Kings Lynn to Wisbech Gas Pipeline

Geophysical Survey Result

Produced for Network Archaeology & Murphy Pipelines

KLW061

November 2006

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Mapping Our Heritage

Non-Technical Summary

Magnetic survey was commissioned to examine selected areas along the proposed pipeline corridor for evidence of structures of archaeological interest. The selection was made by Network Archaeology in consultation with the county archaeological curator and was based upon whether deep alluvial soils exist and the proximity of known monuments.

In the event the survey was less successful than it might have been due to the presence of soils unsuitable for magnetic survey within the specified areas. In addition some of the areas rejected may have produced useful data as classification of their soils as alluvium did not take into account their magnetic properties.

The overall quantity of archaeological features found during survey is low and comparable to the quantity identified during the desktop appraisal as definite former features. Most of these latter features have been identified, along with some additions, in the magnetic data.

Large sections of the survey traversed highly magnetic iron-rich sandy soils exhibiting strong magnetic fields of similar and greater strength to those from archaeological features. It must be expected that archaeological features may exist but have been masked by natural variations.

In general, the easternmost 3km section of the corridor has soils suitable for magnetic survey along with areas at the west end over clay. The data from the rest of the corridor is dominated by natural strong responses. These in many cases relate to local variations in the thickness of the soil, hydrochemical effects with respect to naturally-available iron and the presence or absence of palaeochannels and similar features.

The alluvial nature of some of these soils is not thought to be a significant factor in the low quantity of detected features; the presence of both strongly magnetic iron-rich soils and also areas of deep blanket peat has potentially had a greater effect.

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1 Introduction

General location

1.1 Six areas for survey were selected from the total corridor with the largest about 6km long east of Kings Lynn in Norfolk. The furthest area west was north and west of Wisbech in Cambridgeshire. Area, land parcel, RDX and IP numbering increment from east to west. Further lengths were added as changes to the route were required. The ends of the corridor are at NGR 54558, 31367 and 57238, 31637.

Survey areas

1.2 The six areas of survey are between the following IP and parcel numbers (as supplied by Murphy Pipelines):

Area	IP Range	Parcel Range	Maximum Length	Length Available	Selection Criteria
1	2 - ~29	3 – 37	9165m	4022m	General reconnaissance off deep alluvium
2	~26 - ~29	35 (within Area 1)			Adjacent to Blackborough Priory
3	W. of 55 – 56	76 – 78	1134m	1134m	Adjacent to site of DMV
4	73 – S. of 76	111 – 113	772m	388m	Roman pottery scatters and undated mound
5	77 – 79	118	578m	578m	Roman briquetage
6	79A – 79F	123 – 125	1251m	261m	Roman and Saxon pottery scatters, site of bomber plane crash nearby
7	91 – 93	131 – 134	693m	572m	Possible mediaeval settlement on route

1.3 Not all the corridor length was available for survey, as indicated in the above table. The reasons for this are threefold and are:

- The presence of standing crops
- Overgrown or otherwise inaccessible land
- Freshly ploughed fields across which magnetic survey was not feasible or likely to result in severely degraded data.

1.4 If land was cleared of longer undergrowth (i.e., anything above 0.3 – 0.4m) and ploughed and pressed and / or harrowed then further survey could be undertaken. It is inevitable that in autumn survey timing and speed will be heavily influenced by the agricultural regime of individual farmers, compounded in mixed arable areas like Norfolk.

Parties involved

1.5 Murphy Pipelines Ltd is undertaking the construction design of the pipeline on behalf of National Grid Plc with Network Archaeology managing the archaeological input into the Environmental Impact Assessment. ArchaeoPhysica Ltd were commissioned by Network Archaeology to undertake caesium vapour magnetic survey of all suitable parts of the preselected areas, these determined by Network Archaeology and the local county curators in advance of survey. Modifications to the route were made by Murphy Pipelines at various occasions through the fieldwork and these communicated directly to ArchaeoPhysica so that necessary changes could be made.

1.6 Survey grade GPS set out on behalf of ArchaeoPhysica was by Mercedes Planas. Magnetic survey was by Anne Roseveare and Britta Wiesker.

Summary of methodology

Theory and rationale

1.7 The rationale behind the use of caesium vapour technology for this project was to maximise the chances for the detection of archaeological features in alluvial soils that are traditionally described as less suitable for shallow magnetic survey. This is usually because the complexity of buried soils is substantially greater where there have been temporal variations in water content over a protracted period, e.g. within fenland. Substantial variations in the depth and thickness of deposits are common with silt-filled palaeochannels, solution hollows etc. often predominant in the results of any survey and each having different magnetic properties.

1.8 Caesium vapour technology is both more sensitive (by at least an order of magnitude) than traditional fluxgate instruments and exhibits a lower noise floor resulting in better resolution of weak anomalies. The use of non-gradiometric sensors (impossible with fluxgate magnetometers due to the measurement process) avoids the suppression of broad diffuse anomalies from deep sources. In practical terms this necessitates the use of total field instruments, principally caesium technology and hence the benefits are twofold.

1.9 By deployment of the instrument upon a special non-magnetic platform, usually wheeled, the distortions inherent to the surveyor's gait and body are minimised along with interference from batteries and the various sets of electronics.

1.10 The benefits of the technology in alluvial settings stem primarily from the increased sensitivity and the ability to image features at depths limited only by their susceptibility contrast. This is relevant as it is theoretically possible to have archaeological features at a wide range of depths depending on the local fluvial and alluvial history.

1.11 Not all anomalies in alluvial environments are weak; in fact many of the naturally-created anomalies are relatively strong and comparable in magnitude to those from archaeological sources. This can be a source of major ambiguity in gradiometer data where the full extent and form of the anomalies from natural sources is unlikely to be adequately visualised. The chemical mechanism that generates these two sources of anomaly is currently not well known except that it is most effective where there are cycles of wetting and drying of particular marsh or fenland soils. Where silt particles that have been subject to this alteration are free to migrate in water they can be distributed into negative features like channels, pits and ditches, leading to marked magnetic contrast between their fills and the surrounding material.

1.12 Cultural sources can also contribute through a secondary process known as the Le Bourgne effect which is due to cyclic heating and cooling of soils, often associated with hearths. Magnetic particles from these tend to accumulate throughout archaeological sites and allow them to become detectable with a magnetometer. In seasonal alluvial environments the additional method of locomotion provided by water augments this process of dispersal and can create significant magnetic enhancement of fills. Part of this process is the creation of strong magnetic fields through detrital remanent magnetism (DRM) as particles settling in water slowly align themselves with the magnetic field and create a localised strong magnet.

This project

1.13 With this project the situation was more complex, unfortunately rather more so than had been expected when the areas for survey were originally selected. The reasons for this are due to the exact nature of soils along the length of the pipe corridor and differences from the presumed model of alluvial sediments at the west end and chalk and glacial-derived materials at the east. There are two forms of wetland soil in the alluvial zone, one of which is true alluvium while the other is a marine clay and these behave differently within the Earth's magnetic field. The alluvium, as noted above, contains an abundance of magnetic materials at a range of depths and quite rightly the environment is regarded as difficult to survey. However, marine clays tend to be relatively uniform and therefore features cut into them with silt-rich fills are often easily detectable.

1.14 At the east end it had been presumed that the full 6km of length selected for survey would be more suitable for magnetic survey in the basis that it did not overlay alluvial deposits. Unfortunately half of this length included deposits of highly magnetic iron-rich soil which contribute extremely large natural variations of both sufficient amplitude and spatial variation to completely obscure and distort anomalies from archaeological sources. In addition, other areas of the same area of survey contained blanket bog with peat depths exceeding a metre.

1.15 The outcome is therefore not entirely what would have been hoped as there are areas of ambiguous results and in the case of peat bog, irrelevant data. Subjection of the data to advanced processing and gradiometric simulation did allow the areas over magnetic soil to be examined in detail but not to the extent that conclusive evidence of archaeological features was apparent.

Instruments & survey resolution

1.16 A Geometrics G858 MagMapper was used as a dual channel cart-mounted magnetometer with sensors fixed at approximately 0.3m height to provide measurements along two parallel tracks 1.0m apart. Coverage was total within each block of survey, either 30m or 45m wide.

1.17 Where intense magnetic contamination from adjacent power cables, steel pylons, pipes etc, e.g., in area 5, the instrument was used as a short (0.8m) vertical gradiometer to improve rejection of this contamination.

1.18 In all areas the data was examined in measured total field, residual component and pseudogradient form.

2 Geology

Overview

Solid and drift geology

2.1 The eastern end of the corridor lies on Lower Cretaceous Chalk with, apparently, a limited area of Upper Greensand. The chalk was thought to extend under the whole of area 1 and to increase the potential for good magnetic results relative to the deep alluvium further west, hence the allocation of this area for continuous survey. To some extent this seems to be correct although fluvial effects in non-alluvial soils (e.g., the Downham) had a far greater influence than in chalk-derived soils containing less iron and at a higher elevation.

2.2 Once the chalk has ceased to be close to the surface and therefore predominant in soil formation, drift geological materials and particularly alluvium predominate. For this reason the positive benefits of underlying chalk on environmental magnetic survey had ceased within 3km of the east end of the corridor.

2.3 Near Blackborough End a nearby outcrop of sandstone continues beneath the survey with extensive deposits of sandy ferruginous soils. This has resulted in a substantial change in the surface magnetics due to the fundamental change in rock type.

2.4 Most of the corridor and certainly all the length west of area 1 is dominated by alluvial deposits of sufficient depth to reduce the contribution of the solid geology to the magnetic field to an insignificant level within the bounds of this survey. There are localised variations between degrees of wetland which may reflect changes in the deeper geology, perhaps originally the sites of low islands.

2.5 The weathered sandstone deposits found beneath large areas of the western 3km of area 1 are highly magnetic due to the presence of large quantities of iron in the binder between the sand granules. This sort of soil equates with the Newport 2 or Downham type and is affected by variations in soil moisture, especially fluctuations in the height of the water table. The Downham soil type tends towards formation of an iron pan that itself is not particularly magnetic due to complete oxidation of the iron but less oxidised material does exist in the soil in the form of nodules of iron accumulated through water action.

Soil descriptions (from Written Scheme of Investigation)

- Isleham 2, eastern tip of project, deep permeable sandy soil with peaty subsoils
- Burlingham 1, near Middleton, deep coarse fine loamy soil
- Newport 2, between East Winch & Blackborough End, deep well drained often ferruginous
- Downham, near Blackborough End, deep permeable sandy and coarse loamy often ferruginous affected by ground water
- Wisbech Association, flank Great Ouse and Nene, deep stoneless calcareous coarse silty soil
- Wallasea 2 Association, around Wiggenhall, seep stoneless clayey with localised peat
- Blacktoft, east of Wisbech, West Walton, deep stoneless calcareous permeable coarse and fine silts

Soil magnetic character

Area	Division (parcel numbers)	'Background' magnetic character	Soils	Generic type	Potential for magnetic detection of archaeological features
1	6 – 10	Essentially non-magnetic soils characterised by even texture and lack of variation	Peat deposits over glacial gravel, possibly giving way to the east to soil type Isleham 2	Dry with localised fens	Very poor, assuming any exist within peat
1	10 – 15	Smoothly variable amplitude background lacking strong anomalies from fluvial or alluvial sources. The detection of individual cultivation furrows illustrates the relatively high natural susceptibility of the topsoil relative to the subsoil. Localised variations in topsoil depth create broad diffuse positive anomalies. Exhibits strong magnetic fields where deep in-filled features like glacial cracks exist	Mainly silt and gravel with silt-filled pockets in upper part of gravel. Probably corresponds to soil type Burlingham 1. Within parcel 15 there is a visible (magnetically) transition to the light sandy soil favoured by the soft fruit growers	Dry	Excellent – almost all negative features tend to produce positive anomalies and stony areas are usually visible to a total field magnetometer.
1	22 - 26	Large amplitude (+/- 50nT) anomalies with spreads of 25m or more from deep sources dominate the entire survey. Large quantities of equally magnetic but shallower sources are typical of material raked up by ploughing. These can have peak amplitudes of 70nT or more. Long linear anomalies mark areas of different hydrological properties. Typical of formerly widespread boggy ground	Iron-rich sand with some flint gravel, contains degraded sandstone and a variable depth cover of peat. This is most likely to be soil type Newport 2	Dry but with localised fens	Very poor as anomalies from archaeological features are distorted and masked by far larger natural variations

1	27 – 34	Very similar to the previous classification but lacking the smaller intense anomalies so overall dominated by high amplitude variations and smoother in appearance. The most intense variations are slightly more localised indicating similar localisation of hydrological variations. A fluctuating water table in the past is likely to have had a major effect upon soil magnetism	Marginal non-alluvial fenland soil, iron rich and with pronounced hydrologically-induced magnetic variations, most likely to be soil type Downham	Marginal	Very poor as anomalies from archaeological features are distorted and masked by far larger natural variations
2	34 – 37	Essentially non-magnetic soils characterised by even texture and lack of variation. Where these are thin there are broad subtle changes in magnetic field from strongly magnetic alluvial features beneath, variation often < 5nT across 100m	Deep peat deposits over non-alluvial marginal fenland soil, probably soil type Downham at depth but not clear. These fields are the transition from the dry ground to true fenland.	Fenland transition, wetter to west and south	Very poor, assuming any exist within peat
3	75 – 78	The superimposition and erosion of numerous magnetic silts leads to a continuum of highly variable magnetic field punctuated with sinuous linear anomalies where magnetic silts have collected in former stream channels. Overall variation is of the order of +/- 30nT	Classic deep alluvium with numerous former creek features and mottling typical of seasonal inundation in the past. This may be soil of the Wisbech Association type	Fenland, calcareous alluvium	Variable; features are usually detected but recognition can be difficult. Total field magnetic survey is an optimal technique
4	111 – 113	Fairly uniform magnetic field with broad weak anomalies from deep natural sources and variations in soil cover. Shallow sources visible as distinct enhancement of the field (< 10nT) but overall not a particularly magnetic environment	Deep loamy soil, not rich in iron, increasing clay towards west – not particularly alluvial in character, probably the Wallasea 2 Association	Marginal	Moderate, depends upon local conditions and the types of buried features.

5 & 6	118 - 124	Overall a uniform field with variation of less that 1nT in 100m where there is an absence of features. Silt-filled features, e.g., former channels produce anomalies of < 10nT but high contrast renders them obvious in the data.	Clay rich soil containing numerous former creek features with silt-rich fills. This would seem to be marine clay, probably originally tidal, hence the creeks. This is presumed to be of type Wallasea 2 Association	Fenland over marine sediments	Good but depends upon local conditions and the nature of the feature, i.e. silt rather than clay-filled. Small features not likely to be detectable
7	131 - 134	Classic alluvial mottling, +/ 5nT, from localised iron conversion in individual pools and sediments, some stronger variations where silts have concentrated in former channels (10nT)	Silty soil with some clay, less so than further east, has an abrupt change to alluvial silt beneath shallow peat in 134. Probably soil type Blacktoft	Fenland, calcareous alluvium	Variable; features are usually detected but recognition can be difficult. Total field magnetic survey is an optimal technique

Geological influence upon archaeological result

2.6 Looking at the overall result the geological situation is more variable than perhaps originally thought with peat cover in particular more extensive than identified in the WSI. In addition, the magnetic effect of the Newport 2 and Downham soil types had not been taken into account during the allocation of areas for survey, with the result that significant quantities of the surveyed area have unfortunately returned an ambiguous result.

2.7 At the same time, the identification of alluvial soils has apparently not differentiated between marine clays and alluvial sediment but they support magnetic enhancement through cultural and fluvial events in different ways. Area 5 for example, over marine deposits has clear examples of former channels and possible early drainage whereas area 7 over calcareous alluvium has produced a characteristically unclear result.

2.8 Magnetic survey of alluvium does often produce useful archaeological results provided the complex geochemistry of these soils is taken into account. Small features are not always reliably detected but where negative archaeological features are able to accumulate silt a significant anomaly often results.

2.9 It is difficult to recommend a revised survey strategy as ArchaeoPhysica was not party to the original consultation and decision-making process but it is clear that mixed alluvial and dryland environments like this need to be approached perhaps differently from projects in less extreme geological conditions.

3 Catalogue of results

Parcel	Survey	From IP	To IP	Spot Ref. X	Spot Ref. Y	Description
1	N	0	1	572064	316326	Road
2	N	0	2	572025	316356	Adjacent to gas station - interference from strong spurious magnetic fields
3	N	1	4	571903	316066	Field with troublesome stock
4	N	4	5	571761	315777	Disused railway
5	N	4	6	571674	315718	Under crop
6	N	5	6	571563	315606	Obstructed by plough and manure
7	N	5	7	571479	315537	Freshly ploughed - ground too soft and corrugated
8	N	6	8	571501	315432	Chicken runs
9	N	7	8	571441	315396	Road
10	Y	7	9	571402	315274	Area of non-magnetic peaty soil clearly defined at N end of field only, giving way to S to area of cultivation within former boundary ditches (46 to 48). Possible ditch (44) up to 2m wide near S boundary. Probable drain (45)
11	N	8	9	571358	315153	Track
12	Y	8	10	571349	315071	No significant features identified. Silty loam with flint gravel, soil deepens slightly to W end. Possible area of debris in the eastern end, probably adjacent to former stream channel. Field drains 35m apart (41 to 43) and modern cultivation evident
13	Y	10	11	571181	314935	Straight section ditch type feature (40) running parallel to current field boundary 80m from W. Second ditch type feature 14m from W, parallel to 1st. Frost crack runs across 1st ditch. Silty loam with flint gravel, soil depth above gravel variable
14	Y	11	12	570990	314799	No significant features identified. Silty loam with flint gravel. Faint linear natural features, silty pockets
15	Y	12	14	570688	314679	Towards western end change in soil characteristics, becoming sandier with silty pockets, those at (38) potentially man-made. Faint ditch fill or natural channel (39). Survey partly obstructed by sunflower crop
16	N	14	14A	570297	314598	Under crop
17	N	14	15	570460	314686	Track
18	N	15	16	570317	314759	Under crop
19	N	15	16	570166	314764	Road
20	N	16	17	570095	314841	Under crop
21	N	16	17	569971	314946	Under crop

22	Y	16	18	569731	314956	Iron rich soil with no peat, exhibiting strong alluvial character with typically large and diffuse magnetic anomalies. A magnetic matrix of sandy silt with sparse flint and broken sandstone, localised peat formation on top. Former valley of Nar River. Moat not definitely identifiable but likely candidate (36 & 37). No other significant features
23	N	17	18	569493	314903	Track
24	N	17	19	569359	314778	Rough ground after potato harvest
25	N	18	20	569163	314637	Woodland and scrub
26	Y	19 (& 18A)	20 (& 20A)	568993	314580	Field boundary in desktop not detected but possible curving ditch (35) amongst the natural anomalies. Thin curvilinear feature (33) possibly part of a ring ditch c. 20m diameter. Drain (32) detected on revised route. Highly magnetic soils continue west from parcel 22. Silty ferruginous, with strong pan & flint. No other significant features identified on either route
27	Y	19	21	568734	314500	Field boundary in desktop not detected. No other significant features identified. Soil shows classic magnetic alluvial character. Flint gravel in soil but no sandstone
28	Y	20	22	568488	314386	Field boundary in desktop not detected. Ditch fill detected (34) 2m wide, at an angle to existing boundaries
29	N	21	22	568389	314259	Under crop
30	N	21	24	568224	314122	Under crop and with overgrown areas
31	Y	23 & 20A	25	568071	314030	No significant features identified. Soil shows classic magnetic alluvial character below peat
32	Y	24	25	567924	313985	Field boundary not detected. No other significant features identified
33	N	24	25	567767	313977	Peat, uneven and soft. Partly waterlogged
34	Y	24	27	567626	313961	Field boundary in desktop detected (26 & 27) but no other significant features identified. Scatter of debris (28) may be due to maintaining the field entrance. Peaty soil
35	Y	26	28	567498	313910	No significant features identified. Two possible pit type features, though these may be natural (24 & 25). Peaty soil
36	N	27	28	567396	313928	Woodland. Area to south of wood surveyed
37	N	28	30	567179	313861	Large clumps of vegetation. Peaty soil
75	Y	54	55	560040	312556	Strong creek-type anomalies in deep alluvium. No significant features identified. Remains of ploughed-out boundary were visible on the surface. Heavy agricultural usage probably removed source of magnetic anomaly
76	Y	54	56	559682	312523	Strong magnetic anomalies from multiple serpentine creeks and alluvial mottling. No significant features identified.
77	N	55	56	559485	312409	Road
78	Y	55	56	559223	312289	Strong magnetic anomalies from multiple serpentine creeks and alluvial mottling. No significant features identified.
111	Y	73	74	550909	312221	Field boundaries identified (21 to 23), including some not previously known. Silty loam, rough in places
112	N	73	76	550704	312470	Freshly ploughed
113	Y	75	76	550580	312663	Field boundary ditch in desktop (18) identified with debris in fill (19). No magnetic alluvial character to soils. Two faint ditch-type features - possibly wheel ruts? (20)

118	Y	77	79	549961	313199	Ditch 1.5m wide crossing palaeochannels (15). Also small rectilinear enclosures defined by narrow ditches, or perhaps furrows (16 & 17)
119	Y	78	80	549690	313331	Water main (14) and tile drains detected (13). Very uniform magnetic background, typical of homogenous clays with several distinct palaeochannels up to 8m wide. Narrower connecting channels may hint at artificial drainage. At S end canalised creek with sinuous natural predecessor
123	N	79A	79B	549213	314104	Freshly ploughed
124	Y	79D	79E	548948	314245	Previously unknown field boundaries detected (8, 9, 11 & 12), possibly related to SMR MNF18977. Also possible pit fills (5 & 10). Tile drains evident (6 & 7). Very uniform magnetic background, typical of homogenous clays
125	N	79E	79F	548762	314267	Rough, silty loam
126	Y	85	86	548266	314178	No significant features identified. Rough, silty loam
131	Y	91	92	547341	314179	No significant features identified. Some physical traces of structural materials in soil by road. Magnetic background typical of homogenous clays with localised mottling typical of alluvial environment. Possible palaeochannels. Scatter of debris (4).
132	N	91	92	547139	314224	Road
133	Y	92	93	547106	314162	Curving channel or ditch type anomaly (3) up to 3m wide, alongside road, possibly natural
134	Y	92	93	546972	314135	Pair of possible ditches towards eastern end (1 & 2). Possible palaeochannel mid-field. Magnetic background typical of homogenous clays with localised mottling typical of alluvial environment, changes abruptly to alluvium beneath shallow peat in W half
223	N	79B	79D	549118	314221	Set out removed by persons unknown
225	N	14	14A	570022	314523	No access - horse paddock
226	N	14A	18A	569725	314413	Long grass
227	N	18A	19A	569268	314040	Woodland
228	N	18A	19A	569061	314034	Woodland
229	Y	19A	20A	568661	313957	Possible trace of cultivation furrows (31). Soil shows classic magnetic alluvial character, weak under peat
230	Y	19A	24	568270	313957	Possible drain or ditch feature 1.5m wide (29). Possible pit type feature though this may be natural (30). Soil shows classic magnetic alluvial character, becoming weaker to W end as peat depth increases

Caveats

3.1 Geophysical survey is literally that, a systematic measurement of some physical property related to the earth. There are numerous sources of disturbance of this property, some due to archaeological features, some due to the measuring method, others that relate to environment in which the measurement is made. No disturbance, or 'anomaly', is capable of providing an unambiguous and comprehensive description of a feature, in particular in archaeological contexts where there are a myriad of factors involved.

3.2 The measured anomaly is generated by the presence or absence of certain materials within a feature, not by the feature itself. Not all archaeological features produce disturbances that can be detected by a particular instrument or methodology. For this reason, the absence of an anomaly must never be taken to mean the absence of an archaeological feature. The best surveys are those which use a variety of techniques over the same ground at resolutions adequate for the detection of a range of different features.

3.3 Where the specification is by a third party ArchaeoPhysica will always endeavour to produce the best possible result within any imposed constraints and any perceived failure of the specification remains the responsibility of that third party.

3.4 Where third party sources are used in interpretation or analysis ArchaeoPhysica will endeavour to verify their accuracy within reasonable limits but responsibility for any errors or omissions remains with the originator.

3.5 Any recommendations are made based upon the skills and experience of staff at ArchaeoPhysica and the information available to them at the time. ArchaeoPhysica is not responsible for the manner in which these may or may not be carried out, nor for any matters arising from the same.

4 Conclusion

Significant results

4.1 The survey has been informative upon the nature and extent of buried soils but less so upon archaeology, primarily due to a slight mismatch between soil types and survey areas. It seems likely that further archaeological features could be found, including within surveyed areas.

4.2 Significantly, the identification of the moated site location in area 1 can only be tentative, due to the natural soil conditions. The moat may have used or modified natural channels.

4.3 The results in the southern part of area 4 showed the known missing field boundaries but also revealed further ones that were previously unknown, forming part of the same system.

4.4 At the southern end of area 5, multiple linear anomalies could represent parts of a field system unrelated to the current layout.

4.5 In area 6, a range of likely archaeological features have been detected which may be associated with SMR MNF18977, including ditches / drains and possible pits.

4.6 The parts of area 7 closer to the road show characteristics of slightly drier ground than their surroundings: these parts contain the ditch type features likely to be of archaeological interest. These may be associated with settlement but do not relate to current field boundaries.

4.7 In general, traces of settlement and cultivation tend to occur on soils associated with drier ground. However, it is possible that elements of these may continue below peat, where they are less detectable geophysically.

Recommendations

4.8 The geophysical contractor would ideally have more input into the allocation of areas for detailed survey, probably coupled with trial survey as an assessment phase to delineate areas of 'bad ground'. This could simply be a DGPS-tracked centreline assessment rather than intensive survey and would normally be combined with field inspection and also examination of borehole records and exposed sections where available.

4.9 This does not advocate an archaeological magnetic scanning-type approach – the objective is to assess conditions at this initial stage, not to locate archaeological features. Once this is done, survey can be allocated in blocks in areas most likely to maximise returns.

5 Appendices

Survey metadata

Project information

Project Name	Kings Lynn to Wisbech Gas Pipeline
Project Code	KLW061
Client	Network Archaeology & Murphy Pipelines
Fieldwork Dates	5th September until 21st October, intermittently as crops were cleared
Personnel	Anne Roseveare Britta Wiesker Martin Roseveare
Draft Report Date	N/A
Final Report Date	12th November

Location

Country	England
County	Norfolk & Cambridgeshire
Nearest Town	Kings Lynn (East) and Wisbech (West)
Landholding	Various
Co-ordinates	57238, 31637 (East end) & 54558, 31367 (West end)
Co-ordinate System	OSTN02

Environmental data

Geology – Soil	Various
Geology – Parent	Chalk, glacial gravel (flint) and marine alluvium
Topography	Predominantly flat, slight rise into Norfolk at East end
Hydrology	Artificial drainage throughout
Current Land Use	Arable with a small amount of pasture
Historic Land Use	Arable
Vegetation Cover	Crops or none
Sources of Interference	Various, including traffic, fences, overhead cables, steel pylons etc

Geodetic data

Projection	Transverse Mercator
Co-ordinate System	British Grid via OSTN02
Bearing	Zero
Precision	0.05 internally & global
Instrument Used	Leica carrier-phase (survey grade) gps
Reference Points	Autonomous
References Definition	Mercedes Planas

Process documentation

Method 1 – total field magnetic survey

Measured Variable	Total magnetic field intensity, units nT
Instrument	Geometrics Magmapper G858
Configuration	Dual channel magnetometer, sensors at 0.3m height on wheeled cart
Resolution	Samples at between 0.13m and 0.25m along lines 1.0m apart
QA Procedure	Static test
QA Result	Normal
Data Source Format	Geometrics proprietary STN

Process description

5.1 Data from the base station magnetometer (Scintrex ENVI proton, 0.5 Hz) was despiked and smoothed before being synchronised in time with the caesium vapour magnetic data. The latter was then corrected for diurnal affects by subtraction of the base station data. After application of a heading correction the data was converted from XYZ format to a regular grid through cubic interpolation along each line of survey to 0.25m. A proprietary cross-line interpolation algorithm was then applied to decrease the line separation to 0.5m for imaging.

5.2 The regional field was approximated and removed through application of a 3rd order Butterworth filter which also restored the mean level of the grid to zero, ready for further processing using conventional potential field techniques. This comprised modelling an approximation to the deepest magnetic component within the data and then their subtraction to leave those anomalies most likely to have shallow sources. Further processing resulted in the synthetic vertical gradient model used in this report.

5.3 All stages of processing were used to inform upon the interpretation.

Method 2 – total field magnetic gradiometry

Measured Variable	Total field vertical magnetic gradient, units nT/m
Instrument	Geometrics Magmapper G858
Configuration	Carried vertical gradiometer, sensors 0.8m apart, lower at 0.3m height
Resolution	Samples at between 0.13m and 0.25m along lines 1.0m apart
QA Procedure	Static test
QA Result	Normal
Data Source Format	Geometrics proprietary STN

Process description

5.4 The gradiometer data was corrected for heading variations and then converted from XYZ format to a regular grid through cubic interpolation along each line of survey to 0.25m. A proprietary cross-line interpolation algorithm was then applied to decrease the line separation to 0.5m for imaging.

Archive data

Introduction

5.5 ArchaeoPhysica maintains an archive for all its projects, access to which is permitted for research purposes. Copyright and intellectual property rights are retained by ArchaeoPhysica on all material it has produced, the client having full licence to use such material as benefits their project.

5.6 Access is by appointment only. Some content is restricted and not available to third parties. There is no automatic right of access to this archive by members of the public. Some material retains commercial value and a charge may be made for its use. An administrative charge may be made for some enquiries, depending upon the exact nature of the request.

General description

5.7 The archive contains all survey and project data, communications, field notes, reports and other related material including copies of third party data (e.g., CAD mapping, etc.) in digital form. Many are in proprietary formats while report components are available in PDF format.

5.8 In addition, there are paper elements to some project archives, usually provided by the client. Nearly all elements of the archive that are generated by ArchaeoPhysica are digital.

File types

Extension	Associated Software or Format Information	Example Content
.bin	Geometrics MagMap2000 (version specific)	Magnetometer downloads
.csv	ASCII comma-separated data	Various data files
.dat	Generic ASCII data (may not be human readable)	Magnetometer downloads
.doc	Microsoft Word document (Office 97 and newer)	Report documents
.dwg	Autodesk AutoCAD format (version specific)	Plans & digitised maps
.dxf	ASCII Drawing eXchange format	Plans & digitised maps
.grd	Golden Software Surfer 7 binary or ASCII grid	Survey data
.html	ASCII HyperText Markup Language file	Report files, web pages
.man	Manifold GIS 6.5 and newer (version specific)	Project data
.mdb	Microsoft Access document (Office 97 and newer)	Database files
.pdf	Adobe Acrobat Format (version 6 and newer)	Report files
.r15	Geoscan Research RM15 download (sequential ASCII)	Data files
.srf	Golden Software Surfer document (version 8)	Project data
.stn	Geometrics MagMap2000 ASCII data	Processed magnetic data
.txt	Generic human readable ASCII data	Notes etc.
.xls	Microsoft Excel document (Office 97 and newer)	Spreadsheet files
.xml	AP System or Manifold GIS	Logs, palettes, MS .NET files

5.9 The files listed above represent the usual content of digital archives held by ArchaeoPhysica.

Dissemination

5.10 It is the client's responsibility to ensure that reports are distributed to all parties with a necessary interest in the project, e.g., local government offices, including the HER where present. ArchaeoPhysica reserves the right to display data from projects on its website and in other marketing or research publications, usually with the consent of the client. Information that might locate the project is normally removed unless otherwise authorised by the client.

Background information

Archaeological geophysics

Geophysics is the application of measurements of the physical properties of materials to further our understanding of the Earth. As such it is a broad and diverse discipline with specialisms ranging from deep core and mantle studies through petroleum exploration to "shallow earth" environmental geophysics of which archaeological survey is just one example. The diversity and complexity of many archaeological features makes it one of the most difficult and arguably least well understood branches of geophysics.

The role of the geophysical contractor

Within archaeology, there is a tendency for a narrow range of instrumentation to be used on a routine basis, to the possible detriment of the archaeological resource. Every site has its own physical and archaeological micro-environment and to maximise returns and cost-effectiveness every survey needs to be designed from the ground up. In some cases, this may call for the use of so-called 'novel' technologies, in other cases the old favourites may suffice. Whatever the scenario, the choice of instrumentation, configuration, survey resolution and sampling need to be assessed against the agreed project objectives.

This needs to be done by, or under the direct supervision of, a qualified and experienced geophysicist due to the wide range of parameters to be considered, not least, cost-effectiveness. It is probably fair to say that there are very few circumstances where geophysics is unable to contribute something of benefit, but the means may not be immediately obvious. All surveys by ArchaeoPhysica are tailor-made, even where working to a third party brief. This is because we feel our experience and knowledge must be brought to bear upon the survey design to avoid unnecessary failure later. In many cases, this is simply to fulfil an educational role.

For similar reasons as already outlined, it is essential that interpretation of the geophysical data be undertaken by an experienced geophysicist rather than an archaeologist. Geophysical data is, as discussed in an earlier section, an indirect indicator of archaeological features and to correctly process, analyse and image such data requires specialist knowledge that is not usually available to an archaeologist. In the simplest terms, geophysics is not archaeology and therefore requires the attention of specialist understanding in its own right, in the same manner as analysis of botanical or faunal assemblages.

Geomagnetism

Physical description

The geomagnetic field is at any location the four-dimensional (space and time) vector sum of several discrete components. The temporal component has categories separated by the time over which any variation in their intensity becomes noticeable. Archaeological surveys are concerned with the two most rapidly changing categories, micropulsations and the diurnal field. The former may only last a few seconds and have amplitudes comparable with anomalies from archaeological sources, e.g., 2-5nT. The second is the daily fluctuation in the regional field that is broadly predictable and varies by some 30-40nT per day. This can be complicated by magnetic storms which can contribute field variations of well over 100nT, frequently associated with intense bursts of magnetic noise within the spread of amplitudes associated with archaeological sources. A third temporal variation is due to variations in the distribution of magnetic sources within the Earth's core. Unlike the other two, these occur over years, influencing both the amplitude and direction of the regional field and for archaeological purposes can be safely ignored.

The stationary (non-temporal) component of the magnetic field is the sum of the myriad of magnetic sources within the Earth's crust. These range from deeply buried magnetic minerals through to changes in soil structure and properties due to environmental, agricultural and of course archaeological sources. To provide a sense of scale, the deeply buried sources can contribute anomalies of a few thousand nT across many kilometres of landscape, though visible as changes of only a few nT across the sizes of areas associated with many archaeological projects. In contrast, the environmental and archaeological sources may contribute just 10nT or so, detectable at distances of no more than perhaps 3m for the larger anomalies.

Where anomalies exist of a larger spatial extent than the survey area they form part of the regional field and are caused by the deepest magnetic components of the ground. The remaining field is called the residual and represents roughly the sum of the magnetic sources present within the survey area, whatever their depth of burial. In basic terms, the more sensitive the instrument used to generate this data and the less cluttered the soil, the deeper the source that can be imaged magnetically, perhaps ditch fills or settlement sites concealed beneath marginal peat for example. A branch of geophysical processing called potential field analysis allows the geophysicist to further subdivide these sources, allowing the very shallowest ones, indicative of archaeological sources, to dominate the deeper.

The burial environment

Topsoil is usually magnetic relative to other soils and hence is important for magnetic survey. If topsoil is exceptionally deep it can mask more weakly magnetic features beneath it. Alternatively, regions where the topsoil is locally deeper than elsewhere are usually associated with enhanced magnetic field strength. Archaeological features that incorporate relict topsoil tend to enhance the magnetic field around them.

In some cases, features may exist magnetically that cannot be detected during excavation. This is normal, as some soils with enhanced magnetic properties do not exhibit any visible difference from their surroundings. In addition, some features survive as shadows in the topsoil after they have been physically removed by ploughing. The converse scenario is of course also true: there are many archaeological features that have no detectable magnetic component. Finally, sometimes it will be the case that the archaeological feature itself is not magnetic but some secondary characteristic still allows its detection by magnetic survey. An example is where a ditch has been filled, perhaps soon after excavation, with the same material as its surroundings and therefore lacks magnetic contrast with the surrounding material. As this fill settles, deeper topsoil (whether contemporary or modern) can accumulate in the resulting hollow, creating a local slightly positive magnetic anomaly. An example of this is a grave site where the grave itself is usually nonmagnetic but can occasionally be located by the disturbance of the contemporary surface. Of course if the top of the feature has been truncated by ploughing this effect will disappear.

Hearths, burnt or fired soil and clay, and similar contexts involving the application of heat to soil, tend to become strongly magnetic due to chemical changes in the soil, in particular the conversion of iron oxides to maghaemite and magnetite. Assuming there is adequate iron in the soil initially, the process results in a particularly strong enhancement that is effectively permanent (the degradation that does occur can be regarded as negligible over usual archaeological time scales). This means that hearths can usually be detected with confidence. In addition, the presence of domestic fires at settlement sites tends to lead to an accumulation of magnetic soil throughout the settled area and for a distance beyond. It is possible therefore, that features that are undetectable away from a settlement will become more detectable the closer survey proceeds to the inhabited area, an effect that has been observed in large surveys.

A secondary effect of the same process is that the presence of non-magnetic features may become detectable if magnetic material has accumulated in or around them. A common example is wall footings against which magnetic soil has accumulated, even in trace quantities.

Configuration & measurement

The magnetic field has a direction and intensity and hence it is possible to measure either the intensity of a directional component or the total intensity. The total intensity is measured using a total field magnetometer, e.g., a caesium magnetometer but it is common in UK archaeological surveys to measure just the vertical component, using a fluxgate gradiometer.

In addition, magnetometers can be configured in different ways, usually as single sensor magnetometers or as gradiometers. For this discussion it is assumed that the gradiometer is vertical. A single magnetic sensor measures all components of the ambient field, including the temporal which is not desired and hence needs to be removed from the data during processing. This is usually achieved either through reduction using software or by using a base station magnetometer, one that does not move and simply records the temporal variations so that they can be subtracted from the field data later.

A gradiometer avoids this by having two sensors measuring simultaneously, one sensor being mounted higher than the other. By subtracting the data from the upper sensor from the lower, the temporal component, common to both sensors, is removed. This has a disadvantage in that unless the upper sensor is quite high above the ground, e.g., 3m, the data from it can contain a large component due to shallow and hence archaeological sources. When the data is subtracted this reduces the anomaly strength from shallow sources as well as deep. For gradiometers using widely spaced sensors, e.g., the Bartington Grad601-2 (1m) or the ArchaeoPhysica wheeled instrument (1.2m), this is much less of a problem than for shorter ones, e.g., the Geoscan Research FM36 (0.5m).

One advantage of vertical gradiometers is that they provide slightly better defined edges of anomalies due to magnetic sources close to them, e.g., magnetic fills in the tops of pits and ditches. A magnetometer, however, will quite often provide slightly larger anomaly strength and the calculated vertical gradient is nearly always a good model of the measured gradient.

Conversely, magnetometers are better at imaging laminar structures and can hence differentiate between soils at the same depth but with different magnetic susceptibility. This is of particular benefit when imaging small areas or sites with complex magnetic properties, e.g., settlement remains.