

REPORT TITLE: FUNDING FOR CENTRAL WINCHESTER REGENERATION
ARCHAEOLOGY

28 AUGUST 2019

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WARD(S): TOWN WARDS

PURPOSE

There has been a commitment by Winchester City Council to explore the options around carrying out some early archaeological investigation in the central Winchester regeneration site. This report recommends the initiation of investigation works and the appropriate authorities and budget to enable the works to progress.

RECOMMENDATIONS:

That Cabinet:

1. Approves the commission of archaeological investigation in the Central Winchester Regeneration area, through a two stage model, based on the principles of the specialist report received.
2. Authorises the Strategic Director: Place to determine the specification of archaeological investigation works to be undertaken in consultation with the Cabinet Member: Housing and Assets.
3. Approves a revenue budget of £250,000 to be funded from the Major Investment Reserve to undertake the archaeological investigation work.
4. Authorises the Strategic Director: Place to establish the appropriate procurement process in accordance with the council's contract procedure rules for the archaeological investigation works.

5. Authorises the Strategic Director: Place to award and enter into the contract for archaeological investigation works, including all necessary legal agreements.
6. Approves an increase to the Central Winchester Regeneration project budget of £18,000 funded by the Major Investment Reserve.

IMPLICATIONS:

1 COUNCIL STRATEGY OUTCOME

- 1.1 The Central Winchester Regeneration (CWR) area will contribute to the Council Strategy objectives through enhancement of the environment of the area, improving the local economy and providing community benefits.
- 1.2 The carrying out of the archaeology recommendations contained in this report will result in work to collect and monitor data which will inform scheme proposals, de-risk the site and preserve land value.

2 FINANCIAL IMPLICATIONS

- 2.1 As outlined in paragraphs 11.1 to 11.16 a one-off budget of £250,000 is requested to carry out the archaeology work to be phased over 6 - 8 years. It is proposed that the £250,000 be funded from the Major Investment Reserve which has been earmarked to fund one-off capital and revenue expenditure in relation primarily to major projects and for which other reserves have not been earmarked.
- 2.2 Of the current central Winchester regeneration revenue budget of £395,000, £388,000 has been spent or committed and up to a further £18,000 is requested for additional works which includes consultation, engagement events, and printing as detailed in paragraphs 12.1 & 12.2. It is proposed that the sum of £18,000 be funded from the Major Investment Reserve.
- 2.3 In respect of the Central Winchester and St Maurice's Covert (see report CAB3182 elsewhere on this agenda), should the requested recommendations be approved, then additional funding from the Major Investment Reserve totalling £327,000 will not be available for other projects. There is no short term payback on these projects so the funding will not be replaced through reduced costs or increased income.

3 LEGAL AND PROCUREMENT IMPLICATIONS

- 3.1 The transfer of funds and the procurement of specialists to undertake archaeology investigative work located at the Central Winchester regeneration project site is requested. The decision is the procurement and award of contracts as part of Central Winchester Regeneration for a 6 - 8 year period with a total value of £250,000.
- 3.2 The exact scope of the contract is to be determined so if the recommendation is agreed, further discussions with SLR on this matter will take place to establish how the contract is split between consultancy services and works. This will dictate which procurement route is to be followed and SLR will assist in the procurement process as needed. If a consultancy contract is required, it is anticipated that the EU tender threshold (OJEU) will be exceeded and

therefore a competitive procurement will take place unless there is a suitable framework in existence.

- 3.3 If a works contract is required, it is anticipated that the OJEU threshold will not be met and therefore a competitive procurement will take place conducted in accordance with WCC's Contract Procurement Rules.
- 3.4 The procurement process used will be compliant with the Public Contract Regulations 2015 (if applicable), the Council's Contract Procedure Rules and Financial Procedure Rules for contracts of the relevant size.
- 3.5 The Council has power to enter a contract with a third party by virtue of section 111 of the Local Government Act 1972, providing the power to do anything is calculated to facilitate, or is conducive or incidental to the discharge of any of its functions. Under section 1 of the Localism Act 2011, the Council has the power to undertake any activity a normal person could undertake, for the benefit of the authority, its area or persons resident or present in its area. The Council may be satisfied it has the enabling power(s) to award and enter into the relevant agreements.
- 3.6 The Council has an obligation as a best value authority under section 3 of the Local Government Act 1999 to "make arrangements to secure continuous improvement in the way in which its functions are exercised, having regard to a combination of economy, efficiency and effectiveness." By following due process the Council's Contract Procedure Rules and Financial Procedure Rules, the Council will have observed its other statutory duties, including in regard to the duty to obtain best consideration.
- 3.7 Whilst a Judicial Review challenge is always a possibility where the Council has fully complied with the correct procedures, the risk of a successful challenge is considered minimal.

4 WORKFORCE IMPLICATIONS

- 4.1 Specialist consultant support is required to assist officers to carry out the archaeology work, the costs of which are included in the £250,000 budget requirement.

5 PROPERTY AND ASSET IMPLICATIONS

- 5.1 Archaeological investigations will be carried out across the central Winchester regeneration site on council owned land. The data collected will help to de-risk the site and preserve land value. The data collected on water levels may benefit other areas in relation to potential flood risks.

6 CONSULTATION AND COMMUNICATION

- 6.1 The option to progress archaeology investigations has been extensively discussed through engagement around and at adoption of the Central Winchester Regeneration Supplementary Planning Document, at Cabinet

(Central Winchester Regeneration) Committee meetings and at the archaeology information day in December 2018.

- 6.2 Communication around the discussions has been published via the Central Winchester Regeneration website and email database as well as through the dedicated broadsheet, published spring 2019.

7 ENVIRONMENTAL CONSIDERATIONS

- 7.1 None at this stage but data collected from the early investigations across the Central Winchester Regeneration site will go on to inform future proposals, further evaluation strategies, construction methods and mitigation requirements, helping inform future planning decisions.

8 EQUALITY IMPACT ASSESSEMENT

- 8.1 The project has identified that archaeology investigation works are required prior to any scheme implementation. An Equalities Impact Assessment (EqIA) assessment is a consideration for the Council and officers will review the process to ensure that any disadvantaged or vulnerable people are not discriminated against.
- 8.2 If any potential impacts are identified as part of the archaeological investigations they will be assessed and addressed appropriately.

9 DATA PROTECTION IMPACT ASSESSMENT

- 9.1 Officers have considered any data protection requirements and none are considered to be applicable at this stage around archaeology work.

10 RISK MANAGEMENT

- 10.1 Risks associated with the archaeology works are attached at appendix D.

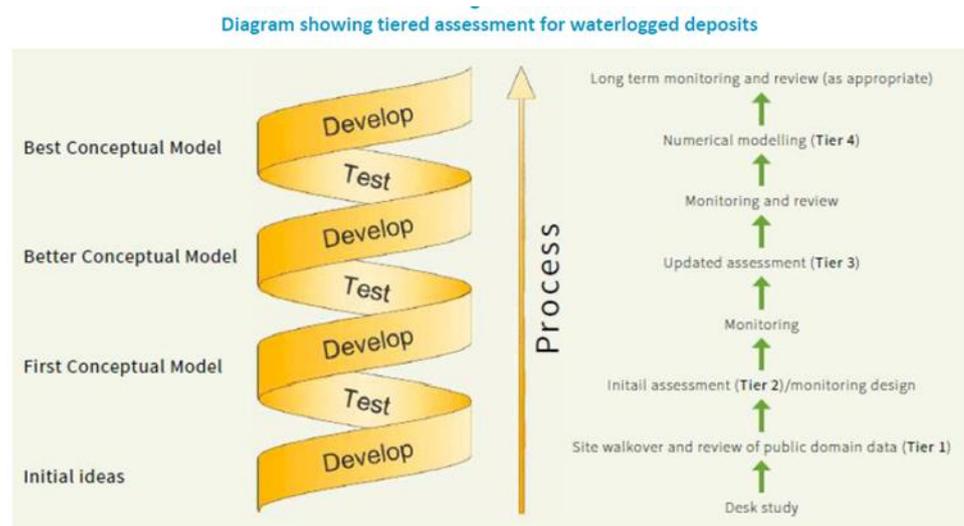
11 SUPPORTING INFORMATION:

11.1 **Background**

- 11.2 Throughout the development and adoption of the Central Winchester Regeneration Supplementary Planning Document (CWR SPD), the subject of archaeology has been of great interest and discussion with members and the wider local community.
- 11.3 Current National Planning Policy Framework guidance is to preserve archaeological remains in situ where possible i.e. to carry out minimal intrusive works across a site of interest to maintain maximum preservation of deposits.
- 11.4 Following the report by the independent archaeology panel (see appendix A), commissioned to inform the guidance contained in the CWR SPD, an archaeology information day was held in December 2018.

- 11.5 The panel's recommendations were in accordance with guidance contained in the NPPF. The information day, held in public, allowed the panel to explain, discuss and answer questions around the recommendations that were made and included as guidance in the CWR SPD.
- 11.6 The conclusion from the information day was that Winchester City Council could carry out some early investigations on the site to inform decisions later on down the line and these conclusions were outlined to Cabinet (CWR) Committee in report CAB3142 (CWR), 19 March 2019
- 11.7 The works discussed at the information day were outlined in report CAB3142 (CWR), but needed further detailing and costs by specialist consultants to ensure that robust but relevant investigations were commissioned if progressed.
- 11.8 Specialist consultants SLR were subsequently appointed to carry out a scoping exercise to;
- a) identify suitable investigation work to be carried out
 - b) provide a cost estimate for those works
 - c) provide estimated time scales to carry out the works
- 11.9 SLR have now provided their report and this can be seen at appendix B, and a summary of the report can be seen at appendix C.
- 11.10 **Details of proposal**
- 11.11 SLR were asked to provide a report outlining a suggested course of action with regard to early archaeological investigations across the CWR site.
- 11.12 The report contains a detailed analysis of why the council should be carrying out work at this stage, what work should be carried out and how and finally an estimate of costs and timescales.
- 11.13 A summary of the key information contained in that report follows;
- a) Why we need to carry out early investigation work;
 - (i) Sufficient, relevant data is required to ensure robust decisions are made during the planning process
 - (ii) Developers investing in the CWR area require reliable data to inform scheme design, construction and financial modelling
 - (iii) Data might indicate that conditions are unsuitable for preservation or that remains have already been damaged by earlier development and this might lead to an alternative approach

- (iv) Data collected at this stage will de-risk the site and therefore help to maintain the site value going forward.
- b) What approach WCC should take;
- (i) It is known from existing data that the CWR site is waterlogged and the SLR recommendations therefore make recommendations for such areas.
- (ii) The report recommendations centre around guidance issued by Historic England on how to approach archaeology in waterlogged areas. This is illustrated in the SLR report (appendix B) and in the figure below:



From Historic England's guidance Preserving Archaeological Remains 2016, Appendix 3, p.13

- (iii) In summary, the guidance recommends a tiered approach to investigations starting with desk based analysis, followed by collection of deposits and analysis to establish baseline data.
- (iv) The guidance goes on to recommend ongoing monitoring of conditions to collect sufficient data over a period of time allowing for seasonal and annual variations. This will provide sound information to base development and planning decisions on going forward.
- (v) The SLR report references what is considered to be an exemplar project for waterlogged conditions which was carried out in Nantwich. Details can be seen in full in the SLR report.
- (vi) The project in Nantwich comprised two phases;
- phase 1; collection of deposits and analysis of the data to establish the baseline conditions. In Nantwich, this took 3 years.

- phase 2; a sustained period of water monitoring to identify hydrological patterns such as groundwater or rainfall recharge, seasonal or annual change to water levels and chemical quality, so that these data could be compared to the baseline to detect trends in the conditions for preservation of archaeological remains. In Nantwich, this was a 5 year period.

(vii) SLR have considered both the Historic England guidance and the experience of Nantwich to recommend how WCC should proceed

c) **SLR Recommendations**

- (i) WCC should adopt a programme of investigation works similar in nature to that of Nantwich, which follows Historic England guidance.
- (ii) WCC should procure and appoint contractors to carry out the investigative work on a phased approach.
- (iii) Phase 1 – establish baseline conditions. Based on the Nantwich model and experience, this is likely to take 12 months. With monitoring against that baseline happening during succeeding years as Phase 2.
- (iv) Phase 2 – ongoing monitoring for an extended period. Based on Nantwich and best practice, this should be for a period of 5 years to balance out exceptional events but valuable data would be gathered over the first year, and subsequent years could coincide with the beginnings of regeneration activities. The costs of this monitoring have been included in the overall budget request of £250,000.
- (v) SLR acknowledge that phase timescales may have to be adapted to accommodate development across the site but recommend that data is collected where possible for as long as possible.
- (vi) Using the Nantwich example an indicative estimate of cost is:
 - Phase 1 = £93,330 + VAT
 - Phase 2 = £120,625 + VAT
 - Total = c.£214,000 + VAT
- (vii) With an allowance of 15% for annual increments to apply costs at today's level and a small degree of contingency, it is advised that a budget of £250,000 excluding VAT should be allowed for,

with a total project duration period, potentially, of up to 6-8 years.

- (viii) SLR recommends that WCC implements the investigation work as soon as possible to maximise the amount and quality of data required.

- 11.14 WCC has made a commitment in January 2019 (CAB3124 refers) to explore options to progress work as outlined above with a view to beginning investigation work on site and the SLR report outlines the real benefits of doing this at an early stage.
- 11.15 The existing Central Winchester regeneration project revenue budget does not have sufficient funds to proceed with this work.
- 11.16 Approval and funding of £250,000 is therefore sought to enable procurement, appointment and implementation of the investigation work set out in paragraphs 11.11 to 11.16 in this report.

12 **Central Winchester Regeneration – general**

- 12.1 The current revenue budget for the project is either spent or almost fully committed.
- 12.2 Over the coming months, there will be a requirement to carry out further public engagement as set out in the table below. To that end approval is sought for an additional £18,000 budget as detailed in the table below:

	£000
Approved budget	395
Spent or committed	(388)
Remaining budget	7
Estimated further requirements	
Printing costs including SPD	3
Hoardings (repair and maintenance) and window stickers	5
Exhibitions and engagement events with tenants and public	10
Contingency including potential legal costs	7
Total	25
Total increase in budget required	18

13 OTHER OPTIONS CONSIDERED AND REJECTED

- 13.1 The Council could decide not to proceed with the archaeology investigation work at this stage.

- 13.2 If this approach is taken, there will be significant time delay when development plans come forward as this data will be required as part of the planning process.
- 13.3 Lack of archaeology data will also potentially affect the land value as there will be more risk involved to future developers. By knowing the conditions of the deposits across the site, developers will be able to make informed decisions when negotiating, designing and preparing viability appraisals.
- 13.4 The option not to proceed is therefore not recommended.

BACKGROUND DOCUMENTS:-

Previous Committee Reports:-

CAB3034 (CWR) – 20 June 2018 Adoption of Supplementary Planning Document

CAB3061 (CWR) – 10 July 2018 Central Winchester Regeneration Update

CAB3077 (CWR) – 25 September 2018 Central Winchester Regeneration Update and Establishment of Advisory Panels

CAB3106 (CWR) – 27 November 2018 Central Winchester Regeneration update

CAB3124 (CWR) – 22 January 2019 Central Winchester Regeneration Progress

CAB3142(CWR) – 19 March 2019 Central Winchester Regeneration Update on Progress

APPENDICES:

Appendix A: Archaeology Panel Report

The Archaeology Panel Report can be accessed from the CWR page on the WCC website: <https://www.winchester.gov.uk/projects/central-winchester-regeneration-technical-reports>

Appendix B: SLR Archaeology Report

SAXONGATE, WINCHESTER

Archaeological Deposit Characterization
Prepared for: Winchester City Council

SLR Ref: 406.06762.00004
Version No: 3
June 2019

SLR 

Winchester City Council
Archaeological Deposit Characterization
Filename:
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June 2019

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1.0 INTRODUCTION

1.1 Summary

This document has been written to assist with effective early planning for the proposed Saxongate (Regeneration) project, so that the potential impacts on buried archaeological remains can be identified at an early stage, and used to inform design and the decision-making process. By following best practice to gather specific data as early as possible, potentially damaging and costly design details can be minimised, and appropriate management measures adopted for the future long-term conservation of the archaeological deposits.

The survey work recommended below will help understand the options for sustainable development balanced against the conservation value of significant historic remains. To achieve this, best practice requires data-gathering as early as possible, with sufficient data points to ensure a robust statistical base for interpretation of test results, preferably over the duration of several years to even out seasonal and annual fluctuations in hydrological conditions. Ultimately the survey programme needs to establish the extent and condition of buried archaeological remains, their vulnerability to change within the burial environment through regeneration of the area, and whether it would be viable to conserve the deposits during and following demolition and reconstruction of the area.

Alternatively the data gathered by the recommended surveys may suggest that deterioration would result from the proposed regeneration project, or indeed that the deposits are already under threat and will decay if no proactive action is taken. In these scenarios it would be important to maximise the scientific value of the deposits, through a programme of archaeological excavation, recording, analysis and dissemination of the investigation results, instead of trying to manage the long-term preservation of the deposits.

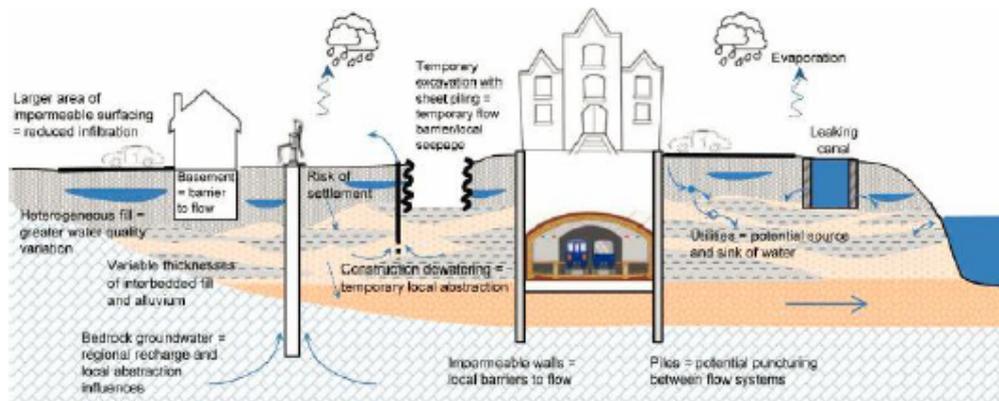
1.2 Background understanding

The "Saxongate" site covers c.6ha in extent, mainly consisting of hard surfaces and modern buildings, through which pass various water-courses (open and underground). Archaeological deposits have been estimated to survive up to c.4m in depth, with good artefact preservation in the upper levels, and with waterlogging assumed to have preserved organic remains in deeper parts of the site. The deposits comprise lenses of alluvial and anthropogenic-influenced silts, as well as tufa, with chalk the geological bedrock underlying the Holocene sequence.

Although two main excavations and several smaller investigations/watching-briefs have been undertaken in the Saxongate area, bespoke ground investigation for deposit characterization and hydrological modelling has been very limited in extent, and the majority of the data-sets are not publicly available. The nature, condition and significance of these archaeological deposits is therefore poorly understood at the present time, and it is uncertain to what degree they would have suffered direct damage and long-term degradation from previous activities such as the changes to the built environment that occurred in the 1980s. Figure 1 shows a schematic representation of the types of environment and threats for waterlogged deposits within an urban context.

Advice is therefore sought by the council on the design, costs, implementation and duration of an appropriate scheme of work to sample and monitor the deposit sequence within Saxongate.

Figure 1
 Schematic representation of below ground hydrological environment and urban threats



From Historic England 2016 guidance "Preserving Archaeological Remains p.22

1.3 Scope of Works

The aim is to gain a better understanding of the buried deposits within Saxongate by characterizing their physical and chemical nature, their origins and hydrological influences. A suitably experienced consultant archaeologist is required by WCC to advise them on the following key tasks:

- Recommendations for an overall strategic approach
- Options appraisal as to various methods and techniques that could be applied
- Guidance on designing an appropriate scheme of investigation
- Indicative estimate of costs and duration of works
- Input to the procurement process and documentation
- Foundation design and innovative design solutions to minimise impacts
- Oversight of investigation, assessment and monitoring work

1.4 Remote sensing survey techniques

Various options are available for detecting features below ground surface including aerial and satellite imagery, multi-spectral scanning, LiDAR, and a range of geophysical prospecting techniques. Within an urban context the applicability of such techniques is far more compromised than in rural locations, however, and the only useful non-invasive method is ground-penetrating radar (GPR)¹. This is more complex than more traditional geophysical survey, and generally more expensive as it needs a large amount of data processing. It transmits an electromagnetic wave into the ground which will bounce back from any change encountered within the deposits up to c.2m depth, although depths achieved will depend on the nature of the deposits. For example heavily saturated clays or modern materials which intervene between the instrument and base of deposits, will reduce

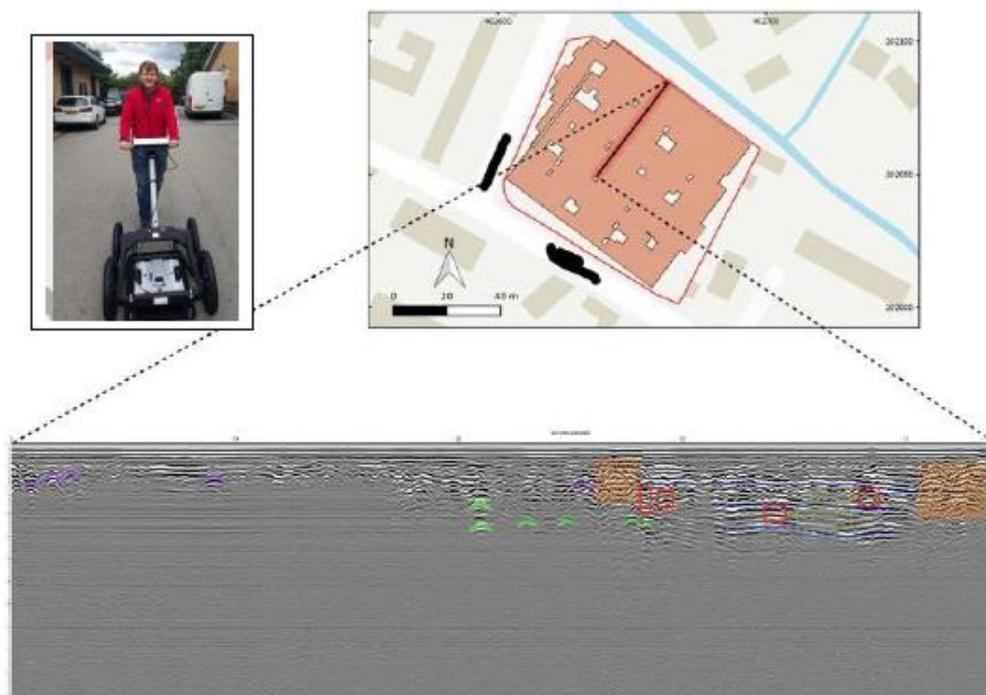
¹ With thanks to Magnitude Surveys for their specialist help on summarising the applicability of GPR in an urban setting

the effectiveness of this technique. The time taken between sending and receipt of the signal is used to build a time slice through the deposit profile (Figure 2), and the data are usually calibrated against a control feature, such as buried services.

The advantage of GPR lies in the fact that it can produce results from urban contexts, both indoor and outdoors, providing a flat surface is available for the survey equipment. It can also indicate the depth of the features detected, and with enough time slices, the data can be processed to produce plans at different dates.

Disadvantages are that application in areas in proximity to water-courses risk poor penetration depth due to saturated clays, and modern materials such as reinforced concrete produce a "ringing" effect which can invalidate the results. The processed data always need human interpretation, and the validity of these interpretations would then need to be proved by intrusive archaeological trial trenching or test pitting.

Figure 2
 GPR within an urban context with time-slice plot of results beneath



Images courtesy of Magnitude Surveys Ltd

1.5 Intrusive archaeological investigation

Archaeological investigation has occurred previously in the western part of the Saxongate area at The Brooks (1987-8), and Lower Brook Street from the 1960s and later (mostly within the car park). Trial trenching or test-pitting within an intensively used urban area is a complex and expensive operation, and although this method of

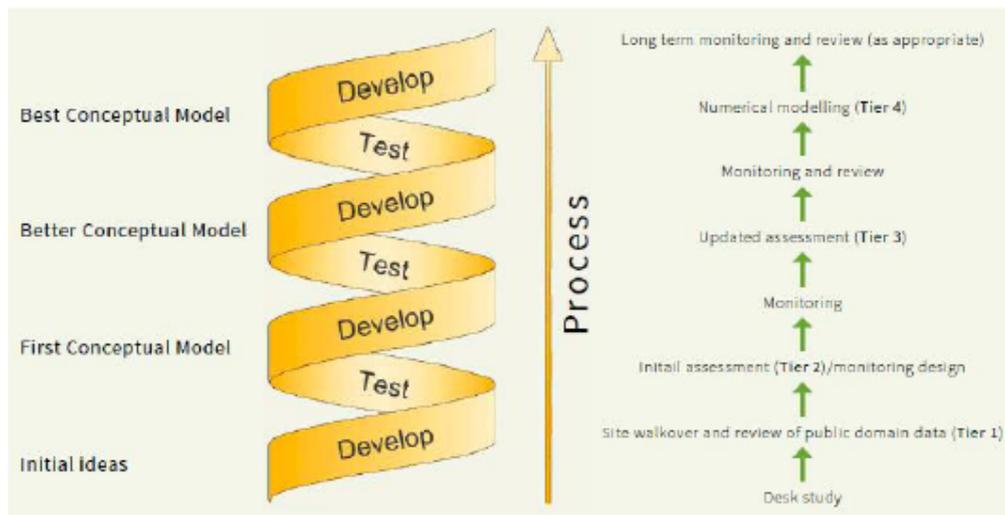
investigation would provide key-hole insight to the type of remains and the nature of the deposits preserved beneath the extant surface, it also introduces decay of organic archaeological remains in proximity to the trial pits through drying out of the deposits that become exposed to oxygen ingress and sunlight. Geoarchaeological investigation using boreholes minimises such potential damage, and helps to characterize the sedimentary deposits, although it provides very little information on features and structures, or artefactual preservation.

1.6 Historic England guidance for waterlogged deposits

In 2016 Historic England published a detailed series of advice papers on waterlogged archaeological remains with recommended methods for investigation of their character and vulnerability assessment². Sections 2.2 – 2.4 of this guidance discuss a structured approach to data gathering starting with desk studies of available information, progressing to intrusive investigation for characterization of environmental conditions and preservation assessment, whilst Chapter 4 examines the issues of water availability and stress, advocating a tiered approach in 4.5 to gaining an understanding of the hydrological regime (Figure 3). Appendix 3, p.13 defines this as:

- Tier 1 is described as a desk study to derive the first conceptual model;
- Tier 2 is a basic qualitative assessment of water balance to identify groundwater levels, flow directions and identify key potential influences on the groundwater system;
- Tier 3 is a conceptual model tested using site-specific measurements, simple analytical equations and long-term average water balances, to arrive at a 'better conceptual model'; and
- Tier 4 recommends development of a numerical groundwater model, calibrated and validated against monitoring data from the site and surrounding area.

Figure 3
 Diagram showing tiered assessment for waterlogged deposits



From Historic England's guidance *Preserving Archaeological Remains 2016*, Appendix 3, p.13

² Williams, J., Howarth, C., Sidell, J., Panter, I., and Davies, G. 2016 *Preserving Archaeological Remains Decision-taking for Sites under Development* (and five appendices) Historic England

This guidance included several case studies including the c.4m deep archaeological deposits that underlie the historic core of Nantwich in Cheshire. The particular relevance of this is given below as an exemplar to assist Winchester with planning an appropriate approach in the conservation of the archaeological remains within the Saxongate area.

1.7 Application to Saxongate

Existing Tier 1 desktop studies have been undertaken for Saxongate which provide a detailed overview of the archaeological resource³ and a preliminary assessment of the hydrogeological conditions⁴ in which archaeological remains have been preserved. A coarse conceptual model has been made possible based on this level of information, but it is insufficient for effective decision-taking by the planning authority and for prospective developers who need more robust data in order to design and budget for schemes that would both regenerate the area, whilst minimising harm to significant archaeological remains, in compliance with national planning policy.

To resolve this deficit in knowledge a more systematic approach to developing this conceptual model is required, through implementation of Historic England's Tier 2 intrusive survey, so that appropriate and proportionate sampling can be achieved to characterize the deposits. Once a grid of datapoints across Saxongate has been established an improved conceptual model can be hypothesized, and then tested through a Tier 3 programme of water level and water quality monitoring.

This level of data will ensure that future decision-making is appropriately informed, and allow the options for development and conservation to be properly incorporated in project planning. It will assist commercial operators to identify risks and opportunities, and increase confidence to encourage investment, as well as ensuring council officers and elected members are able to fulfil their responsibilities in addressing national planning policy expectations.

Best practice and national guidance emphasizes the importance of gathering such data as early as possible, and the longer the period in which data can be gathered, the more reliable the models are that can be reconstructed from these data. The information generated by such surveys and the subsequent onsite monitoring provide an essential baseline from which the master planning exercise and detailed designs can be developed with confidence.

³ Ottoway, P. April 2017 *Central Winchester Regeneration Project Archaeological Desk-Based Assessment* PJO Archaeology

⁴ RPS January 2017 *Desk Study and Preliminary Risk Assessment: Central Winchester Regeneration* RPS Group JER1070

2.0 Nantwich Waterlogged Deposits project: exemplar

2.1 Summary

The nationally strategic aim of the Nantwich Waterlogged Deposits project was to develop and test a scientifically rigorous methodology for characterizing and monitoring the historic buried remains in urban waterlogged deposits so that management plans could be designed to secure the long-term conservation of such remains in ancient urban centres where this is viable.

The objectives of the project were to provide a predictive model of the location of waterlogged deposits in Nantwich, to understand the parameters of their formation and their preservation, and to assess their vulnerability. A two phase project was adopted with Phase 1 comprising characterization of the deposits and establishing the baseline conditions, and Phase 2 consisted of a five year programme of water quality monitoring to identify hydrological patterns such as groundwater or rainfall recharge, seasonal or annual change to water levels and chemical quality, so that these data could be compared to the baseline to detect trends in the conditions for preservation of archaeological remains.

From this model a strategy for promoting the preservation of waterlogged deposits in Nantwich was developed, and the resultant strategy was promoted so that regional and national best practice could be informed to assist with the preservation of urban waterlogged deposits at other locations. Winchester would be one such, which should benefit from the knowledge acquired during the pioneering studies undertaken at Nantwich.

2.2 Key parameters for measurement

The Nantwich project tested the effectiveness of various techniques and methodologies for characterizing waterlogged deposits and the preservation conditions for archaeological material within them⁵.

Some key parameters have been identified, and it is possible to identify the most essential elements from the suite employed during the Phase 1 baseline characterization and Phase 2 monitoring programme. This helps for planning the cost effectiveness of future monitoring schemes within waterlogged areas in the UK.

From the Nantwich experience a targeted programme of investigation with sufficient rigour to supply valid data for characterization and monitoring purposes could be employed for Saxongate comprising the following techniques:

Essential techniques

- Permeability and porosity testing of sediments, and in particular the cultural horizons and sediments vertically adjacent;
- Geochemical testing of sediments for ammoniacal nitrogen, ferrous and ferric iron, sulphates and sulphides (or percentage difference between total sulphur and sulphates) to establish baseline sample storage and laboratory testing to be done under as oxygen-free conditions as possible);
- Redox measurements using in situ rigid resin/platinum probes connected to a datalogger (redox cannot be measured in unsaturated conditions);
- Water levels and rainfall on a daily basis;

Desirable (but not essential) techniques

⁵ SLR Consulting Ltd November 2009 *Nantwich Waterlogged Deposits Report No. 2 The Character and Extent of Archaeological Preservation* Cheshire County Council & English Heritage 3839 Main; Malim, T., Swain, M., and Panter, I. March 2017 *Nantwich Waterlogged Deposits Report No. 4 Phase 2: Monitoring Programme Results and Interpretation* Historic England HEEP 3839 Main SLR Consulting Ltd

- Water quality dip meter testing particularly dissolved oxygen on a quarterly basis;
- Gas monitoring, particularly methane and carbon dioxide on a quarterly basis;
- Geochemical analysis of water samples on an annual basis to confirm validity of water testing dip-meter results;
- *In situ* moisture testing from sediments which comprise the cultural horizon and from the stratigraphic sequence above and immediately below it, using either Total Domain Reflectometry (TDR) or Frequency Domain Reflectometry (FDR) techniques.

The validity of gas emissions in helping to characterize whether conditions conducive for preservation exist, requires accurate scientific dating so that modern contamination does not present misleading data. The Nantwich project has built on previous experimental work to show how this can be achieved, and a detailed methodology for gas sampling is available in the final Nantwich report⁶. The importance of the accurately dated gas emissions is that the results can be considered as closely related to the organic remains which have been preserved, rather than providing data from more indirect water quality proxy indicators derived from a mixture of sources which have become combined within the dipwell.

2.3 Baseline data gathering (Phase 1 (HE Tier 2))

Following the desk study of previous archaeological investigations and borehole data at Nantwich⁷, the programme continued with two stages of borehole sampling and assessment of c.30 sediment cores so that the physical and chemical character of the burial environment in which archaeological remains are preserved, could be interpreted⁸. This was complemented by a scientific dating programme through use of dendrochronology and radiocarbon determination. An iterative approach was adopted so that each phase in the programme could be discussed with the steering group, and the results used to inform the next phase of work. On completion of the deposit characterization phase, assessment of palaeoenvironmental remains, diatoms and waterlogged wood was conducted. Interpretation of the results required application of a simplified terminology so that valid comparative analysis and synthesis could be undertaken.

2.3.1 Drilling and sampling

Core retrieval

The most suitable technique for intrusive investigation for deposit characterization and sampling was a compact windowless sampling rig to obtain percussive core samples, extracted in cylindrical Perspex sampling tubes which preserves the samples intact and protects them during transportation. This technique uses a heavy weight attached to a sliding runner enclosed behind a metal cage to hammer in a metre-long sampling barrel to obtain a one metre core of soil contained within the plastic tube. A tubular metal case is advanced outside the cutting barrel every time a sampling tube is advanced. This ensures that any overlying loose material does not collapse in on top of the material below, ensuring that a sequentially continuous sample is obtained. This is essential in correlating the depth of sampling with the chronological succession of deposition.

The rig was also very compact, and being mounted on tracks it is highly manoeuvrable, enabling the rig to access locations quickly and easily (Figure 4). In addition to providing high quality samples quickly and

⁶ Malim, T., Swain, M., and Panter, I. March 2017 *Nantwich Waterlogged Deposits Report No. 4 Phase 2: Monitoring Programme Results and Interpretation* Historic England HEEP 3839 Main SLR Consulting Ltd (section 4.6)

⁷ SLR Consulting Ltd July 2007 *Waterlogged Archaeological Deposits. Nantwich, Cheshire: Desktop study of archaeological and borehole investigations* Cheshire County Council & English Heritage

⁸ This phase fits within Historic England's guidance at Tier 2

safely, windowless sampling at Nantwich was the most cost-effective solution available. Although this method can struggle to penetrate harder materials at depth it was considered not to be a problem as it would only be necessary to sample soft superficial deposits at depths of less than 6 metres.

Figure 4
Drilling rig for retrieving cores and installing dipwells



Porosity testing

Undisturbed samples from cultural horizon(s) and stratigraphically conjoined sediments above and below to identify the percentage of void spaces within these deposits. Sub-sampling cores when possible, but alternative method (if an open face was available) was to insert sample tubes or tins to extract a small monolith through the cultural horizon and adjoining deposits.

Sample testing

Sub-samples of the sediment cores were selected on site for subsequent laboratory assessment, with an allowance for laboratory assessment of two sub-samples from each core. The selected samples were assessed for:

- Water content (moisture content);
- Organic matter content (loss on ignition);
- Carbonate content;
- pH;
- Nutrients (nitrates and phosphates);
- Sulphates and sulphides; and, additionally
- Particle size distribution

The laboratory tests were undertaken at suitably accredited (e.g. UKAS) chemical and/or geotechnical laboratories and in accordance with relevant British Standards Codes of Practice, BS5930:1999 and BS1377:1990. For future assessment it is recommended that the methodology employed recently at Avaldsnes, Norway (Martens and Bergersen 2015⁹) is followed. In this study sediment samples were packed in plastic bags which were then inserted into another plastic bag containing an oxygen scavenger to create anaerobic conditions. All samples were stored at 4°C and opened in a nitrogen atmosphere with analysis of redox sensitive parameters also conducted in a nitrogen atmosphere. Whether commercial UKAS approved facilities have this capability will need to be ascertained, as the methodology does not appear to be included with the relevant British Standard (BS 1377, part 3, 1990). A similar problem with potential ingress of atmospheric oxygen into the groundwater sample bottles could be mitigated by the use of vacuum canisters.

Sediment particle size assessment

Particle size analysis used a MasterSizer 2000 optical unit, using a Hydro2000MU accessory unit for sample mixing (by the tumbler method). Each sample was placed into a clean glass jar with a secure lid, and the jar rotated about its circumference for 30 full revolutions (jars would be thoroughly cleaned between samples). The less than 1 mm fraction was added to dispersant (water) in the Hydro2000 MU unit, until an obscuration factor close to 15% was obtained – this obscuration allowed the operator to set the concentration of the sample when it was added to the dispersant and is a measure of the amount of laser light lost due to the introduction of the sample within the MasterSizer 2000 analyser beam. The MasterSizer uses the optical unit to capture the actual scattering pattern from the field of particles and then calculates the size of the particles that creates this pattern. The output is in the form of a percentage distribution of particle size.

Sediment descriptions on site

Descriptions of the sediments represented in the core samples and the boundaries between them were made in long hand to comply with (but not limited to) the requirements of BS5930 the Code of Practice for Site Investigation (i.e. to include at least a record of colour, consistency, structure, weathering, lithological type, inclusions and origin) and also summarised for presentation following Troels-Smith (1955).

⁹ Martens, V.V., and Bergersen, O. 2015 In situ site preservation in the unsaturated zone: Avaldsnes Quaternary International 368, 68-79.

The details from these descriptions made the visual presentation and interpretation of the results, comparison and generalisation between boreholes, very complicated. It was therefore decided to assign individual lenses from the detailed logs into groups that conformed to one of five categories:

- Made ground: records from the higher part of the borehole which included brick, mortar, modern materials, or identifiable inclusions datable to the 18th – 20th centuries
- Archaeological deposits: silts, clays and sands, black – light grey in colour, which contained evidence of human activity such as ash, charcoal, pottery, bone etc
- Mineral-rich deposits: grey clays, silts and sands that contained no organic or archaeological inclusions but were not part of the natural drift geological sequence
- Non-carbonised organic-rich deposits: plant-microfossils, wood, leather, plant debris and sulphide smell
- Fluvio-glacial deposits: records from the lowest part of the borehole describing sands that form the top of the natural geological sequence

Such generalization may have led to some slight discrepancies between the detailed reports of the various disciplines involved in this project, but it has served to make the data more intelligible and transferable between different specialists.

The boreholes were extracted in one metre plastic sleeves which had to be split in order to examine and describe the sediment sequences in the field (some were similarly examined at the laboratory as recording of the cores proved to be a longer process than their recovery).

The properties of the sediments were recorded and a preservation category (PC) assigned to the layers following the state of preservation scale (SOPS)¹⁰ established by the Bergen excavation office for the recording of borehole samples.

The cores were subdivided into subsamples according to their stratigraphic composition and placed into labelled polythene bags. Where the sediment was consolidated the sampling was undertaken so as to preserve the stratigraphy. Where unconsolidated, the depth range of the sequence was recorded but the internal stratigraphy of the subsample could not be retained.

Macrofossil recording

Plant and invertebrate remains in the processed subsample fractions (washovers and residues) were recorded briefly by 'scanning' (using a low-power microscope where necessary), identifiable taxa and other components being listed on paper. When the fractions were primarily mineral in nature or of charred remains they were dried prior to recording and when predominantly of waterlogged organic material they were examined wet. A five-point scale was employed to record the proportion of organic material recovered in the washover fraction.

Microfossil recording

Microfossil content and preservation was investigated using the 'squash' technique of Dainton (1992)¹¹. This was originally developed specifically to assess the content of eggs of intestinal parasitic nematodes

¹⁰ http://www.riksantikvaren.no/filestore/veileder_komp.pdf *The monitoring manual, procedures & guidelines, for the monitoring, recording and preservation/management of urban archaeological deposits* Riksantikvaren (the Directorate for Cultural Heritage in Norway, and NIKU

¹¹ Dainton, M 1992 A quick, semi-quantitative method for recording nematode gut parasite eggs from archaeological deposits *Circoea*, *the Journal of the Association of Environmental Archaeology* 9, 58-63

but routinely reveals other microfossils, such as pollen and diatoms. The assessment slides were scanned at 150x magnification with 600x used where necessary.

Condition assessment of preserved wood

Standard wood decay tests (Panter and Spriggs 1996)¹² were carried out including maximum water content, density and "loss in wood substance".

Maximum Water Content: this is a measure of the amount of water present within the sample of wood expressed as a percentage of the dry weight. High water content (usually greater than 185%) indicates a high level of decay of the wood.

Density Assay: the density of wood is determined by the amount of "wood substance" present per unit volume (Dinwoodie 1989)¹³ and hence a reduction in "wood substance" (through decay) will result in a lower density. Density values were determined by weighing the sample in air and submerged under water and using standard formulae (Cook and Grattan, 1990)¹⁴.

Loss in Wood Substance: is defined as the difference between the sample density and the density of undecayed wood of the same species. For example, the standard density of English oak is 0.56g/cc.

2.3.2 Geochemical assessment of the sediments

Samples were selected following on site assessment of each core in discussion with the project palaeoenvironmentalist. Samples were selected from those deposits that appeared to be "archaeological" and also from deposits that appeared to have an organic component. Further samples were also taken from predominantly mineral sediments and also from around fragments of wood. Overall, whilst not all boreholes were sampled, sufficient samples were taken from a range of deposit types to enable deposit characterisation.

Approximately 250g of sediment was extracted from the core and stored in an airtight plastic container which was then kept at a low temperature until despatch to the laboratory. The majority of samples were despatched within 96 hours of sampling. Parameters measured by the laboratory (using standard techniques) included pH, loss on ignition, total organic carbon, natural moisture content ratio and assays for total sulphur, sulphide, sulphate, nitrate, carbonate and phosphate. Unfortunately the laboratory was unable to undertake iron II and III assays.

Rationale for tests

The suitability of a burial environment for preservation of organic material can be determined by looking for a number of chemical species which are termed redox sensitive parameters.

Redox sensitive parameters

Decay processes within soils and sediments are primarily an oxidative process mediated by microorganisms. In deposits where oxygen is abundant aerobic organisms will utilise this oxygen to oxidise organic material, and the oxidation reaction is always accompanied by the reduction of other compounds. When the oxygen supply is exhausted further oxidation/reduction (redox) reactions will occur again mediated by specific groups of microorganisms, and represented by the predominance of

¹² Panter, I., and Spriggs, J. 1996 Condition Assessments and Conservation Strategies for Waterlogged Wood Assemblages in Hoffman, P. et al (Eds) *Proceedings of the 6th ICOM Group on Wet Organic Archaeological Materials Conference, York*

¹³ Dinwoodie, J.W. 1989 *Wood: Nature's cellular polymeric fibre-composite* The Institute of Metals

¹⁴ Cook, C., and Grattan, D.W. 1990 A method for calculating the concentration of EG for freeze-drying waterlogged wood in Hoffman P. (Ed) *Proceedings of the 4th ICOM Group on Wet Organic Archaeological Materials Conference, Bremerhaven*

different chemical species/compounds within the burial environment. Therefore oxidation reactions will occur even if oxygen is absent. The major redox sensitive parameters that can be measured include:

Table 1 Redox sensitive parameters (from Corfield 2007)

System	Redox potential range (mV) corrected to pH 7	Microbiology
Oxygen disappearance	+500 to +350	Aerobes
Nitrate disappearance	+350 to +100	Facultative anaerobes
Manganese ²⁺ formation	Below +400	Facultative anaerobes
Fe ²⁺ formation	Below +400	Facultative anaerobes
Sulphide formation	0 to -150	Obligate anaerobes
Methane formation	below -150	Obligate anaerobes

The above redox sensitive compounds will be utilised by the microorganisms in order to oxidise organic material present in the burial environment, and once a compound has been exhausted, or is absent, then the microbes will utilise the next compound lower on the list. Aerobic bacteria require oxygen to be present, facultative anaerobic bacteria can grow in both oxygen rich and oxygen free environments and obligate bacteria can only grow in oxygen free environments.

Therefore it is possible to characterise the nature of a burial environment by either identifying which redox sensitive parameters are present or by measuring the redox potential (termed Eh, measured in mV) using a suitable redox probe. In order to better understand measured redox values, it is important to identify which redox sensitive parameters are present within the burial environment.

Additional tests carried out on each sediment sample included phosphates (to assess level of nutrients for microbiological activity, Loss on Ignition (LOI) to assess overall concentration of organic material in the sediments, and carbonate and pH to identify whether the deposits were acidic or alkaline in character. Further tests automatically undertaken by the laboratory included total organic carbon (TOC) and moisture content ratios.

2.3.3 Monitoring well installation

A 50 mm diameter slotted PVC monitoring well was installed in boreholes to provide a means of monitoring groundwater and gas emissions, and obtaining groundwater and gas samples as required. Well screens were positioned to intercept water levels within the underlying soil strata, and the annulus between blank casing and the borehole was sealed with bentonite. A rubber bung with a gas tap was placed on top of each well to allow natural soil gases to build and be monitored using a gas analyser. Each hole was capped off with a stopcock cover set in concrete.

The condition of several monitoring dipwell covers and gas taps gradually deteriorated over time, particularly in areas with high traffic volumes. Ongoing maintenance of the headworks was therefore required to ensure that the wells remained accessible.

2.3.4 Groundwater baseline testing

The depth to groundwater and the base of the well were measured using a dip meter, and the total organic vapours were measured using a GMI gas surveyor calibrated to pentane. Groundwater samples were taken using a peristaltic pump discharging through a flow cell connected to a digital water quality meter made by Hannah® instruments Ltd. All of the groundwater samples were filtered using a 45 micron filter. Properties including pH, eH (REDOX Potential), conductivity, temperature and dissolved oxygen were recorded using the water quality meter.

The analysis for sulphate, sulphide, sulphur, nitrate, phosphate, acid soluble carbonate, carbonate alkalinity, natural moisture content, total organic carbon and loss on ignition was completed at an accredited laboratory. Separate samples were taken using preservatives according to the instructions from the laboratory. These included hydrochloric acid and zinc acetate.

2.3.5 Permeability testing

In situ permeability testing was undertaken in order to assess the differences in permeability within the varying sediments. The tests used a plastic cylindrical slug that had been lowered into the water column to displace a fixed volume from the dipwell. Once the groundwater level had returned to rest conditions the plastic cylindrical slug was removed as quickly as possible. The rate of groundwater recharge was then measured using a pressure transducer to calculate the length of time that the water level took to stabilise. The results were then analysed to calculate the permeability of the deposits at each location.

2.4 Summary results from baseline characterization

Baseline geochemical conditions were described during the initial borehole survey conducted in 2007, following analysis of samples from sediment samples extracted from window samplers. The concentrations of principal redox sensitive parameters, including sulphates, sulphides, nitrates as well as nutrients such as phosphates were determined using UKAS standards¹⁵. The conclusions drawn from these data were that whilst shallow surface sediments were oxidising, deeper sediments could be considered as more reducing in character because the sulphate and nitrate concentrations were low, sulphide was detected in several samples and the pH values were broadly neutral. Taking everything into consideration, the evidence pointed to redox conditions residing between the sulphur and iron boundaries, conditions that, although not optimum, could be conducive to the continued preservation of organic materials, especially where deposits remained saturated and anoxic.

2.5 Water quality monitoring and laboratory testing (Phase 2 (HE Tiers 2 - 3))

2.5.1 Duration and multi-level monitoring

The Nantwich Waterlogged Deposits Phase 2¹⁶ monitoring programme was conducted over a five year period from 2011 – 2016 and was designed to provide scientifically robust data on how preservation conditions within the urban waterlogged deposits beneath the town changed over time. In three locations multi-level dipwells were installed to monitor specific cultural horizons and compare to the data from the full depth dipwells.

2.5.2 Overview

This programme consisted of 18 groundwater dipwells which were monitored every three months and sampled annually, while rainfall was recorded daily. Water quality was assessed for changes in dissolved oxygen, conductivity, pH, temperature and redox potential. Gas meter readings were also taken quarterly, staggered with

¹⁵ (UK Accreditation Service for laboratory testing)

¹⁶ This would fit with Historic England's guidance at Tiers 2 - 3

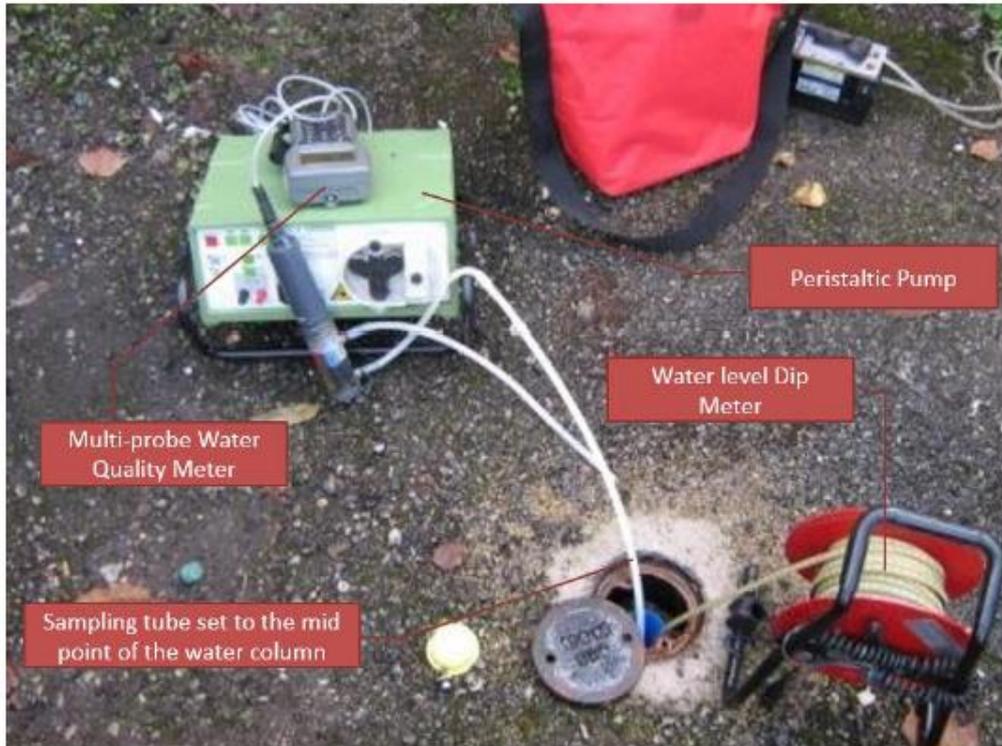
the groundwater testing. Groundwater levels were measured using an audible dipmeter, whilst water quality was assessed by inserting a digital water meter into the dipwell (Figure 5).

In addition the water level was measured automatically on a daily basis at six key locations, so as to provide more detailed data for comparison with the quarterly monitoring. Groundwater samples were taken annually so that they could be tested in a laboratory for what levels of specific chemicals were present. This provided comparative data and a good control, helping provide confidence in the quarterly results of groundwater sampling.

The depth to groundwater and the base of the well were measured using a dip meter during each monitoring and sampling visit. The annual sampling for geochemical indicators was designed in order to provide comparative data for the quarterly monitoring. The quarterly monitoring round and daily monitoring by transducers, were included in the monitoring regime to provide data for understanding seasonal variation, as well as relationship to rainfall events.

Figure 5
Monitoring equipment





2.5.3 Annual sampling for ex situ laboratory analysis

For the annual sampling round groundwater samples were taken in accordance with USEPA guidelines using a peristaltic pump discharging through a flow cell connected to a YSI 556™ digital water quality meter. Properties including pH, eH (redox Potential), conductivity, temperature and dissolved oxygen were recorded using the water quality meter, and each dipwell was purged of stagnant water until the water quality parameters stabilised. The flow cell was then disconnected to avoid cross contamination, and the sample containers supplied by the laboratory were filled using the peristaltic pump, and all of the sample containers containing preservatives were filled with water filtered in the field using a 45 micron filter. The preservatives included hydrochloric acid, nitric acid and zinc acetate. The analysis for pH, conductivity, sulphide, sulphate, nitrate, ammoniacal nitrogen, total dissolved iron, iron II, iron III, dissolved manganese, manganese II, manganese IV, sodium, chloride, phosphate and dissolved methane was completed at an accredited laboratory.

2.5.4 Quarterly sampling for in situ field measurements

For the quarterly monitoring visits when samples were not required, the water quality parameters were recorded *in situ* using the YSI 556™ digital water quality meter. The measurement probes were placed into the monitoring well using a 4m long cable, instead of using the flow cell and peristaltic pump. The probes were left in situ for approximately 15 minutes until the readings had stabilised and the results for each parameter were recorded. This approach was adopted to save time and reduce costs.

2.5.5 Daily monitoring

Daily monitoring was employed at selected locations by installing transducers (data loggers), to monitor more detailed changes to water levels. These were installed at the base of each monitoring well, and the data were downloaded during the quarterly sampling round using an optical reader connected to a field laptop computer on a quarterly basis. The water level was measured manually using an audible dip meter during installation and at each subsequent data download event to confirm the actual depth to water. A barometric pressure data logger was also installed at Nantwich Museum in order to calibrate the readings from the water level data loggers.

A rain gauge connected to a digital data logger was also installed to the rear of Nantwich Museum. The rain gauge consisted of a calibrated tipping bucket mechanism connected to a data logger that counted the number of tips caused by rainfall.

2.6 Gas monitoring and sampling

Quarterly ground gas monitoring was undertaken in each of the installed seventeen dipwells using a Geotechnical Instruments GA2000 or GA5000 gas analyser. The Gas Analyser was used to measure the concentration of hydrogen sulphide, methane, oxygen, carbon monoxide and dioxide through the gas taps which have been fitted to the majority of dipwells. Methane and hydrogen sulphide are indicators of anaerobic conditions, whilst oxygen, carbon monoxide and carbon dioxide are more indicative of aerobic deposits.

Liaison with Historic England's scientific dating team and with SUERC identified an acceptable methodology and equipment for sampling gas, and rapidly processing these samples to extract a radiocarbon determination for the potential age of the origin of the gas.

2.7 Monitoring duration

Duration of data gathering for monitoring the waterlogged deposits has demonstrated the risks inherent in this if conducted over too short a period, and at Nantwich it was necessary to adopt a period of five years to achieve a robust understanding of trends in the data, and to average out particular events which would otherwise have skewed the results. It is recommended that future monitoring programmes gather data over a period of at least five years. Furthermore the results have raised some potential discrepancies between the redox measurements gathered from water sampling and what the geochemical conditions from the sediments would suggest, and this highlights the need for specific research comparing the results of *in situ* sampling and analysis, with *ex situ* laboratory testing of samples¹⁷.

2.8 Capillary fringe and preservation conditions

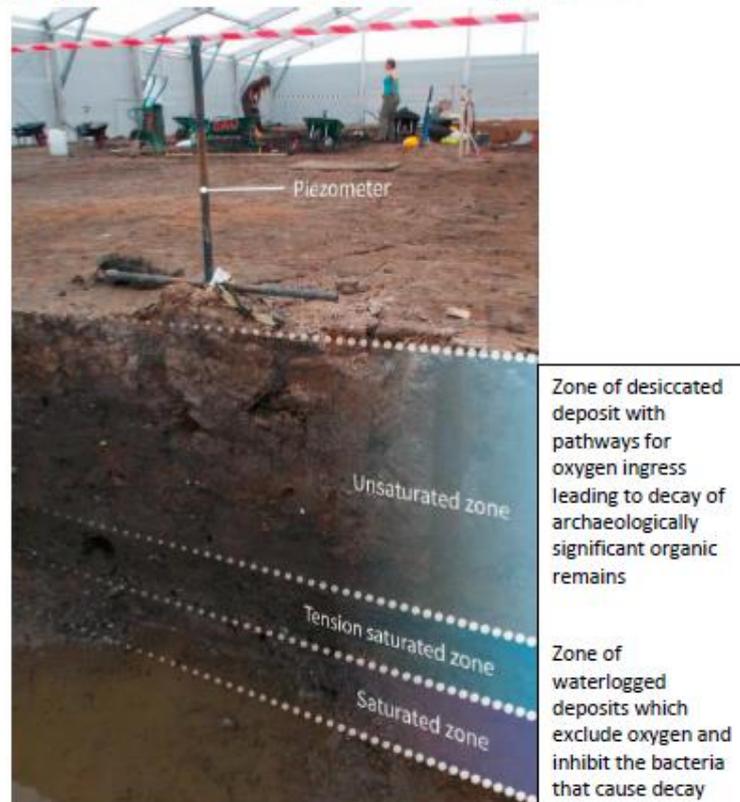
The significance of the vadose zone (or capillary fringe/tension-saturated zone) for preservation of organic remains has often been overlooked in the past, although various studies have been conducted in the last decade aimed at increasing understanding of the role that capillary action can play in producing conditions conducive for preservation. This is the zone above saturated deposits, but where capillary action sucks up sufficient moisture to fill voids in the sediment and therefore exclude most or all oxygen ingress (Figure 6).

Further research into preservation conditions in urban waterlogged deposits is required to identify key trigger points for minimum and maximum conditions necessary for the continued preservation of organic remains. Norwegian studies of sediments have characterized good preservation conditions as including ammonium at

¹⁷ Feedback received from three geoarchaeologists who reviewed the draft report offered very different opinions and levels of scepticism about the validity of sampling anaerobic deposits and laboratory testing of them. However, the holistic approach adopted at Nantwich allowed for *in situ* and *ex situ* complementary techniques so that the effect of potential methodological flaws could be minimised.

levels of over 50 mg/kg, sulphide at over 100 mg/kg, sulphate at over 500mg/kg and reduced iron at over 80%. Poor conditions are represented by nitrate at levels of over 10 mg/kg, sulphate at less than 500 mg/kg, reduced iron at less than 20%¹⁸.

Figure 6
 Capillary fringe (Tension Saturated Zone) as part of waterlogged deposits



From Historic England's Preserving Archaeological Remains 2016 p.24

2.9 Main conclusions from the Nantwich pilot project

The Nantwich study has demonstrated the need to adopt an holistic approach to the understanding of the dynamics of the urban waterlogged environment. Neither a single parameter, nor single test will adequately describe the nature of the burial environment and the degree of preservation of the archaeological resource. There is a need for applying multiple methods and use of multiple proxy indicators to substantiate results and assist with interpreting valid trends in the data.

¹⁸ Martens, V.V., and Bergersen, O. 2015 *In situ* site preservation in the unsaturated zone: *Avaldsnes Quaternary International* 368, 71.

The study has also revealed the pitfalls inherent in using proxy indicators such as redox and gas measurement, where there are significant risks in "over-interpreting" the results - soil redox reactions are by their very nature highly complex and influenced by external factors. Too much can be read into a set of single spot readings. Although the correlation between good preservation and a highly reducing environment is well established, the precise mechanics of preservation in a highly dynamic urban environment remains less understood. The vadose zone remains one of the least understood environments, and further research, along the lines conducted in Nantwich, should be initiated to help solve the conundrum of well-preserved organic archaeological materials found above the saturated deposits.

Overall the Nantwich project has identified the difficulties involved in producing a coherent understanding of all the complex issues that help to preserve, or threaten, buried remains. Equally challenging is the problem of how to influence decisions at a sufficiently strategic level to provide effective long-term management as the best approach is to change behaviour so that future infrastructure, public realm and building projects in the town are designed in such a way as to encourage re-watering of the deposits. These would include permeable surfaces, sustainable urban drainage (SUDs) or Swales, rain gardens and similar approaches for appropriate water management.

The aim is to raise awareness of the issue among decision-makers in the local authority (including spatial planners and engineers), whilst also educating developers in the importance of the archaeological resource and its sensitivity to intrusive works. Standing buildings are threatened if the drying-out of waterlogged deposits results in subsidence, a factor that might ultimately be more persuasive than concern for the buried archaeology itself.

3.0 Key points for Saxongate to consider

3.1 Ground Penetrating Radar

Although GPR could be employed in some discrete parts of the Saxongate area, its efficacy for revealing the complexity of below ground archaeological remains would need to be tested through intrusive excavation. This technique might show walls, hard surfaces, banks, ditches, possible timber structures, and their depth below the surface, but it would not characterize the sedimentary matrix in which these potential archaeological features have survived.

3.2 A recommended suite of analyses and their interpretation

3.2.1 Check list for effective monitoring requirements

In addition to clear documentation on aims, objectives, methodology, parameters, personnel, programme and communications, the results from the monitoring programme have suggested some optimum techniques and methodologies which can be recommended for future monitoring projects in other historic urban centres, or where waterlogged deposits are preserved within the unsaturated or vadose zone. The elements of an effective monitoring programme include:

- appropriately calibrated equipment;
- porosity and permeability testing of the sedimentary deposits;
- a sufficient network of monitoring points across the extent of waterlogged remains;
- a series of georeferenced and levelled borehole logs with descriptions of the deposit sequence detailed enough to identify organic remains, their depths within the sequence, and conditions of preservation (based on the Norwegian protocols);
- geochemical analysis of key parameters from the deposit sequence;
- redox and TDR measurements from deposit horizons which contain organic remains;
- annual geochemical sampling using same suite of parameters as used in baseline;
- gas monitoring for carbon monoxide, carbon dioxide, hydrogen sulphide, methane;
- water level, dissolved oxygen, electrical conductivity, pH, temperature; and
- rainfall measurements

The monitoring interval is dependent on issues such as whether annual or seasonal change is being monitored, but the use of data-loggers allows flexibility. Ideally data should be gathered from the specific horizon with organic remains rather than from a wider zone. The suite of groundwater geochemical testing which has been used as proxy indicators of the conditions for preservation within the waterlogged deposits at Nantwich included:

- Nitrate
- Manganese
- Phosphate
- Sulphate
- Ferric iron (III)
- Ferrous iron (II)

- Sodium
- Ammoniacal nitrogen
- Sulphide
- Chloride
- Calcium carbonate
- Carbon

3.2.2 Proxy indicators of reducing conditions

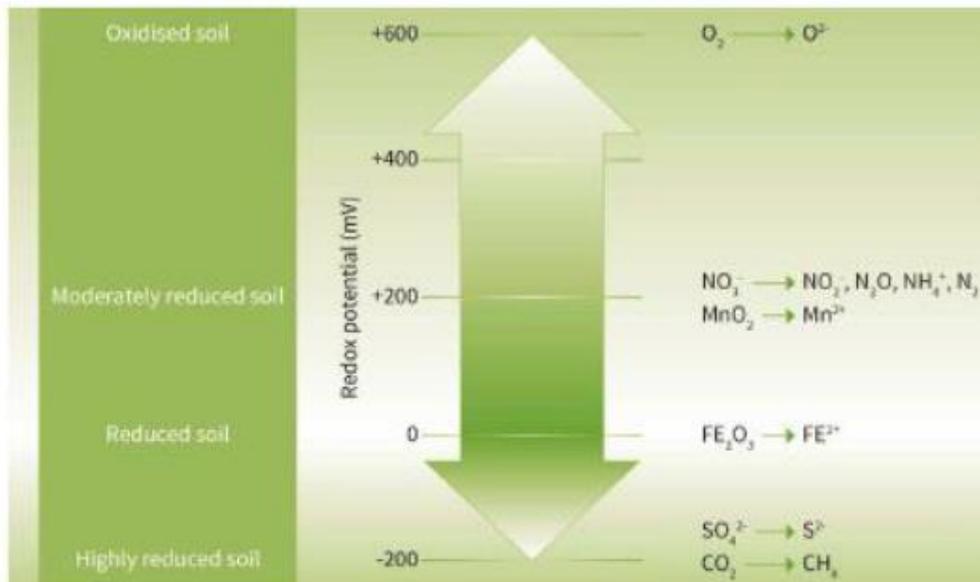
The monitoring data and laboratory analyses permit assessment of whether high levels of degradation are probable due to aerobic conditions, or reducing levels of microbial activity with anaerobic conditions. If dissolved oxygen concentrations exceed 0.5mg/l it is highly likely that aerobic degradation is present¹⁹. The ratio of oxidised and reduced species allows assessment of the redox conditions, for example nitrate and ammonium, oxidised and reduced forms of iron, and sulphate to sulphide ratios.

In summary the chain of electron receptors (or sequence of preference for degradation by micro-organisms) is oxygen → nitrate → iron → sulphate → carbon dioxide (Figure 7). Comparative studies in Norway have suggested that good preservation conditions in sediment require high concentrations of, for example, ammonium (NH₄⁺) >50mg/kg, sulphide (S²⁻) >100mg/kg, sulphate (SO₄²⁻) >500 mg/kg, and less than 80% of reduced iron (Fe²⁺)²⁰. Poor preservation is characteristically defined by low concentrations, e.g. nitrate (NO₃⁻) >10mg/kg, sulphate (SO₄²⁻) <500 mg/kg, and reduced iron (Fe²⁺) <20%.

¹⁹ Carey, M.A., Finnmore, J.R., Morrey, M.J., and Marsland, P.A. 2000 *Guidance on the Assessment and Monitoring of natural Attenuation of Contaminants in Groundwater Environment Agency R&D Publication 95*

²⁰ Martens, V.V., and Bergersen, O. 2015 *In situ site preservation in the unsaturated zone: Avalsnes Quaternary International 368, 68-79.*

Figure 7
 Diagram showing factors that influence poor and good preservation



From Historic England's guidance Preserving Archaeological Remains 2016, Appendix 2, p.4

These chemical analyses inform the initial characterization or baseline survey stage to inform on the current state of preservation, and also during subsequent monitoring to assess whether conditions conducive for preservation exist within the burial environment²¹.

During the Nantwich project the current state of preservation was largely assessed through description of the sediment cores (observation and application of the Norwegian National Standard (NS 9451, 2008²²), assessment of palaeoecological and wood structure, permeability testing, and geochemical analysis of sediment samples.

The monitoring regime that followed on from the characterization of current preservation, focused on groundwater and water quality testing, gas emissions, and geochemical analyses of water samples to assess whether conditions appeared to be conducive for preservation.

3.2.3 Oxygen exclusion

The presence of water has long been understood as a major factor in the reasons for preservation of organic remains as it blocks oxygen ingress into the sediment pores, and so significantly reduces decay rates. Unsaturated archaeological deposits, however, can still contain well-preserved organic remains, as seen in Nantwich in

²¹ See for example Matthiesen, H. 2015 Detecting and quantifying ongoing decay or organic archaeological remains: A discussion of different approaches *Quaternary International* 368, 43-50

²² Riksantikvaren and Norsk Institutt for Kulturminneforskning, 2008, *The Monitoring Manual. Procedures and Guidelines for Monitoring, Recording and Preservation Management of Urban Archaeological Deposits*

dipwells AE and AF for example, where the capillary action through the silts draws moisture up from the water-table into the tension-saturated or vadose zone above. Therefore it is the degree of void space within the sediments which determines how preservation conditions will be affected by oxygen ingress.

Recent studies in Bryggen suggest that when the air content of a sediment exceeds 10 -15% by volume, it will have a noticeable effect on decay mechanisms, but that dissolved oxygen brought in by rainwater is of less importance for the introduction of oxygen into the vadose zone²³. In addition temperature rise accelerates the potential rate of decay for both microbial and chemical reactions, with a 2 – 3 fold increase for a rise of 10°C.²⁴ This only affected dipwell F1 at Nantwich, as most other dipwells recorded temperature change half this range.

The measurement of pH is also important, not only for assessment of redox conditions, but also as an indicator of other chemical changes over time. Studies at Star Carr for example, have recorded a difference in pH between *in situ* measurements and laboratory samples. Increased acidity seems to have been triggered by exposure to oxygen, and even a small reduction in water level or increase in atmospheric oxygen triggered sulphate production²⁵.

3.3 A guide to redox geochemistry of groundwater

Dissolved oxygen at levels of 0.5 – 2 mg/L indicate that aerobic respiration is probably occurring. The Oxygen – Reduction Potential (ORP or Eh) is the relative tendency of a solute to gain or lose electrons, which in groundwater is normally due to the activity of organisms leading to biodegradation. This is measured in electrical current passing through the groundwater and recorded in mV, and calibrated to the standard hydrogen electrode (SHE) so that oxidising conditions occur above c.400mV with increasingly reducing conditions occurring as the measurement drop to -400mV.

Proxy indicators assess what chemical reactions are happening in groundwater, and how this compares to the scale of reduction occurring. The presence of methane and hydrogen sulphide generated from obligate and facultative anaerobes indicate a high level reducing environment, whereas the presence of sulphate, ferric iron and magnesium indicate reducing conditions, with nitrates and phosphates indicating a mildly reducing environment. The absence of these indicators is found in oxidising conditions (see Table 1).

Table 2
 Summary of Principal redox Indicators

Description	Species present/absent	redox value (mV)	Microbes present	Decreasing rate of decay
Oxidising	Oxygen present	400 and above	Aerobes	
Mildly reducing	Nitrate, Manganese (Mn ⁴⁺) decline,	100 to 400	Facultative anaerobes	
Reducing	Sulphate, ferric Iron (Fe ³⁺) present	-100 to 100	Facultative anaerobes and obligate anaerobes	

²³ Matthiesen, H., Hollesen, J., Dunlop, R., Seither, A. and De Beer, J. 2015 In situ measurements of oxygen dynamics in unsaturated archaeological deposits *Archaeometry* 57, 6, 1078-1094

²⁴ Matthiesen, H., Hollesen, J., and Gregory, D. 2015 Chapter 6 Preservation Conditions and Decay Rates in *Monitoring, Mitigation, Management: the groundwater project – safeguarding the world heritage site of Bryggen in Bergen* Riksantikvaren, p.82-3

²⁵ Boreham, S, Conneller, C., Milner, N., Taylor, B., Needham, A., Boreham, J., and Rolfe, C.J. 2011 Geochemical indicators of preservation status and site deterioration at Star Carr *Journal of Archaeological Science* 38, 2833-2857

Description	Species present/absent	redox value (mV)	Microbes present	Decreasing rate of decay
Highly reducing	Sulphate and ferric Iron (Fe^{3+}) disappear Sulphide (S^{2-}), ammonium (NH_4^+), ferrous Fe^{2+} and methane present	-400 to -100	Obligate anaerobes	

System	redox potential range (mV) corrected to pH 7	Microbiology	Burial environment
Oxygen disappearance	+500 to +350	Aerobes	Oxic
Nitrate disappearance	+350 to +100	Facultative anaerobes	Sub-oxic
Manganese ²⁺ formation	Below +400	Facultative anaerobes	
Fe ²⁺ formation	Below +400	Facultative anaerobes	
Sulphide formation	0 to -150	Obligate anaerobes	Anoxic
Methane formation	below -150	Obligate anaerobes	

3.4 Indicative level of costs

Until the specifics of the Saxongate programme have been designed, it would be difficult to calculate a budget. Using Nantwich as a model, however, an indicative estimate of cost can be suggested. The Phase 1 programme of borehole sampling (30 boreholes), baseline characterization, dipwell installation, analysis and reporting from 2007 – 2010 cost £93,330 + VAT. Phase 2 included some further borehole sampling and dipwell installation (six boreholes for multi-level installations) but the majority of the project comprised the five year water quality monitoring programme and subsequent reporting from 2011 – 2017 at a cost of £120,625 + VAT.

The total budget over 10 years was c.£214,000 + VAT, and with an allowance of 15% for annual increments to apply costs at today's level and a small degree of contingency, it is advised that a budget of approximately £250,000 excluding VAT should be allowed for, with a total project duration period of eight years. This includes time for designing an appropriate approach, procurement, implementation, establishing the baseline conditions, monitoring of those conditions over five years, analyses, interpretation and reporting.

3.5 Options for Saxongate area

At Nantwich cores were taken from 30 locations to help define the character of the waterlogged deposits and to map their extent over c.10ha, and 18 dipwell locations were used for the five year monitoring programme. In Bryggen 40 boreholes²⁵ and a similar number of dipwells for long-term monitoring, were used over a much smaller area (c.1.5ha). The Saxongate area is approximately 6ha and there are many logistical issues with finding suitable locations for boreholes/dipwells, however, a grid of locations with at least three lines running north – south and five lines running east – west is recommended. This would require 15 – 20 locations.

²⁵ Riksantikvaren 2015 *Monitoring, Mitigation, Management: The Groundwater Project – Safeguarding the World Heritage Site of Bryggen in Bergen*, p.68

4.0 Conclusions

4.1 Archaeological importance: existing understanding

The Saxongate area is known to occupy part of the historic core of the Roman and medieval town and previous excavations have shown survival of archaeological remains of high heritage significance. Additional information has been provided by borehole records and sampling, conducted by various organizations for diverse reasons over the past c.20 years, which has helped development of a tentative 3D model of the deposit sequence.

4.2 Potential threat to archaeological remains

The impact of the extant buildings and related infrastructure on the archaeological deposits is uncertain, and the change that might have occurred to the hydrological conditions could have affected the preservation and significance of the archaeological remains. If important archaeology survives beneath the current built environment, any new proposals for regeneration would need to factor in how development would be sustainable so that its effect on the waterlogged deposits could avoid endangering continued preservation, or that an appropriate mitigation strategy could be implemented.

4.3 Incentives for an improved level of understanding

The public value of our shared heritage is protected through national policy and the planning system, but decision-making needs to be appropriately informed in order to permit or refuse applications for development. Potential developers who might wish to invest in Winchester's future, also need reliable data on which to base their project design and financial planning.

4.4 Why more investigation is necessary

The existing knowledge base for Saxongate is inadequate for these purposes, and further evidence gathering is recommended so that a more robust understanding of the waterlogged conditions and hydrological regime on site is available, as well as a fuller appreciation of the significance of archaeological remains. This report has identified several potential approaches, and flagged up some positive and negative factors for each. A best practice approach has been given through the exemplar of the Nantwich project, and the recommendations provided by Historic England guidance, so that the specific burial environment in the Saxongate area can be characterized and its sensitivity to change understood.

4.5 Timescales

Phase 1 of this programme of work would be to establish the baseline conditions over year 1, with monitoring against that baseline happening during succeeding years as Phase 2. Although best practice would recommend a period of five years for monitoring to balance out exceptional events (high rainfall, harsh winter, water shortage) valuable data would be gathered over the first year, and subsequent years could coincide with the beginnings of regeneration activities. The results from the first year(s) might indicate that conditions are unsuitable for preservation of some archaeological remains, or that the existing building stock foundations have had a major detrimental impact already, and so a different conservation strategy would be required, such as archaeological excavation, recording and analysis.

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Appendix C: SLR Archaeology Report Summary

ARCHAEOLOGY

Background to the Central Winchester Regeneration Site

- ✦ Archaeological deposits have been estimated to survive up to c.4m in depth
- ✦ Good artefact preservation in the upper levels
- ✦ Waterlogging assumed to have preserved organic remains in deeper parts of the site
- ✦ The nature, condition and significance of archaeological deposits is poorly understood and any damage is uncertain



ARCHAEOLOGY

Background to the Central Winchester Regeneration Site

- ✦ Regeneration proposals need to factor in how development would be sustainable so that its effect on the waterlogged deposits could avoid endangering continued preservation, or that an appropriate mitigation strategy could be implemented
- ✦ Decision-making needs to be appropriately informed in order to permit or refuse applications for development
- ✦ Potential developers who might wish to invest in Winchester's future need reliable data on which to base their project design and financial planning



ARCHAEOLOGY

Background to the Central Winchester Regeneration Site

- ⌘ During the archaeology event in Dec '18, it was agreed that further evidence gathering is needed to better our understanding of the waterlogged conditions and hydrological regime, and gain a fuller appreciation of the significance of archaeological remains:
 - ⌘ Geoarchaeological boreholes
 - ⌘ More detailed hydrological assessment (and water monitoring if required)
 - ⌘ Installation of water monitoring equipment in selected borehole locations (minimum one year)
 - ⌘ Ground Penetrating Radar (GPR)
- ⌘ Advice was therefore sought on an appropriate scheme of work to sample and monitor the deposit sequence at Central Winchester Regeneration (CWR)



ARCHAEOLOGY

Scope

- ⌘ An experienced consultant archaeologist has been procured to advise on the following key tasks:
 - ⌘ Recommendations for an overall strategic approach
 - ⌘ Options appraisal as to various methods and techniques that could be applied
 - ⌘ Guidance on designing an appropriate scheme of investigation
 - ⌘ Indicative estimate of costs and duration of works



ARCHAEOLOGY

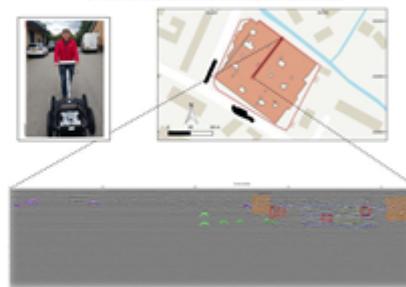
- W A report has been produced which explains how following best practice and data gathering as early as possible can help to minimise potentially damaging and costly design details and how appropriate management measures can be adopted to help conserve archaeological deposits
- W The report sets out a recommended programme of survey work to help understand:
 - W The extent and condition of buried archaeology remains
 - W Their vulnerability to change within the burial environment through regeneration of the area
 - W Whether it would be viable to conserve the deposits during reconstruction of the area or whether deposits would deteriorate from the proposed regeneration / they are already under threat and will decay if no proactive action is taken
 - W If deposits would deteriorate it will be important to maximise their scientific value, through a programme of excavation, recording, analysis and dissemination of the investigation results



ARCHAEOLOGY

Ground Penetrating Radar (GPR)

- W GPR transmits an electromagnetic wave into the ground which will bounce back from any change encountered within the deposits up to c.2m depth
- W GPR can also indicate the depth of the features detected, and with enough time slices, the data can be processed to produce plans at different dates
- W However, areas in proximity to water-courses risk poor penetration depth due to saturated clays, and modern materials such as reinforced concrete can invalidate the results. The processed data always need human interpretation, and the validity needs to be proved by intrusive archaeological trial trenching or test pitting



ARCHAEOLOGY

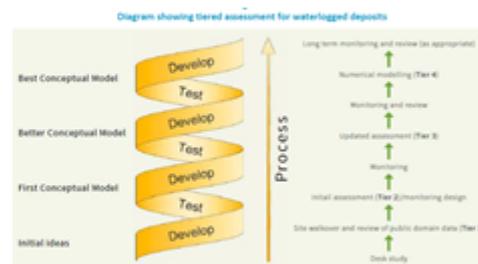
Intrusive archaeological investigation

- ✘ Archaeology investigation has been carried out in the western part of the CWR area (The Brooks and Lower Brook Street) from the 1960s and later
- ✘ Whilst trial trenching or test-pitting will be required eventually, it is complex and expensive in urban areas, and although it will provide key-hole insight to the type of remains and the nature of the deposits preserved beneath the extant surface, it introduces decay of organic remains in proximity to the trial pits through drying out of the deposits that become exposed to oxygen ingress and sunlight
- ✘ Geoarchaeological investigation using boreholes minimises such potential damage, and helps to characterize the sedimentary deposits, although it provides very little information on features and structures, or artefactual preservation.

ARCHAEOLOGY

Historic England guidance for waterlogged deposits

- ✘ Tier 1 - desk study to derive the first conceptual model;
- ✘ Tier 2 - basic qualitative assessment of water balance to identify groundwater levels, flow directions and key potential influences on the groundwater system;
- ✘ Tier 3 - conceptual model tested using site-specific measurements, simple analytical equations and long-term average water balances, to arrive at a 'better conceptual model';
- ✘ Tier 4 - numerical groundwater model, calibrated and validated against monitoring data from the site and surrounding area.



ARCHAEOLOGY

Historic England guidance for waterlogged deposits

- ⌘ Existing Tier 1 desktop studies have been undertaken for CWR which provide a detailed overview of the archaeological resource and a preliminary assessment of the hydrogeological conditions in which archaeological remains have been preserved. A coarse conceptual model has been made possible based on this level of information
- ⌘ A more systematic approach to developing this conceptual model is required, through implementation of Historic England's Tier 2 intrusive survey, so that appropriate and proportionate sampling can be achieved to characterize the deposits
- ⌘ Once a grid of datapoints across CWR has been established an improved conceptual model can be hypothesized, and then tested through a Tier 3 programme of water level and water quality monitoring
- ⌘ This level of data will ensure that future decision-making is appropriately informed, and allow the options for development and conservation to be properly incorporated in project planning. It will assist commercial operators to identify risks and opportunities, and increase confidence to encourage investment, as well as ensuring council officers and elected members are able to fulfil their responsibilities in addressing national planning policy expectations



ARCHAEOLOGY

Nantwich Waterlogged Deposits Project

- ⌘ A two phase project was adopted:
 - ⌘ Phase 1 - characterization of the deposits and establishing the baseline conditions
 - ⌘ Phase 2 - five year programme of water quality monitoring to identify hydrological patterns such as groundwater or rainfall recharge, seasonal or annual change to water levels and chemical quality, so that these data could be compared to the baseline to detect trends in the conditions for preservation of archaeological remains



ARCHAEOLOGY

Nantwich Waterlogged Deposits Project

- ✦ Baseline data gathering (Phase 1 (HE Tier2))
 - ✦ Two stages of borehole sampling and assessment of c.30 sediment cores so that the physical and chemical character of the burial environment in which archaeological remains are preserved, could be interpreted
 - ✦ An iterative approach was adopted so that each phase in the programme could be discussed with the steering group, and the results used to inform the next phase of work
 - ✦ On completion of the deposit characterization phase, assessment of palaeoenvironmental remains, diatoms and waterlogged wood was conducted
 - ✦ Interpretation of the results required application of a simplified terminology so that valid comparative analysis and synthesis could be undertaken



ARCHAEOLOGY

Nantwich Waterlogged Deposits Project

- ✦ Water quality monitoring and laboratory testing (Phase 2 (HE Tiers 2 - 3))
 - ✦ Conducted over a 5 year period and was designed to provide scientifically robust data on how preservation conditions within the urban waterlogged deposits beneath the town changed over time
 - ✦ 18 groundwater dipwells which were monitored every 3 months and sampled annually, while rainfall was recorded daily. Water quality was assessed for changes in dissolved oxygen, conductivity, pH, temperature and redox potential



ARCHAEOLOGY

Nantwich Waterlogged Deposits Project

- W Water quality monitoring and laboratory testing (Phase 2 (HE Tiers 2 - 3))
 - W Gas meter readings were also taken quarterly, staggered with the groundwater testing
 - W Groundwater levels were measured using an audible dipmeter, whilst water quality was assessed by inserting a digital water meter into the dipwell



ARCHAEOLOGY

Timescales

- W Phase 1 of this programme of work would be to establish the baseline conditions over year 1, with monitoring against that baseline happening during succeeding years as Phase 2
- W Although best practice would recommend a period of five years for monitoring to balance out exceptional events (high rainfall, harsh winter, water shortage) valuable data would be gathered over the first year, and subsequent years could coincide with the beginnings of regeneration activities
- W The results from the first year(s) might indicate that conditions are unsuitable for preservation of some archaeological remains, or that the existing building stock foundations have had a major detrimental impact already, and so a different conservation strategy would be required, such as archaeological excavation, recording and analysis

ARCHAEOLOGY

Indicative Costs

- ✎ Until the specifics of the Central Winchester Regeneration programme have been designed, it is difficult to calculate a budget. Using the Nantwich example an indicative estimate of cost can be suggested:
- ✎ Phase 1 (3 years) = £93,330 + VAT
- ✎ Phase 2 (5 years) = £120,625 + VAT
- ✎ Total (10 years) = c.£214,000 + VAT
- ✎ With an allowance of 15% for annual increments to apply costs at today's level and a small degree of contingency, it is advised that a **budget of approximately £250,000 excluding VAT** should be allowed for, with a total project duration **period of 8 years**.
- ✎ This includes time for designing an appropriate approach, procurement, implementation, establishing the baseline conditions, monitoring of those conditions over five years, analyses, interpretation and reporting.



Appendix D: Archaeology Risks:

Risk Number: 5			Risk Owner: Project Executive			
Risk Title: Failure to carry out recommended archaeology investigations ahead of development						
Causes	Consequences	Current Controls	Current Risk Score		Risk Proximity	Financial impact
			Likelihood	Impact		
Cabinet do not approve the recommendations and the investigations are not implemented	Reputational damage Insufficient data to enable informed decisions during the planning process Decreases in land value Potential issues with attracting developers Costs incurred if issues arise during the construction phase	Mitigate: 1) Take report to Cabinet outlining rationale, estimates costs and timescales	Highly Unlikely	Moderate	1	££££
Immediate actions?		Target Date	Residual Risk Score			
			Likelihood	Impact		
Take a report to Cabinet to outline rationale, estimate costs and timescales for approval		August 2019	Highly Unlikely	Moderate		

Risk Number: 6			Risk Owner: Project Executive			
Risk Title: Data collected is insufficient / unreliable and therefore of little value to potential developers						
Causes	Consequences	Current Controls	Current Risk Score		Risk Proximity	Financial impact
			Likelihood	Impact		
Unexpected environmental influences or failure of equipment	Potential financial loss to WCC and delay to the programme	Mitigate: 1) Seek specialist expertise to help form appropriate recommendations for investigations 2) Continue to JLL as SPC, with regards to land value	Unlikely	Low	4	£££
Immediate actions?		Target Date	Residual Risk Score			
			Likelihood		Impact	
Ensure expertise is in place throughout the set up and monitoring so any issues can be identified quickly and dealt with appropriately		Autumn/Winter 2019	Highly Unlikely		Low	