VINDOLANDA
CHARITABLE TRUST

CARVORAN/MAGNA PRELIMINARY REPORT

BORE HOLE INVESTIGATIONS AUG-OCT 2021

PUBLICATION DECEMBER 2021

1. INTRODUCTION

Carvoran/Magna Roman fort and Hadrian's Wall and vallum between the unclassified road to Old Shield and the field boundary west of the fort in wall miles 45 and 46

Scheduled Monument No: 1010991

A reconstruction of Magna fort looking from the south.

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1.1 ARCHAEOLOGICAL CONTEXT

Magna is situated in the Parish of Greenhead, Northumberland. The site is owned and administered by the Vindolanda Trust (since 1972) and the entirety of the area to be surveyed is set within that area of the Trusts owned scheduled land (as seen in figure 1.). List Entry Number:1010991, National Grid Reference: NY 66590 65785.

The site of Carvoran/Magna remains one of the most intriguing and well-preserved Roman military landscapes yet to be surveyed along Hadrian's Wall. The site is likely to have started as a Pre-Hadrianic Stanegate fort before being further developed into a Hadrian's Wall fort after cAD122.

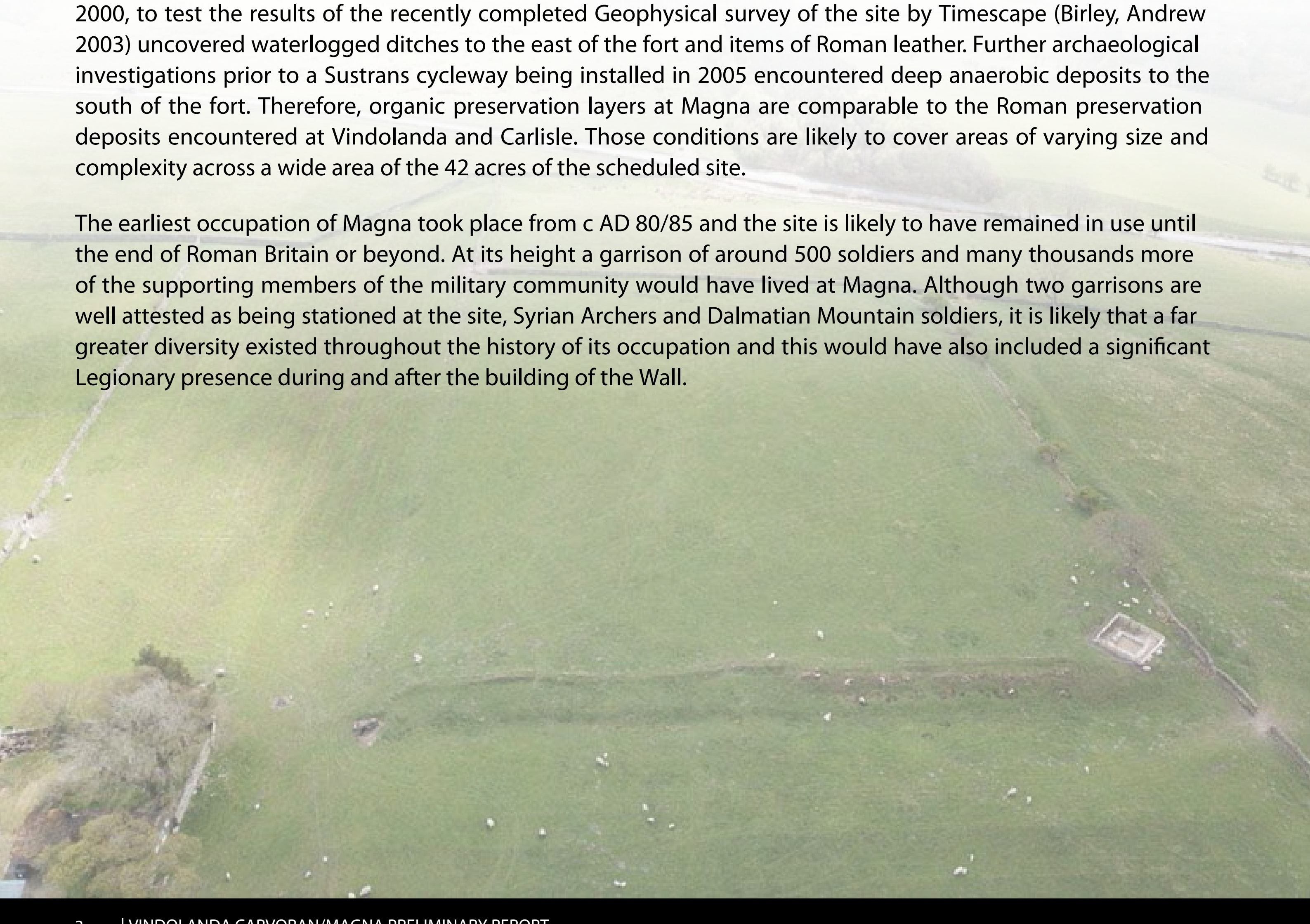
The settlement held a commanding position in the landscape as the junction between three Roman roads, the Stanegate, Military Way and Maiden Way.

The Hadrianic fort, replacing a pre-existing structure may be one of the last wall forts to be completed and as such the need to better understand its history will improve our knowledge of the evolution of the frontier.

This evolution is best shown by the way in which a later feature, the vallum (a large ditch to the south of the Wall) was diverted around the fort (between the fort and its closest milecastle, number 46 to the northwest) reducing the military zone between the two Hadrian's Wall ditches significantly. It has been suggested that the vallum diversion was due to the presence of an ancient bog. However, such a feature in the landscape would hold few challenges for Roman military engineers, and the central sector of Hadrian's Wall has numerous examples where the vallum has been dug through boggy or difficult terrain.

Brief archaeological investigations at Magna, with trial trenching undertaken in 1973 (Birley 1998), showed that the central pier of the later Hadrianic north gate of the fort rested upon well preserved wood. Further work in 2000, to test the results of the recently completed Geophysical survey of the site by Timescape (Birley, Andrew 2003) uncovered waterlogged ditches to the east of the fort and items of Roman leather. Further archaeological investigations prior to a Sustrans cycleway being installed in 2005 encountered deep anaerobic deposits to the south of the fort. Therefore, organic preservation layers at Magna are comparable to the Roman preservation deposits encountered at Vindolanda and Carlisle. Those conditions are likely to cover areas of varying size and complexity across a wide area of the 42 acres of the scheduled site.

The earliest occupation of Magna took place from c AD 80/85 and the site is likely to have remained in use until the end of Roman Britain or beyond. At its height a garrison of around 500 soldiers and many thousands more of the supporting members of the military community would have lived at Magna. Although two garrisons are well attested as being stationed at the site, Syrian Archers and Dalmatian Mountain soldiers, it is likely that a far greater diversity existed throughout the history of its occupation and this would have also included a significant Legionary presence during and after the building of the Wall.



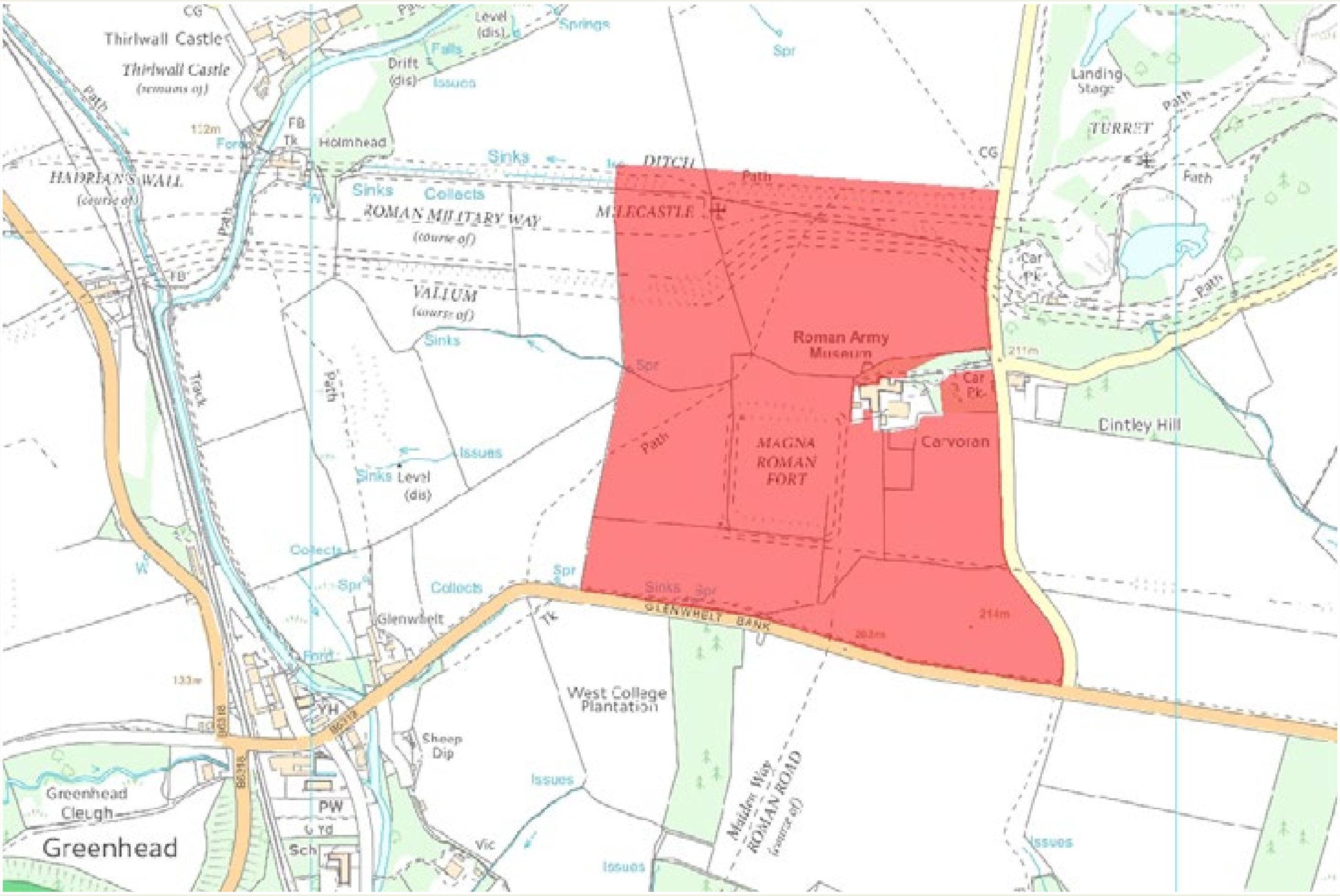


Figure 1: *The fort of Magna/Carvoran. Scheduled area shown in red.*

The Vindolanda Trust, which owns and manages the site, has become increasingly concerned about rapidly changing environmental conditions at Carvoran/Magna. The notable desiccation of a marshy area which historically covered a considerable part of the northern part of the scheduled site (shown in figures 2 as 'bog') and the re-appearance of hitherto sunken features such as the tops of fort ditches and Roman walls which have not been visible in the landscape prior to the middle of the 19th century (figures 2 and 3).

The plan below, drawn by Henry McLauchlan is the earliest detailed survey of the site and was published in 1857. This plan clearly marks the location and extent of the 'bog' covering an area of the site between the north wall of the fort and the vallum diversion to the south of the Wall. What is not shown on the plan are the outlines of the fort's multiple defensive ditches, which had been filled in by farming activities by 1857 and were no-longer visible features in the landscape.

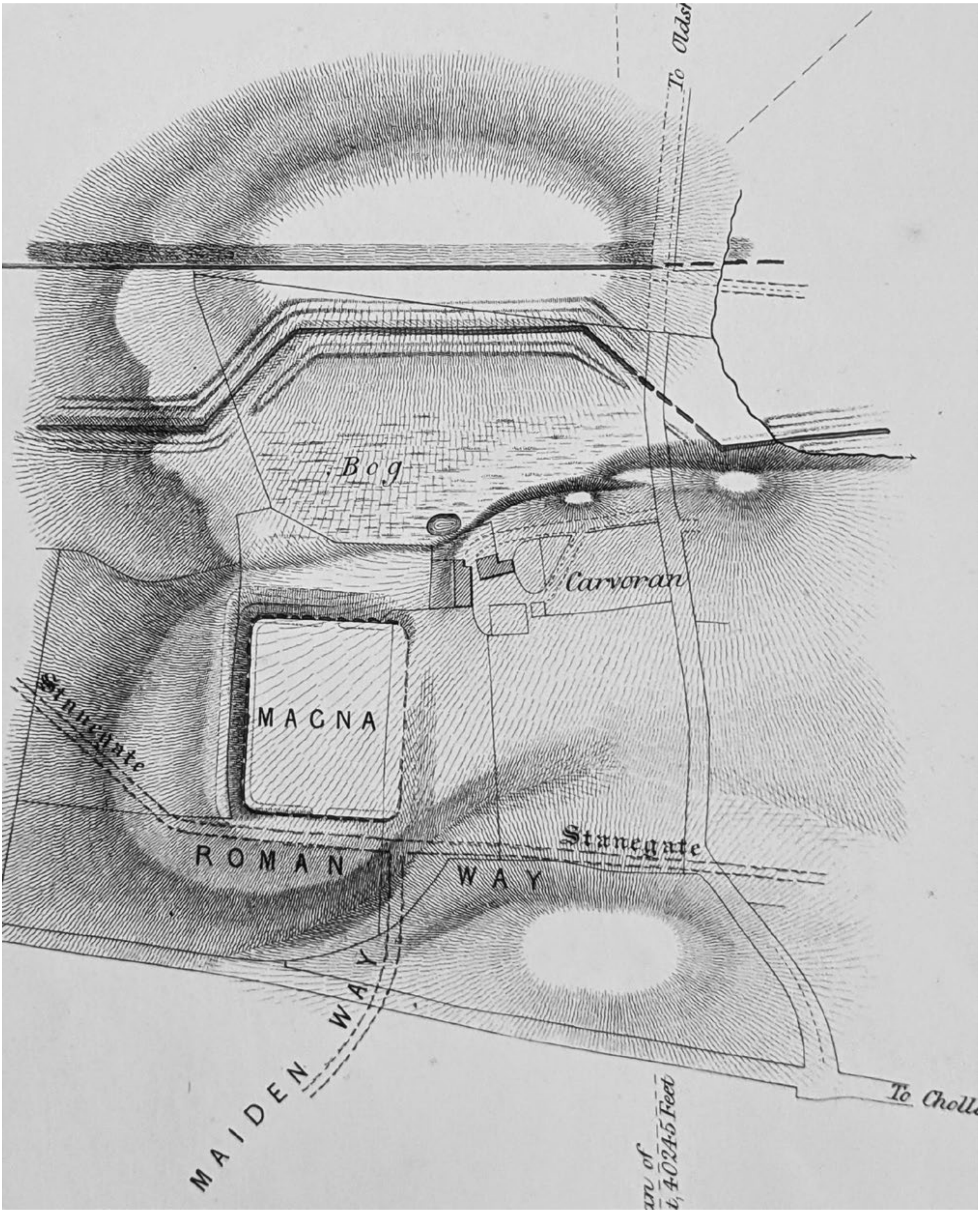


Figure 2: *The 1857 McLauchlan plan of Magna/Carvoran.*

In the past decade, the outline of the fort ditches started to reappear as material/fill held within the ditches has dropped below the levels of the top of ditches embankments.

Figure 3: *The SUMO composite image taken by drone in September 2019.*

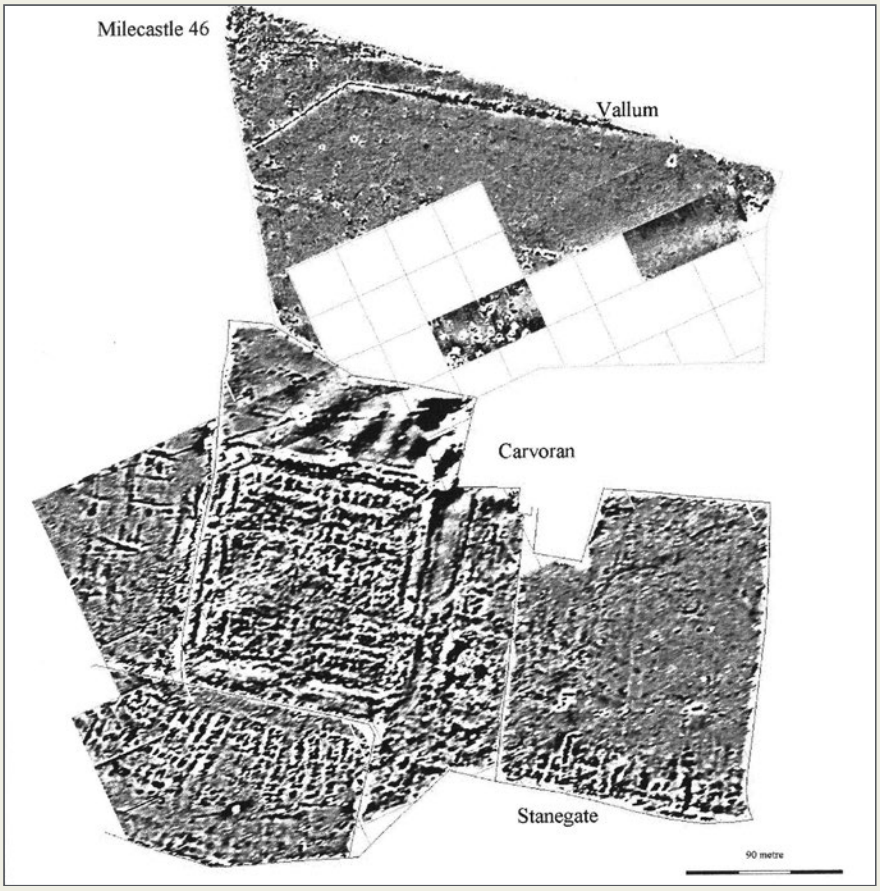


Figure 4: *Carvoran/Magna Geophysical Survey 1999. Greyscale magnetometry plot.*

Figure 5: *Timescape interpretative plot of the magnetometer survey. 1999.*

In 1999, Timescape was commissioned by The Vindolanda Trust with support from English Heritage to conduct a Magnetometer survey of Carvoran/Magna. While this was largely successful, due to the sites wet ground conditions large areas of the 'bog' were inaccessible to survey and the forts defensive ditches were not readily detectable, as shown in figure 5. In 2018 the Vindolanda Trust, becoming increasingly concerned by the changes taking place at the site, started consultations with specialist colleagues and archaeologists at Historic England with the aim of developing strategies for understanding, mitigating and managing the changes taking place at the site.

Figure 6: Map of Carvoran – showing archaeological features and hydraulic systems layouts, showing recent and historical data surveys – Guiney et al 2021.

LEGEND

Areas of archaeological interest

▨ Pre-Hadrianic Timber Fort
▭ Hadrianic Stone Fort
▨ Archaeological structures
▣ Turret
■ Commanding officers baths
━ Roman roads

Water sources and supply system

● Wells
💧 Springs
━ Rills
······ Aqueduct route

Drainage/sewage system

━ Earlier fort ditches
━ Ditches
━ Probable drains
━ Hypotetical drains
← System general outflow

■ Bog

1.2 SAMPLING PLAN 2021

The purpose of the project was to ascertain to what extent climate change or a range of other potentially interconnected elements, such as ground drainage, site management and ongoing agricultural practices, may be contributing to areas of visible desiccation at the site of Carvoran/Magna.

The proposed assessment survey and strategy was designed to ascertain the state of the archaeological deposits across different areas of the site by utilising proven geoarchaeological techniques coupled with the rapid advancement in Geophysical technology. This included improvements in monitoring techniques and assessment, geoarchaeology methods and preservation assessment techniques. Key artefacts and remains are likely to be organic in nature, particular in the form of waterlogged wood and leather, and publications have set out best practice techniques which can be applied.

The location of the bore holes was determined and directed by the requirement to avoid known structural features shown in the Timescape survey of the site and to provide a comparison between environmentally sensitive areas. The location of the bore holes was also selected to achieve a transection through the site from the north (vallum, bore hole 1) to the south (bore hole 5) with an extra bore hole placed into the most pronounced area of marsh or bog (bore hole 3) to add an extra field of data toward appreciating what was happening in this sensitive part of the site where the desiccation issue was the most obvious at ground level.

Figure 7: Proposed bore hole locations (red circles indicated the proposed bore hole locations). This composite image of Magna was taken in 2019 by SUMO archaeological services.

1.3 FIELD ACTIVITIES

The field activities were undertaken between 19-23rd August 2021.

Precision drilling equipment was obtained from https://www.vanwalt.com/ as recommended by Historic England 2016: Preserving Archaeological Remains documents, in particular Appendix 4, Water monitoring for Archaeological Sites: https://historicengland.org.uk/images-books/publications/preserving-archaeological-remains/heag100e-appendix4-water-monitoring-for-archaeological-sites/. Van Walt provided a half day's training at the site, and issued certificates to all of the team which also included comprehensive health and safety training.

Figure 8: *Precision drill training*

Day 1:- For the purposes of training, the location bore hole 4 was selected as it may have required the most support from the training provider to successfully execute (Figure 8). This area was expected to be the most demanding and challenging of bore holes locations due to the nature of the ditch fill which, as expected, was full of Roman fort wall facing stones and rubble from the nearby collapsed north wall of the fort. Despite the expected difficulties, the location of bore hole 4 was deemed as a desirable option due to its central site location and the historic discovery of wooden remains below the north wall of the fort from trial trenching which took place in the early 1970's (Birley R, 1998). This evidence was corroborated by the discovery of organic and waterlogged deposits in other ditch sections explored in 2001 (Birley Andrew 2003, 283-295).

Unfortunately, the large number of facing stones encountered in this area prevented a cohesive core retrieval despite several attempts to achieve a core sample along a section of the length of the forts inner northern ditch. A maximum depth of between 1 metre to 1.3metres was achieved before the bore encountered significant stone deposits and the bore hole was unable to reach below this layer to establish the nature of the ditch fill below the collapsed stone layer. As the sampling strategy had been carefully developed to avoid damaging stone remains at the site, further attempts to core a bore hole into this ditch were abandoned.

Day 2:- **Bore holes 2 and 3.** The strategy was to core one hole for a recording sample, (which were taken every 10cm distance (Figure 9), photographs were recorded and samples placed in universal tubes) and a second core was to be completed and immediately placed in a -20 freezer for further laboratory analysis. This strategy was developed to ensure that future microbiological, radiocarbon and biomarker work could be undertaken. The completion of the second core enabled a slotted tube to be placed in-situ for the location of piezometers which were set up to take readings in the successful bore hole locations once an hour for a 10 year duration, providing longer term monitoring of the subterranean ground conditions at each location.

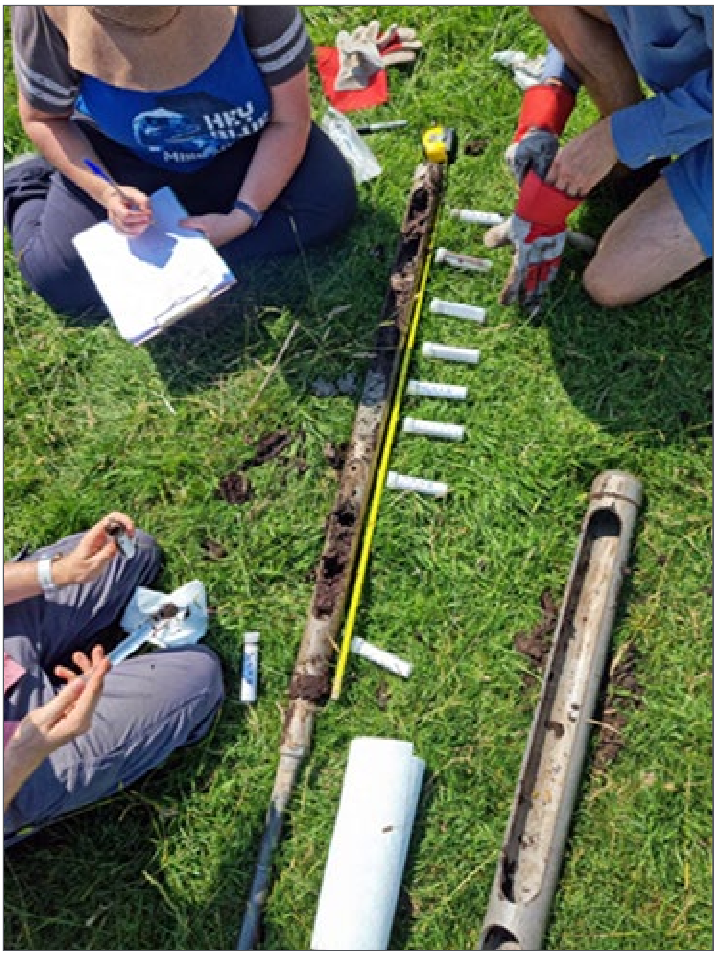


Figure 9: *Typical core retrieval and recording strategy*

Day 3:- **Bore hole 1 and 5.** Bore hole 1 was located in the vallum and Bore hole 5 near the Sustrans cycleway

Bore hole 1 was located in the middle of the ditch, it was originally suspected to be the deepest ditch, however, the presence of backfill and chipping from the nearby Wall Town Quarry was located at approximately 2meters depth, and further depth showed consideration mixed clay and stones. The eventual depth obtain was approximately 3.8meter and thus the bore hole had reached below the water line, and a monitoring station could be deployed but no analysis of the obtained cores has been undertaken.

Bore hole 5 was a challenging site, located on the steep slope next to the Sustrans cycleway. The suspicion of anaerobic preservation was confirmed, noted by the odour, colour and presence of animal bone both burned and still containing marrow. This layer was to a depth of nearly 5 meters. The use of a monitoring well at this location is an ideal way to monitoring any changes further up the site that may impact on this important area.

Day 4:- **Deployment of Piezometers**

For bore hole locations 1, 2, 3 and 5, piezometers were deployed, these were Solinst level loggers, with manual barometer correction. The barometer for Aug-Oct was located in bore hole 1. The barometer was relocated to a dry location post October.

Figure 10: Borehole 5 – Deployment of Peizometer

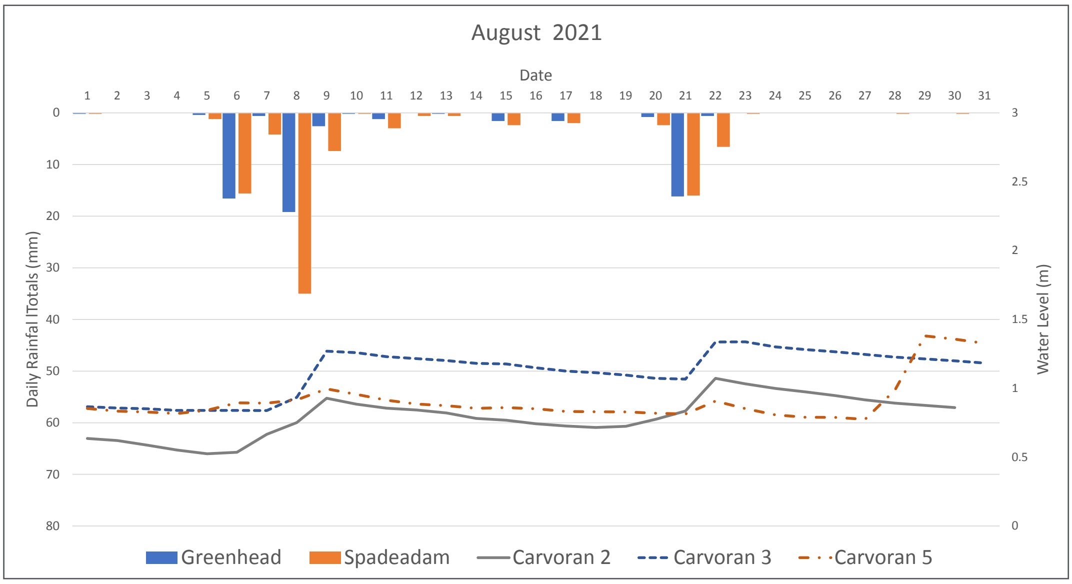
The deployment of the piezometers have a battery life of ~10 years, and guidance was followed from best practice guideline, Historic England 2016: Preserving Archaeological Remains documents, in particular Appendix 4, Water monitoring for Archaeological Sites:

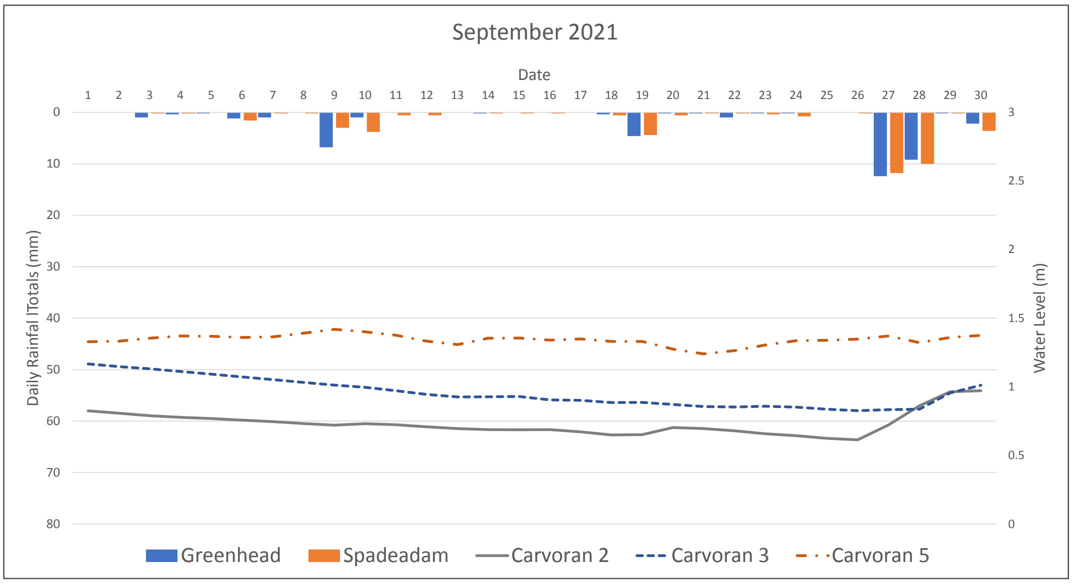
https://historicengland.org.uk/images-books/publications/preserving-archaeological-remains/heag100e-appendix4-water-monitoring-for-archaeological-sites/.

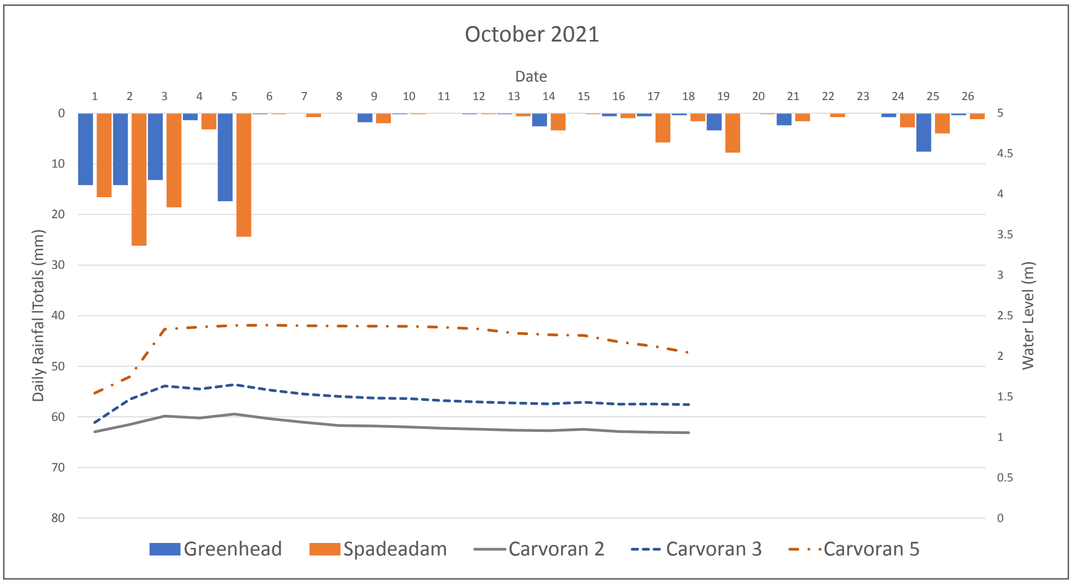
Bentonite was used to hold the top of the pipe and a stone slab was used to disguise and protect the top of the tube from interference from walkers and livestock.

1.4 RAINFALL AND PIEZOMETER DATA

Continuous rainfall data with a temporal resolution of 15 minutes was obtained from Environment Agency tipping bucket rain gauges located at Greenhead (S of the site) and RAF Spadeadam (N of the site). Rainfall and ground water level data is presented for August to October and for bore hole 2, 3 and 5.







Bore hole monitoring summary:

- Increase in ground water consistent with rainfall.
- Bore hole 5 – was interfered with, as indicated by the change in ground water level at the end of august.
- Bore hole 2 – very low level of ground water – this is supported by the sampling data below.
- Bore hole 3 – low level of ground water, the slow release of water indicates the ground has water holding capacity.
- Bore hole 5 – August and September were very dry months, in October the ground water raised significantly, and this was consistent.
- Temperature data is also available for all piezometer sites.
- Localised high intensity rainstorms matched the increase in groundwater was detected by the piezometers. However, smaller localised rainfall may occur at Carvoran which we cannot see due to the distance of monitoring stations at Spadadam, noting the significant difference in rainfall on the 8th August between Greenhead and Spadadam. Smaller rainfall spikes don't appear to show major change in groundwater, only going into upper soil layers, quickly absorbed by very dry peat layers without impacting upon lower ground water levels. This may mean that the rainfall missed the site due to distance between the monitoring station and Magna. A more comprehensive and local monitoring station is therefore recommended to provide better fidelity of data to for monitoring the local environment.

Recommendation:

- Remote monitoring considerations
- Redox monitoring of ground waters, as well as soil, to show redox state of the environment
- Weather station recording on site

1.5 GEOCHEMISTRY

The following parameters were measured from the soil sample taken from the first core approximately every 10cm.

Moisture

- Undertaken to determine the percentage of water within the soil samples
- Gravimetric measurement - difference between the weight of wet and dry soil sample, carried out in an oven. Complementary to the piezometer measurements.

pH

- Determination of acidic and alkaline soil conditions.
- Peat soil is very acidic, often due to microbial decay processes, but also underlying geochemical features.
- pH can aid the understanding of soil history.
- pH can impact on artefact preservation and changes needs to be carefully monitored.
- pH was measured using a Mettler Toledo handheld device.

Conductivity

- Soil electrical conductivity measure the ability of soil water to carry an electrical current.
- Soil conductivity measurement are indicative of nutrient concentration, such as salts Na, NH_4^+ contained.
- Conductivity was measured using a Mettler Toledo handheld device.

Total Carbon and Total nitrogen

- The measurement of total carbon within soil, provides the carbon which is stored as soil organic and soil inorganic.
- The measurement of total nitrogen indicates soil fertility and coupled with soil carbon, indicates soil formation processes.
- The behaviour of nitrogen and carbon in soil is complex, but monitoring can inform past events and land practices, especially fertilisation.
- TC and TN was determined using Elementar vario TC and TN exceed instrumentation.

Elemental composition

- The measurement of inorganic elements from soil has shown to be an excellent adaption of a geochemical techniques for archaeological investigations.
- The measurement of inorganic elements, can indicate 'lifestyle' area, such as oven/food preparation area, waste and disposal areas and burning areas.
- For example, increase calcium and phosphorus can indicate burning areas.
- A Thermo Niton™ XL5 pXRF was used for the following elements:- Magnesium (Mg), Aluminium (Al), Silicon (Si), Phosphorus (P), Sulphur (S), Chlorine (Cl), Potassium (K), Calcium (Ca), Titanium (Ti), Chromium (Cr), Manganese (Mn), Iron (Fe), Zinc (Zn), Rubidium (Rb), Strontium (Sr), Palladium (Pd), Silver (Ag), Cadmium (Cd), Antimony (Sb), Lead (Pb)

Results are presented for each borehole:-

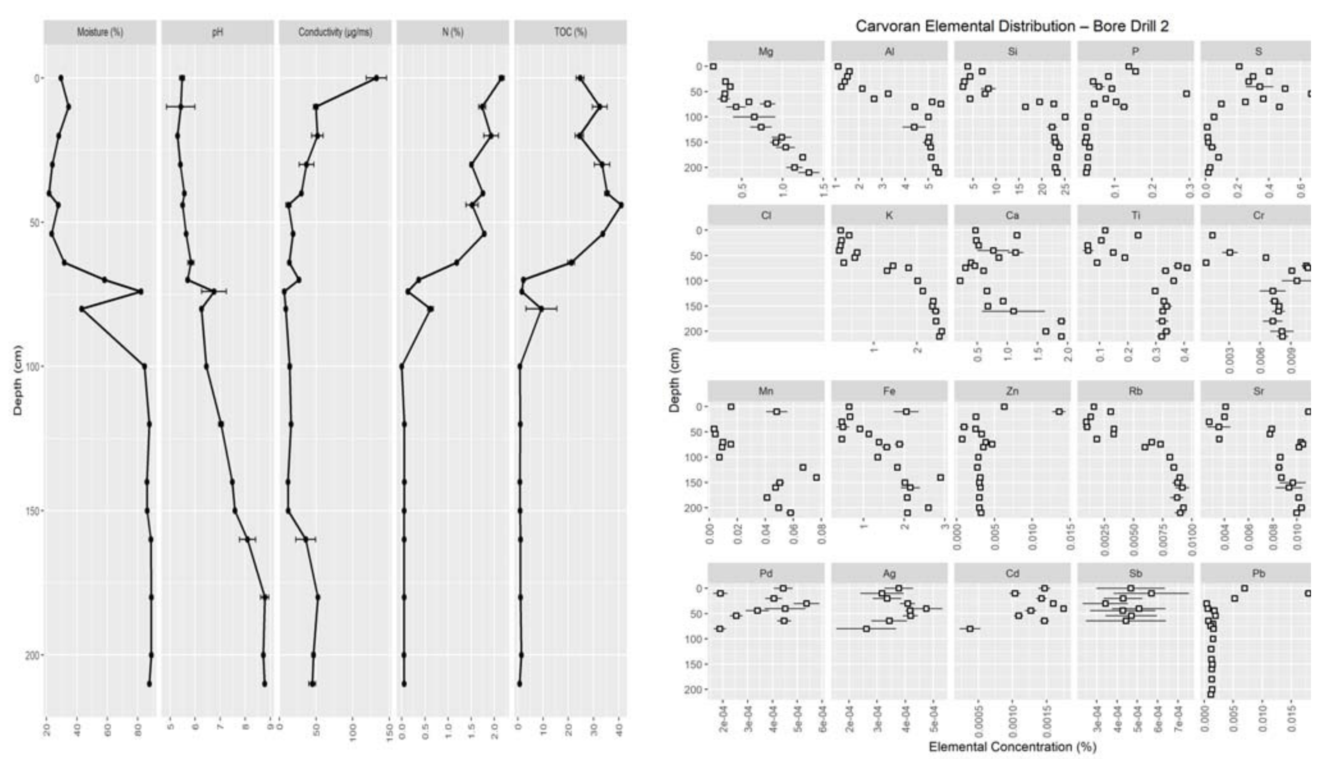


Figure 11 :- Bore Hole 2 – Geochemical data

Images for in situ core recording and dried sample are pending.

Moisture

- Very low percentage moisture between 0-64cm depth = 27% moisture
- Moisture does not increase until 75cm depth, which is consistent with the measurement of the water table at 68cm in second bore hole
- Healthy peat should contain 75% moisture

pH

- Average 5.5 0-64cm – above water table
- Gradual shift toward alkaline conditions with depth and increased moisture content
- Acidic and alkaline conditions in one soil profile is unusual and may risk rapid destruction if the carefully balanced conditions are adjusted

Conductivity

- Inverse relationship with moisture content through the profile

Total carbon

- Lower than expected for peat deposits

Elemental

- Phosphorus and sulphur content diminished substantially as moisture increased with depth. High sulphur content in drying and oxygenising soils produces sulphuric acid, which rapidly disintegrates archaeological material.
- High iron content throughout the profile, but steadily doubled in concentration through the profile
- Potassium increased substantially when transitioning from peat to clay. Potassium is abundant in deposits with high organic clay mineral content, as shown below 75 cm. Potassium may also be an indicator of organic-rich deposits.
- Alkaline environments should see high availability of magnesium, phosphorus, sulphur, potassium and calcium, but phosphorus and sulphur are in their lowest concentrations in the alkaline depths.
- Calcium generally increases with depth. Calcium is an indicator of archaeological deposits and refuse areas, but high concentrations may indicate that this material is under dissolution effects. Calcium reacts with the hydrogen in water to produce weak carbonic acids that dissolve rock and may impact buried artefacts.
- Increase lead concentration at upper test samples
- Silica and Aluminium increases in lower deposits

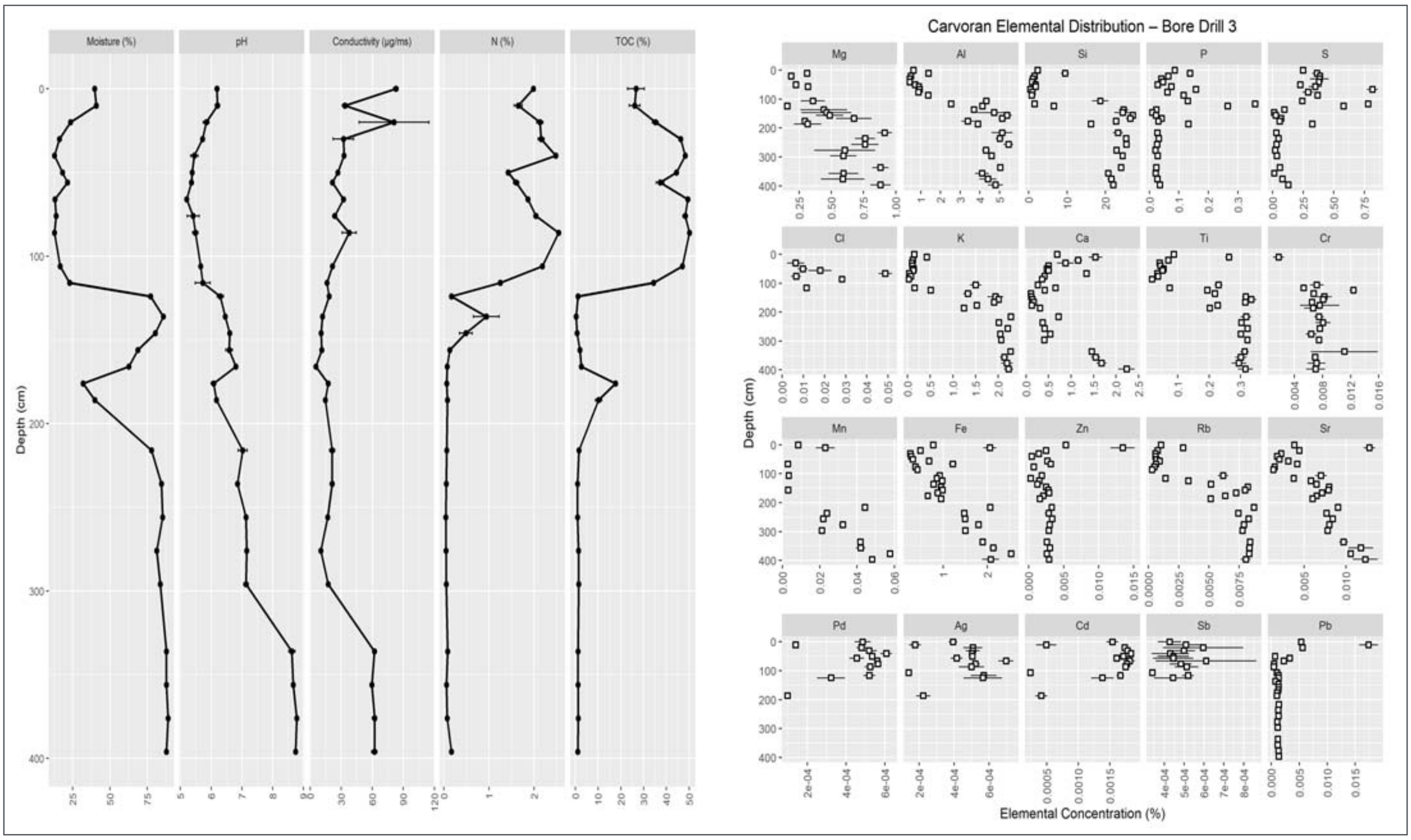


Figure 12 :- Bore Hole 3 – Geochemical data

Moisture

- Very dry in the top 110 cm. This is drier than Bore 3 (current bog) but they have similar moisture content below 200 cm,
- Interface of peat, clay, peat determined at approximately 75-100cm depth
- Peat from 101 showed increased and expected levels of moisture at 81%

pH

- Average 5.5 0-70cm – above water table
- Gradual increase in pH level through the soil profile, with a sharp increase toward alkaline conditions between 300 and 340 cm, reflected by conductivity.

Conductivity

-

Total carbon

- 10-64cm depth – 35% Total carbon
- Rapidly drops and not detected to substantial amounts in peat layer two

Elemental

- Phosphorus – significant change at interface - 74cm
- Phosphorus varies widely through the peat layers but a significant change at the interface at 74 cm, and remains stable and consistently low in the clay layers, particularly below 200 cm.

- Potassium substantially increases in the clay layers representing the general potassium-rich composition of clay and possible abundance of archaeological material as discussed with Bore 2.
- High sulphur content in the top layers, increasing in the second peat layer. This is associated with acidic and poorly preserving conditions, particularly in low moisture conditions. Sulphur decreases and moisture increases with depth, returning to potentially well-preserved conditions.
- Iron increasing depth
- More consistent trend in calcium content, which could indicate reduced dissolution effects and archaeological material, particularly alongside the high potassium content.

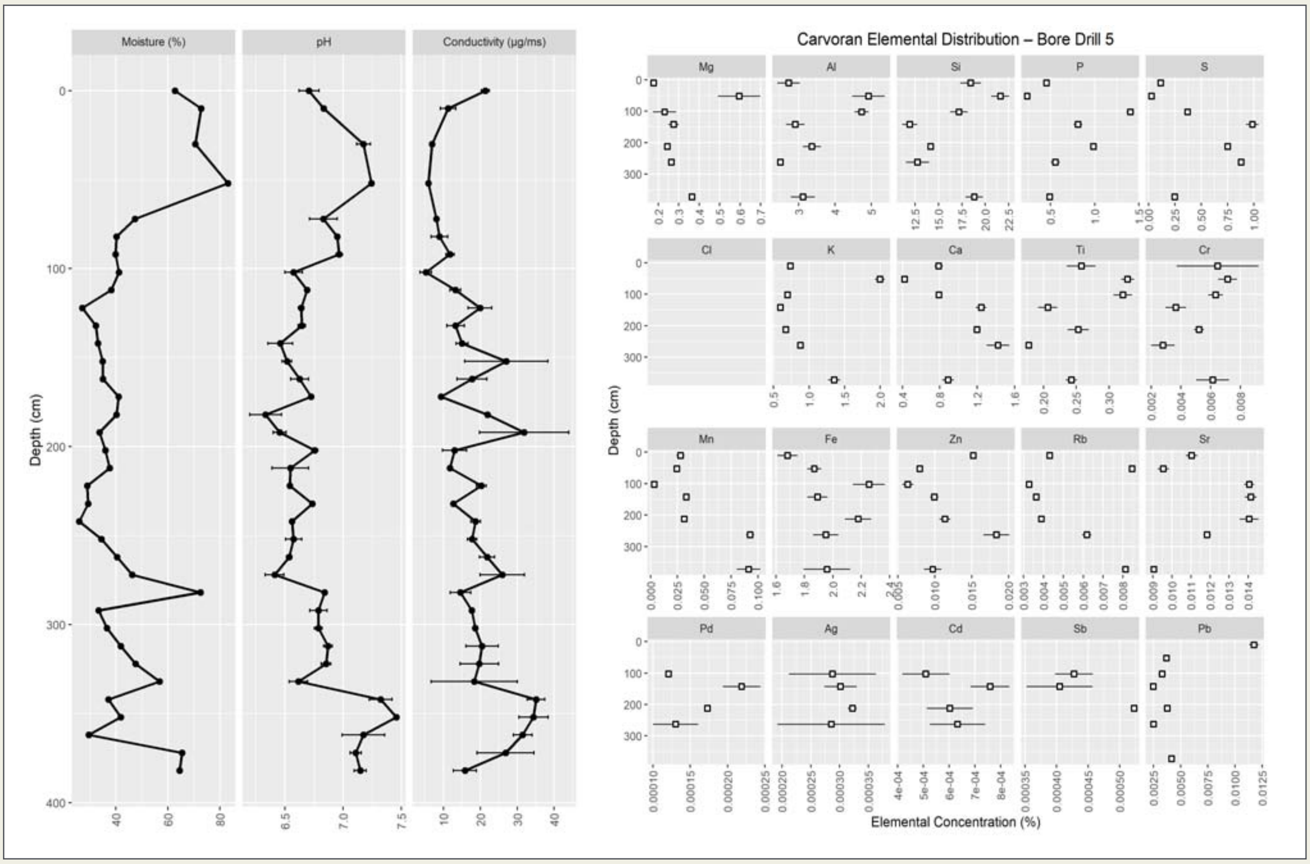


Figure 13 :- Bore Hole 5 – Geochemical table

Moisture

- Moisture content remains comparatively consistent through the profile. Moisture does not reach the extent of saturation observed in Bore 2 or 3, but also does not reach the dryness of the top peat layers of Bore 2 and 3.

pH

- Average 6.7 throughout core
- pH level and conductivity showed the most variation out of all three bore holes

Elemental

- Overall elemental distribution is widely scattered through Bore 5 whereas Bore 2 and particularly Bore 3 were more stable and consistent, reflecting the changes in soil composition more closely rather than changes in interfaces/types or archaeological deposits.

- Phosphorus, potassium and calcium are comparatively low through the profile, indicating a low likelihood of archaeological material. Increased phosphorus content compared to bore hole 2 and 3
- High levels of sulphur indicates poorly preserving conditions, particularly if aerobic and acidifying. This is reflected by the distribution around the interface of neutral and acidic pH level.

FUTURE CONSIDERATION

Radiocarbon

- Samples have been prepared for radiocarbon measurement and are pending analysis.

Biogeochemical

- By understanding the relationship between climatic, microbial and biogeochemical proxies, then reconstructions of past climate and environmental history may aid the future interpretations, including the combination of data from pollen, diatoms and use of stable isotopes. Furthermore, coupled with the microbial information below, microorganisms are the drivers of geochemical alterations, and parameters such as soil pH and temperature, can be determines by determination of lipid markers and Glycerol dialkyl glycerol tetraethers (GDGTs). The excellent state of preservation and undisturbed sequences at Carvoran/Magna would enable a future sampling strategy to collect and record biogeochemical data in a robust and planned manner

Microbial

- Studies to allow the understanding of diversity, structure and function of microbial communities are common in environmental science but are minimal within an archaeological context. Understanding microbial communities and importantly, archaeological environment interactions with microbes and artefacts, can allow us to better determine degradation and preservation within a site. To fully understand these processes and how they affect preservation requires a holistic approach of geoarchaeological and microbiology techniques are required. Although, no Historic England guidelines currently exist. Microbial communities are greatly affected by and have impacts upon environmental change.

Measuring these communities can allow us to understand:

- Climatic changes which impact upon preservation
- Nutrients cycling within preservation areas
- Anaerobic/aerobic environmental impact upon preservation and degradation
- Comparable differences between sites

Technological advances in DNA sequencing have enabled microbial archaeology to move from novel to established tools (Warinner et al., 2017). The second bore hole core is currently stored at -80 °C at the National Horizons Centre. By maintaining the soils at these temperatures, we are preserving the microbial DNA held within them. We would suggest that future sampling strategies also collect samples in this way to allow comprehensive microbial analysis.

At the National Horizons Centre, there is access to DNA extraction, PCR and sequencing technology which would allow us to identify and characterise microbes at different layers within the site. Furthermore, the use of qPCR technology to map gene activity within the layers allowing us to track how activity of the microbes change at different depths and locations and linking this to both environmental change and preservation within the site. This would be suggested as a starting point for microbial analysis at this and similar sites within future studies and would allow hypotheses to be generated around specific issues linked to preservation, environmental and climate change.

Micromorphology

- Targeted sediment micromorphology may help understand microscale geochemical processes and impacts for example of cycles of wetting and drying. This would also provide a more in depth picture of the nature of sediments and site formation history, in conjunction with palaeoecological analyses (Macphail and Goldberg 2017). Sampling strategy for this should be informed by geochemical data and field observations of transitions between different deposit types.

RECOMMENDATIONS

1. The North to South transit of bores holes enabled a time sequence to be investigated but misses other information.

   A West to East transit following the established bore hole methodology would be helpful.

2. Monitoring wells for site specific weather events, the current use of Greenhead and Spadadam monitoring sites indicates gaps of localised weather events.

   A weather monitoring station installed for long term and sustainable monitoring would provide better and more localised rainfall data for Magna.

3. The results from bore hole 2 and 3 show poor peat condition, bore hole 3 indicated a lake was present below the surface, but very little is known about the size and extent of this feature.
   Additional geophysical surveys and extra bore holes to survey the lake area.

4. The piezometers have provided a great way to directly monitor temperature and ground water level.
   Use of conductivity meters in current and new bore holes to monitor oxidising and reducing environments.

5. Bore hole 4 was challenging and establishing a well was not successful.
   Additional bore hole on an East or West transit to ensure a monitoring station for condition changes can be established.

6. Microbiological, biogeochemical and micromorphology have shown to have great potential.
   Develop a core sampling plan for sites which considers all aspects of collection, especially towards techniques which are in development.

7. Changes in soil pH can have dramatic and devastating impacts upon preservation.
   Careful consideration to water sources, including wider monitoring of water chemistry and modelling flood areas.

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Carvoran/Magna in 1964 in June.

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