159	166	260	135	108	107	89
93	147	133	165	199	301	275	224	226	173
140	132	159	163	176	199	152	203	183	202
241	188	153	191	207	171	164	123	134	230
97	78	75	118	133	214	172	182	162	118
93	116								

Flag Fen FFB21 WD41 TR2

95	70	83	67	48	48	91	169	107	105
68	67	60	44	68	241	121	79	89	68
89	157	174	171	131	167	99	81	116	85
104	110	66	77	70	143	197	201	131	101
116	118	103	78	117	167	155	157	120	145

Flag Fen FFB21 WD45 TR2

102	119	104	133	100	99	137	104	131	124
96	95	52	39	34	42	44	36	39	41
39	47	43	47	31	42	34	35	24	39
48	37	38	45	36	44	33	31	34	29
29	30	40	46	52	59	74	56	64	61
59	63	75	39	77	130	110	100	76	96
76	110	110	86	68	84	105	100	90	106
100	141	147	127	103	105				

Flag Fen FFB21 WD46 TR2

81	123	116	81	130	84	70	122	102	117
95	88	95	70	76	124	109	92	52	103
148	129	83	103	84	74	56	93	80	78
81	103	59	50	52	66	53	74	74	86
85	93	75	92	79	73	83	91	82	77
76	76	96	71	81	95	90	118	108	

Flag Fen FFB21 WD59 TR2

240	192	108	97	144	143	170	154	108	122
150	169	194	198	167	228	181	136	147	140
165	140	113	99	146	135	179	210	214	204
169	167	164	175	231	192	159	162	169	165
158	184	161	140	197	198	198	184	181	161
162									

Flag Fen FFB21 WD67 TR2

82	62	63	71	79	77	75	84	60	59
74	67	62	60	67	60	74	65	51	67
71	52	59	74	50	62	68	60	63	70
59	63	69	59	58	59	72	68	45	50
55	62	64	71	51	57	62			

Flag Fen FFB21 WD76 TR2

100	47	61	105	108	98	68	110	125	128
78	178	211	241	283	319	318	267	254	252
349	381	329	276	234	297	376	462	307	297
406	417	245	441	403	447	342	360	340	241
276	431	351	288	232	328	330	263	568	457
297	462	506							

Flag Fen FFB21 WD79 TR2

73	89	112	115	123	104	104	94	82	100
132	126	113	85	64	89	65	69	60	107
132	160	90	117	59	75	78	96	111	101
64	65	77	109	75	96	71	112	126	111
71	148	119	118	167	152	104	157	101	124
155	161	95	139	159	150	115	124	123	117
132	158	120	151	168	219	147	131	112	131
167	181	184	99	133	126	131	155	164	128
100	167	189	225	139	176	158	131	176	204
225	187	128	92	120	110	134	99	100	91
90	117	113	148	116	107	123	109	119	106
87	130	136	119	141	120	121	133	127	118
184	220	146	155	136	127	112	98		

Flag Fen FFB21 WD81 TR2

71	64	99	75	96	90	91	96	74	77
78	89	65	43	52	39	60	64	82	49
44	73	45	54	84	72	85	73	65	56
46	60	93	79	71	34	63	83	90	60
83	52	56	35	71	70	74	48	63	49
43	38	61	41	56	74	67	70	59	57
75	62	62	51	68	47	61	43	63	64
59	76	75	75	105	81	81	69	68	65
68	80	107	77	96	103	71	67	75	78
83	91	111	97	72	92	108	85	90	63
66	79	82	93	66	72	74	76	86	90

Flag Fen FFB21 WD92 TR2

151	135	180	208	270	300	220	299	294	372
229	298	433	413	647	558	598	599	680	524
448	672	419							

Flag Fen FFB21 WD93 TR2

202	199	170	112	213	149	156	164	201	251
297	130	102	104	113	151	161	245	196	309
339	450	363	482	242	186	240	276	234	205
209	158	216	187	514	446				

Flag Fen FFB21 WD106 TR2

123	101	154	127	97	199	103	161	250	179
146	167	180	198	176	145	151	177	83	147
165	164	166	140	137	119	264	284	236	167
123	202	167	177	211	175	235	198	199	260
227	238	183	177	181	254	216	170	334	339
304	291								

Flag Fen FFB21 WD113 TR2

105	136	103	86	76	60	111	136	89	97
104	94	74	124	96	116	83	98	96	82
85	94	87	58	68	111	128	106	113	111
69	46	52	81	98	105	86	90	88	88
108	106	64	56	54	59	53	52	50	62
56	40	46	56	73	79	70	59	83	87
54	57	54	90	90	63	47	44	42	46
41	39	37	52	61	62	63	58	55	69
61	83	84	69	110	96	94	72	105	103
112	146	144	109	156	119	128	129	147	144
165	132	97	134	184	170	193	212	142	164
128	122	83							

Flag Fen FFB21 WD145 TR2

93	178	160	214	178	156	210	172	153	145
228	173	223	184	145	168	203	305	275	180
274	347	196	298	402	535	365	293	337	196
305	388	400	306	206	288	235	230	487	452
314	433	493	239	261	457	460	738	773	775
562	347								

Flag Fen FFB21 WD216 TR2

248	267	232	493	367	155	150	272	237	163
226	157	141	240	159	172	149	96	106	93
79	82	91	105	136	88	127	180	225	144
146	127	111							

Flag Fen FFB21 WD272 TR2

30	64	43	65	61	74	62	73	60	54
107	161	109	113	95	100	109	133	143	153
125	107	89	121	155	157	198	112	127	132
158	116	96	146	168	146	206	142	78	78
94	61	55	56						

Flag Fen FFB21 WD297 TR2

99	90	287	207	272	135	229	295	56	144
237	165	107	97	156	156	175	98	148	139
130	131	74	67	64	81	113	175	113	57
134	78	66	139	103	139	123	62	71	86
159	73	112	127	114	147	83	161	135	130
102	68	101	84	105	99	113	119	139	159
141	209	108	174	91	113	194	180	230	161
140	142								

Flag Fen FFB21 WD299 TR2

171	179	204	149	79	86	74	105	68	141
109	174	142	156	189	137	103	115	122	187
153	216	168	241	194	183	103	209	176	177

Flag Fen FFB21 WD325 TR3

72	135	135	158	162	177	139	133	134	130
119	139	164	151	75	110	238	141	125	177
230	259	222	350	250	198	150	248	294	276
224	265	358	321	257	301	168	139	168	278
207	166	132	139	151	188	112	171	125	173
283	283	265	233	323	356	353	155	173	

Flag Fen FFB21 WD326 TR3

47	54	57	64	54	48	102	46	60	44
55	55	43	52	85	94	91	67	61	42
62	45	48	51	52	61	73	99	65	80
65	51	101	148	179	198	172	253	237	160
178	180	250	221	254	195	264	221	160	149

Flag Fen FFB21 WD327 TR3

183	94	164	206	138	167	170	155	151	149
145	134	183	229	227	195	158	191	125	192
180	150	125	99	179	171	166	189	180	181
152	165	180	182	270	213	232	215	253	234
276	302	193	212	319	304	303	341	217	203
256	255	271	202	279	258	244	311		

Flag Fen FFB21 WD330 TR3

212	248	310	334	194	228	169	220	224	165
108	91	97	107	166	193	145	110	149	113
149	130	112	142	165	233	229	217	124	155
139	60	57	62	47	55	51	100	108	123
107	102	71	80	121	136	76	71	53	54
46	70	58	63	41	50	69	46	67	57
52	35	33	59	49	54	63	42	38	36
31	34	39	41	46	41	41	46	54	70
50	70	75	78	50	47	56	61	62	53
51	49	60	117	129	64	46	58	55	49
45	52	59	111	112	96	151	135	106	96
110	149	117	101	94	225	220	105	98	84
115	155								

Flag Fen FFB21 WD331 TR3

98	36	78	59	41	46	101	119	120	112
91	62	97	121	129	129	73	48	73	42
53	44	36	63	54	67	110	75	46	49
70	45	58	65	85	59	76	45	54	141
47	71	47	61	88	54	90	156	149	131
67	44	61	143	66	120	68	112	166	214
239	124	100	152	115					

Flag Fen FFB21 WD333 TR3

383	756	650	707	592	504	466	414	478	584
417	491	522	560	519	421	452	542	273	325
231	194	414	263						

Flag Fen FFB21 WD334 TR3

265	238	378	287	176	241	267	156	105	85
152	96	206	263	288	286	191	294	318	171
230	262	248	152	191	137	146	183	105	72
73	64	77	100	156	98	113	137	110	172
131	109	172	166	244	237	241	148	195	131
78	67	70	62	76	90	83	101	108	90
75	78	118							

Flag Fen FFB21 WD337 TR3

253	273	254	273	159	143	209	188	246	349
374	275	376	363	373	384	441	418	431	468
478	317	271	286	304	285	317	321	299	335
398	357	317	372	317	261	325	314	249	270

Flag Fen FFB21 WD340 TR3

131	118	104	79	94	91	106	97	88	125
142	178	150	128	127	118	119	141	130	108
105	119	108	105	129	136	147	157	196	157
117	132	98	92	113	117	139	154	99	98
113	114	141	141						

Flag Fen FFB21 WD341 TR3

97	192	106	122	201	132	224	171	186	181
227	137	93	145	244	291	284	197	182	246
107	127	188	204	270	145	149	249	237	334
252	283	409	462	366	346	315	354	245	189
227	128	145	153	198	208	193	193	175	131
130	168	193	153	168	130	174	199	199	113
156	99	114	69						

Flag Fen FFB21 WD342 TR3

320	300	254	220	256	426	345	187	162	85
155	241	204	144	170	99	114	164	205	104
146	62	68	129	135	135	64	86	46	77
105	107	188	112	140	112	78	166	134	125
53	93	53	133	112	60	102	42	95	82
111	126	112	68	70	54	116	91	85	57
31	48	44	45	67	59	70	66	72	67
70	58	56	49	57	97	85	83	54	87
57	36	81	79	121	71	56	48	98	71
80	53	71	56	63	48	31	70	53	42
68	94	99	52	47	44	47	59	88	34
43	70	67	57	54	64	65	60	79	81
50	62	83	72	77	74	67	59	62	86
63	45	73	66	59	36	65	64	38	61
52	94	81	82	84	81	50	59	58	61
99	60	72	72	44	54	77	32	74	82
83	41	49	51	51	58				

Flag Fen FFB21 WD343 TR3

129	136	123	104	168	129	138	202	177	150
161	173	197	150	133	145	185	133	187	233
218	156	138	155	91	138	165	140	119	116
116	132	133	108	123	151	217	208	176	136
183	139	210	204	199	146	107	252	180	193
215	178	237	164	233	261	220	334	280	269
249	273	280	361	354	207	239	294	296	280
343	237	203	215	225	219	198	258	270	249
275	210	179	190	168					

Flag Fen FFB21 WD346 TR3

130	191	69	141	108	97	72	72	68	100
176	173	212	206	227	182	111	78	56	146
174	122	138	251	252	255	273	354	257	244
270	240								

Flag Fen FFB21 WD348 TR3

129	118	108	131	86	92	77	87	140	86
104	109	114	84	95	86	94	113	95	89
93	73	89	73	60	56	83	95	80	57
72	62	53	64	62	75	67	46	53	46
54	44	59	43	40	40	38	39	48	46
57	65								

Flag Fen FFB21 WD359 TR3

119	138	92	92	71	87	137	164	107	150
165	161	122	114	116	90	68	117	95	97
158	122	108	90	84	76	115	123	136	99
60	53	81	74	88	113	64	58	142	182
135	133	129	72	155	196	163	144	119	106
143	86	116	107	145	72	84	97	78	87
86	133	110	133	85	66	51	63	75	64
68	65	71	63	68	123	137	119	125	107
99	81	75	64	60	77	101	103	107	88
55	81	97	84	88	70	66	54	51	81
76	73	76	93	136	74	62	66	67	59
70	89	53	85	83	67	83	152	76	128
96	75	67	62	59	88	57	60	86	69
91	61	62	56	68	68	46	63	57	62
57	48	81	68	55	63	51	55	74	76
67	68	73	59	49	67	79	68	40	51
69	53	52	65	76	61	49	60	67	45
50	39	45	48	59	51	50	52	67	42
33	42	50	38	34	37	35	39	61	79
85	122								

Flag Fen FFB21 WD363 TR3

200 164 227 211 164 137 153 137 187 156
257 196 102 133 185 132 154 116 180 192
143 188 173 184 154 140 190 102 205 153
123

Flag Fen FFB21 WD375 TR3

71 54 53 65 62 59 66 49 72 49
55 50 61 64 61 56 48 61 66 66
64 59 55 49 52 59 57 56 62 68
60 75 57 44 49 40 37 50 55 56
60 57 64 50 52 46 46 62 47 47
66 74 43 49 49 56 60 46 51 43
45 41 57 61 63 49 67 50 46 64
84 76 65 78 89 65 83 73 61 57
65 68 66 69 84 92 98 94 84 65
62 80 75 62 87 90 73 95 91 89
83 73 96 99 87 99 85 100 81 76
61 59 87 88 105 106 81 85 83 73
84 86 105 82 80 67 84 71 79 91
123 118 97 101 75 75 71 49 77 88
110 94 67 72 59 62 64 73 77 101
83 97 78 78 66 68 62 53 50 61
54 61 65

Flag Fen FFB21 WD381 tr4

163 89 172 147 98 141 226 207 177 219
239 229 186 200 212 130 154 157 252 250
222 151 179 217 144 130 80 75 141 92
93 171 126 128 150 153 317 338 386 327
249 220 260 255 309 339 276 283 391 409
269 191 238 245

Flag Fen FFB21 WD382 TR3

330 229 265 312 323 287 228 282 313 260
164 155 140 163 172 180 160 215 164 138
168 231 196 165 223 206 189 183 154 201
209 195 192 188 113 114 102 113 215 174
125 166 117 119 202 187 172 214 192 153
167 145 196 164 137 173 237 329 245 185
222 134 131 129 120 137 192 135 99 86
95 119 167 148 164 336 199 186 240 293
315 168 167

Flag Fen FFB21 WD384 TR4

219	285	330	309	234	231	285	231	265	174
221	238	227	309	226	253	257	220	249	239
236	246	233	235	187	129	94	76	88	72
82	117	202	192	153	201	149	181	214	235
206	233	143	94	120	137				

Flag Fen FFB21 WD387 TR4

394	378	292	265	290	196	211	192	221	235
233	205	204	186	139	141	143	105	74	116
95	96	132	164	121	123	102	90	103	161
137	176	143	153	180	209	168	220	216	201
157	287	416							

Flag Fen FFB21 WD390 TR4

465	439	397	445	359	227	293	334	331	356
310	375	327	294	303	296	241	267	323	394
324	379	292	244	338	230	160	73	111	109
102	137	139	299	194	195	169	114	97	128
196	112	139	135	71	86	66	115	151	91
50	175	207	160	117	184	129	89	107	191
171	163	119	102	125	178	182	260	181	276
331	195	273	335	307	378	224	325	257	280
172									

Flag Fen FFB21 WD393 TR4

157	186	209	121	83	86	99	114	74	56
90	61	111	122	69	87	123	118	93	66
61	48	104	61	59	75	58	40	35	31
124	69	31	32	47	63	84	87	66	48
120	159	227	238	201	203	231	219	201	202
228	249	225	194	199	261	216	236		

Flag Fen FFB21 WD394 TR4

272	167	211	322	427	287	533	410	210	188
166	113	86	113	135	115	105	131	115	101
113	80	134	101	75	68	42	40	55	56
43	36	39	119	213	187	238	225	187	196
394	321	562	226	160	255	375	243	411	374
314	351	256	346	198	414				

Flag Fen FFB21 WD395 TR4

143	125	110	92	74	75	84	92	106	99
121	86	101	91	114	158	218	214	241	177
208	149	134	140	194	222	177	182	305	445
349	263	276	246	147	172	208	198		

Flag Fen FFB21 WD397 TR4

279 247 215 138 147 144 163 192 252 253
202 127 131 208 173 169 218 171 117 123
85 82 75 69 110 121 95 63 105 49
134 99 84 94 88

Flag Fen FFB21 WD399 TR4

258 317 279 119 103 104 162 164 168 186
180 267 257 234 282 147 200 184 224 175
183 165 167 102 74 92 108 110 117 188
168 158 144 130 142 110 70 98 102 105
103 75 88 59 97 75 53 108 145 191
111 82 132 92 97 71 124 250 176 228
203 210 192 153 171 346 286

Flag Fen FFB21 WD400 TR4

346 400 280 370 496 299 440 240 317 521
255 399 362 345 329 315 327 193 148 98
109 263 299 291 244 157 97 95 63 104
163 219 169 94 114 67 74 58 53 46
40 35 33 32 30 35 37 38 27 37
30 31 36 40 46 48 44 75 87 136
79 52 62 44 54 77 54 52 36 30
38 35 37 37 39 44 41

Flag Fen FFB21 WD402 TR4

215 119 144 240 177 84 122 98 68 108
105 249 287 208 160 118 209 260 212 132
194 294 236 190 265 227 302 302 102 66
71 88 129 142 256 264 184 83 184 164
179 255 272 276 162 182 219 87 186 179
280 249 219 90 117 78 54 45 43 54

Flag Fen FFB21 WD404 TR4

561 562 566 608 544 537 462 348 359 310
216 205 158 205 184 185 143 200 112 190
192 204 211 238 233 242 164 244 256 224
177 141 138 213 171 129 112 188 199 195
137 175 72 81 94 90 128 123 126 136
114 123 144 92 102 98 133 95 63 54
44 39 57 80 81 93 100 46 44 72
83 103 68 69 46 63 39 57 73 55
48 40 65 61 58 56

Flag Fen FFB21 WD406 TR4

124 122 152 127 77 89 66 59 96 143
258 206 241 307 146 256 301 390 419 400
460 416 617

Flag Fen FFB21 WD408 TR4

612	551	513	317	396	398	400	298	376	341
383	292	267	348	287	331	314	329	283	420
350	255	194	449	280	346	264	237	217	263
208	159	165	238						

Flag Fen FFB21 WD411 TR4

77	56	87	84	136	117	96	66	162	133
83	109	199	118	69	66	98	80	116	68
67	82	108	69	82	74	79	86	67	55
67	42	83	55	62	55	50	60	78	65
79	52	50	71	60	88	96	75	71	64
80	82	86	152	231	235	157	254	221	228
318	228	239	238	294	202	125	288	245	201
213	133	200	112	156	210	128	168	98	137
164	213	211	218	154	152	134	150	163	132
210	133	159	133	144	102	113	232	211	197
239	151	93	116	125	128	219	176	152	158

Flag Fen FFB21 WD412 TR4

72	82	94	74	67	71	91	73	51	48
78	84	64	61	65	61	46	44	73	68
95	59	53	67	85	45	55	54	68	82
70	74	81	92	92	75	54	39	61	50
54	54	63	59	45	52	57	72	85	72
48	61	109	134	169	176	232	163	166	172
131	215	230	179	201	260	220	146	143	153
180	194	184	151	177	131	200	178	137	188
132	180	171	223	208	238	150	141	135	117
234	183	232	120	121	140	162	129	129	206
178	155	201	164	88	87	66	95	85	94
103	99	139	124						

Flag Fen FFB21 WD416 TR4

118	134	188	141	206	201	167	169	163	163
166	164	138	145	114	122	133	149	90	84
114	101	116	141	172	130	122	173	116	82
119	134	142	139	131	128	110	111	110	129
127	66	117							

Flag Fen FFB21 WD441 TR4

106	163	132	125	126	128	142	135	166	146
119	146	92	65	70	111	103	146	149	158
201	204	186	147	145	105	101	122	82	78
64	86	101	85	78	85				

Flag Fen FFB21 WD453 TR4

102	54	69	93	100	112	88	102	133	127
168	178	167	133	100	117	137	81	106	97
169	140	173	174	95	98	111	118	148	148
168	165	153	178	142	153	132	91	273	277
215	215	224	194	120	118	190	181	193	153
127	129	131	154	237	132	182	253	158	144
175	215	294	211	161	107	183	136	213	175
177	132	105	188	105	150	119	153	109	128
146	137	156	206	158					

Flag Fen FFB21 WD455 TR3

152	147	237	205	205	138	137	163	169	300
267	228	199	246	177	277	208	154	189	297
270	227	244	250	140	195	196	266	110	173
184	270	249	261	248	307				

Flag Fen FFB21 WD456 TR3

349	305	242	256	328	220	160	166	151	178
194	178	176	213	177	121	167	224	173	149
216	192	182	167	160	186	212	160	171	181
108	124	104							

Flag Fen FFB21 WD458 TR3

185	145	171	103	77	79	123	146	192	135
100	116	160	171	84	99	137	183	169	121
154	127	166	147	90	126	151	106	103	92
95	76	110	82	60	84	105	123	100	88
81	79	80	81	75	81	101	113	111	81
105	113	91	96	96	95	65	109	91	92
103	87	118	87	98	98	70	72	86	94

Flag Fen FFB21 WD459 TR3

136	163	133	153	103	79	82	122	106	93
90	133	138	125	119	90	86	79	97	115
126	120	136	109	128	112	103	136	102	115
152	157	154	153	153	154	128	119	98	132
122	173	169	142	182	136	109	148	152	162
166	127	121	171	203	161	161	172	175	169
178	170	173	183	198	169				

Flag Fen FFB21 WD604 TR2

51	55	54	56	49	41	40	57	70	52
53	90	84	101	92	83	86	71	73	56
67	58	55	55	57	49	59	62	46	43
42	47	54	45	49	58	38	35	27	30
37	61	54	69	57	55	63	58	66	58
66	100	76	65	150	63	43	44	39	36
36	29	43	45	43	29	25	21	22	24
30	33	38	43	46	40	36	32	32	37
44	42	56	41	37	38	41	47	45	41
34	35	30	27	40	52	43	37	75	49
58	78	44	73	62	38				

Flag Fen FFB21 WD676 TR2

148	219	268	307	233	258	354	522	606	550
552	696	842	663	190	206	234	208	247	259
295	317	74	102	386	438	209	142	287	78
146	250	248	92	237	247	332	419	80	65
152	240	107	113	177	78	94	97	185	72
121	112	144	147	173	54	90	125	170	290
90	100	162	72	92	206	96	76	128	122
54	66	108	199	199	42	56	69	102	97
57	89	103	53	112	128	139	167	170	164
195	138	135	151	151	180	252	225	158	

Flag Fen FFB21 WD690 TR4

400	234	274	135	137	241	320	261	224	302
254	337	346	354	496	493	510	326	255	463
399	570	653	551	642	576	566	631	414	566
262	478	397	118	81	131	231	234	308	192
77	83								

Flag Fen FFB21 WD694 TR2

172	220	219	261	256	167	279	243	290	238
253	236	305	241	193	270	290	220	226	260
377	182	164	220	145	161	128	85	101	110
145	141	111	145	168	129	126	121	180	117
58	78	116	104	95	124	87	88	109	126
88	88	113	78						

Flag Fen FFB21 WD697 TR6

114	80	177	282	279	287	235	140	135	239
193	228	199	95	145	187	178	127	143	159
172	222	232	199	202	202	224	158	112	170
172	153	245	230	233	213	183	229	212	150
303	212	155	181	215	160	195	208	242	226
304	300	196	199	142	124	214	237	212	196
159	185	185	215	213	201	159	199	199	169
110	158	146	199	159	256	205	230	153	125
169	215	247	194	251	155	142	191	155	103
159	185								

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