Safeguarding cultural heritage using novel technologies : the perspective from a UK volunteer-led site

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Safeguarding Cultural Heritage using novel technologies: The perspective from a UK volunteer-led site

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Abstract. Continuing anthropogenic induced climate change poses risks to Cultural Heritage (CH) across the world. In the UK, concerns about future flood risks, increased number of heatwaves and changes to freeze-thaw cycles are at the forefront for managers of CH assets. Importantly, in the UK, and unlike many European countries, cultural, natural and built heritage sites are often run by or with the help of groups of volunteers, whether that being at a national level working in partnership with organisations like Historic England or at a local level with small community trusts. Mellor Archaeological Trust is one such local charity which aims to preserve, maintain and protect the local CH assets for our community and future generations. Climate change and its impacts are, therefore, a big concern for the trust as it looks to plan for the future. After a successful pilot of the STORM service, Mellor was able to demonstrate how the use of inexpensive and novel technologies can help small and large volunteer-led organisations in protecting heritage whilst ensuring that correct procedures are followed. In this paper, we demonstrate the successful use of the STORM service from a UK perspective explaining the benefits and drawbacks and highlight how such services should be utilised by other organisations.

1. Introduction

It is widely accepted that climate change, augmented by the rapid increase of anthropogenic greenhouse gas emissions since pre-industrial levels, will have considerable impacts on our environment, society and heritage [1]. The impact of climate change on our cultural heritage is receiving much attention, understandably concentrating on coastal areas that will be threatened by sea-level change both eustatic [2,3] and, more recently, isostatic.

This paper outlines the approach of one project to these threats and problems - STORM: Safeguarding Cultural Heritage through Technical and Organisational Resources Management, a project co-funded by the Horizon 2020 programme of the European Union, specifically concentrating on the UK pilot site at Mellor, Stockport. The STORM project aims to develop a novel set of tools, models, techniques, and services to aid owners of cultural heritage assets in protecting their sites from the impacts of both climate change and natural disasters amongst other threats.

The Mellor Heritage Project (Figure 1) is one of five pilot sites for the STORM project, each selected for their unique combination of threats and needs [4]

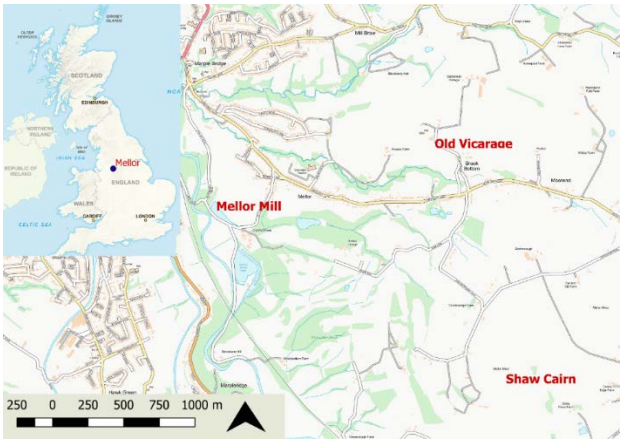

Figure 1: Study Location – Mellor, Greater Manchester, UK

1.1. The Study site

Mellor Archaeological Trust was formed in 2000 as a result of archaeological discoveries in the village of Mellor, Stockport, UK. The aim was to preserve the archaeology for future generations and has since grown to encompass many sites of archaeological interest in Mellor and the surrounding area.

Three such sites have been selected for inclusion in the STORM project: The Old Vicarage site – a site with over 10,000 years of history but with significant Iron-Age and Roman occupation; Shaw Carin – a Bronze-Age burial cairn; and Mellor Mill – an industrial period mill built in 1790s and destroyed by fire in 1892 [5,6,7].

The Old Vicarage site has been occupied in some capacity for the past 10,000 years, beginning with nomadic hunter-gatherers using the uplands as the climate warmed after the Devensian glacial maximum. Excavations at the Old Vicarage site have revealed an Iron Age site comprising two ditches, defining the boundaries of a hillfort. A small outer ditch encompassed an area of 10ha and a much deeper inner ditch encompassed an area of around 2ha. Many postholes and roundhouse gullies have been uncovered. The position of a Medieval aisled hall has also been discovered at the Mellor Vicarage Site. The site is also home to a reconstructed roundhouse built by local college students as part of a European Community Cultural Project. This roundhouse has been designed, to the best knowledge of experts, to a similar specification as that which would have been used on the site 2000 years earlier [7,9].

The site of a Bronze Age burial cairn first excavated in the 1970s, Shaw Cairn has revealed flints, bones, pottery, and an amber bead necklace associated with a central inhumation grave surrounded by later cremation burials [8,9].

Mellor Mill was an impressive mill built in the 1790s by Samuel Oldknow. It was one of the largest cotton spinning mills during its time and became the architectural guide for other mills subsequently built in the region. Oldknow diverted the River Goyt to build two large mill ponds. The Mills was over 120 m long, over 12 m wide and 6 stories high. Burnt down in 1892 and reduced to ground level, the site has been in need of great investment and care and had become overgrown and forested. The Mellor Archaeological Trust and the Canal and Rivers Trust, thanks to heritage lottery funding, are in the process of opening up the mill remains to the public as a mini country park with a CH theme [5,7].

1.2. Volunteer-led

Mellor, as is the case for many sites across the United Kingdom, relies heavily on volunteers to ensure the day-to-day running and general maintenance. Not only is this true for small cultural heritage site, like Mellor, but in the UK even large cultural heritage organisations such as Historic England, National Trust, Royal Palaces, and Natural England all operate under this volunteer-reliant model. Without large numbers of volunteers, cultural heritage preservation in the UK would suffer heavily unless national and regional governments increased their support to offset this loss in the workforce. Continental European

countries, on the other hand, have a more top-down approach where governments, both nationally and locally invest in and support their cultural heritage sector and have greater control over their cultural assets. This is significant for STORM, which could be more easily rolled out in such cases. However, the UK-based sites would struggle to train and develop their volunteer-based workforce on such a wide scale. It was vital, therefore, that the STORM platform was simple to use, required minimal training and development, and was accessible to a wide range of needs and abilities. Only this could ensure that the platform and service were useful and applicable to the UK pilot site and future UK cultural heritage sites which may use STORM. Mellor has a workforce almost wholly volunteer-based. The average age of volunteers for the Mellor site is over 55 years old, and this highlights a key issue unique to the UK pilot. Generally, the Mellor volunteers are not trained professionals but rather members of the public with a desire to protect their local CH.

1.3. Hazards

The environmental threats and the risk multipliers associated with climate change at Mellor are principally precipitation, severe storms, and change in heat-wave/cold wave cycles (Nevell, Williamson & Wit 2019). These threats arise as a result of the location of the three Mellor sites. Shaw Cairn and the Old Vicarage sites are located at elevation on exposed hilltops and are therefore prone to hazards such as high winds and storms. The Mellor Mill site is located at the bottom of a valley through which runs the River Goyt. This site is, therefore, at risk from precipitation induced flooding, but also being remains of an old mill, the exposed masonry is at risk from changes to freeze-thaw cycles. Mellor also highlighted a key anthropogenic hazard – human activity. This can be a natural increase in footfall as the site becomes more used, but also an increase in criminal activity owing to the open, remote location of the site. The hazards identified were used to set out a list of possible scenarios that may be faced by the pilot site and which could be used to test the STORM service and platform. The site, working alongside technical and academic partners developed use cases that could be linked to the hazard scenarios (Figure 2). This formed the basis for the live drills that were run in the last half of the project to assess the usefulness of the service on a per-pilot site basis.

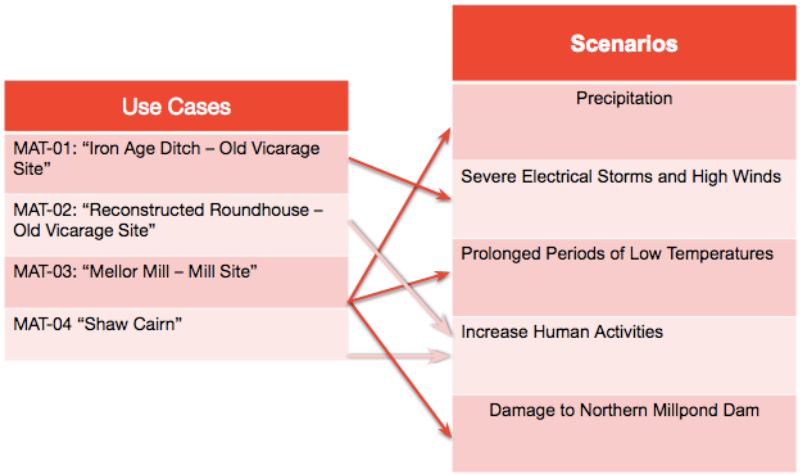

Figure 2: Linkages between Cultural Heritage assets (Use Cases) and hazard scenarios selected to test the STORM platform and service at the UK pilot site

2. STORM Services and Tools

This sections will detail two of the key sensors that were adapted for the Mellor Pilot Site within the context of STORM. It will then chart how a wide range of sensors and tools have been integrated into the STORM platform and how the STORM service as a whole has been utilised at Mellor.

2.1. Automatic Weather Stations

As the Mellor pilot site consists of three unique sites in terms of their individual micro-climate, the solution that was used for monitoring the weather was to select three separate weather stations and deploy one at each Mellor site. This ensured that weather data would be collected close to all four of our use-cases since the sites are located in areas where the localised conditions vary considerably. Shaw Cairn is located high on top of Mellor Moor and is very exposed. Mellor Vicarage is located on a hilltop and is less exposed, and Mellor Mill is located in a valley sheltered from much of the harsh weather experienced across the other two locations.

The weather station selected at Mellor was the Davis Vantage Pro 2 connected to a Vantage connect data logger. This weather station was selected to ensure that a good accuracy and precision were achieved and the data was, within reason, useful to site managers and analysts. Such over the counter weather stations can be purchased at reasonable prices whilst retaining their precision for such uses. Each weather station would principally monitor wind, rain, and temperature. Whilst it should be noted that siting of such "all in one" weather stations can be problematic as all sensors are contained within the same unit, for the purposes of the STORM project these issues are outweighed by the inexpensive nature of the product and the ease at which data can be transmitted to the STORM service and therefore the site. Such a set up can be achieved for less than £1000. This is important for volunteer-led, self-funded sites as it highlights a monitoring solution that can be achieved without large funding.

2.2. NDVI Photogrammetry

A modified DJI X3 camera was purchased where the filters have been modified so that it is able to photograph in the near-infrared and red wavelengths (peak wavelength 660 and 850 nm) whilst filtering out the green and blue ends of the spectrum. The camera is attached to a gimble that is suitable for flying with the DJI Inspire 1 drone. The data is collected and stored on a SD card in both .Raw and .JPEG files. The resulting colourised NDVI image is shown in Figure 3. The monument, Shaw Carin, is clearly indicated correctly (dark red - representing soil and rocks), and the fields below the monument (directly south) and to the east of the monument are correctly coloured green (these are rich pastures for grazing sheep). The range of pixel values as a result of the JPEG compression means that much of the north of the image is incorrectly red, especially the area to the north-east which is similar land use to the south-east of the image despite a very different result.

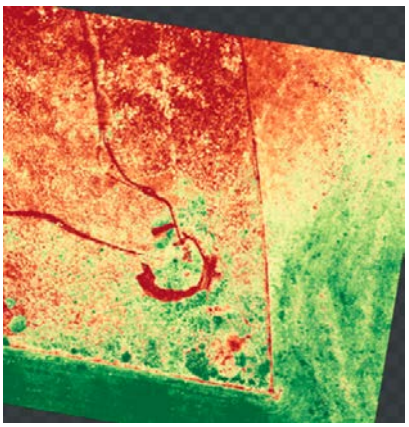

Figure 3: Processed NDVI false colour image output in the GIS

2.3. WASN

Wireless Acoustic Sensor Network (WASN) was supplied to the pilot site for testing at the Old Vicarage area of Mellor. This provided a fantastic opportunity to test the state of the art, novel ideas for specific hazards at Mellor. One such hazard, that the WASN was being trialled was to monitor human activity. The WASN was positioned under a metal bridge which crossed the exposed Iron-Age ditch. In doing

so, Mellor had the possibility of monitoring noises which could be associated with activity close to the asset. Therefore, the technical experts could correlate this data and translate it into useful information that the pilot site can act on to reduce illegal human activity, or in the case of legal activity – the pilot site can take steps to try to understand why activity takes place concentrated on specific areas and can take steps to try to change this if and when required.

2.4. Mobile Phone Gamification

The first three sensors mentioned in the preceding paragraphs give a brief overview of the way data was collected and translated to the pilot site as useful information. Those data were said to be collected *explicitly,* i.e., collected with the knowledge that data would be collected and uploaded to the STORM service where it was converted into useful information that the site could act upon. A STORM game was produced, which was capable of providing the site with *implicit data*. By implicit, the idea was to collect information on human activity utilising not the information recorded when users interact with the application, but instead the information that the app is recording about when, where, and for how long the user is interacting with the app. As with the WASN, this data could inform the site of where footfall is greatest, how visitors and interacting with the site and allow the site manager to alter pathways or the game itself to discourage or encourage visitors to different areas of the site, potentially to ensure the preservation of damaged or prone-to-damage assets. This was key at the Mellor Mill area, where all of the archaeological assets are located at ground level and are freely accessible by the general public.

2.5. The STORM Platform

The sensors installed at Mellor, which include the above-mentioned weather stations and drone photogrammetry, but also wireless acoustic networks (for monitoring human activity close to the site, gamification game responses, allowing the site to monitor when and where site footfall is occurring), surveying and diagnosis services that include laser scanners and photogrammetric methods, all provide the site with a vast and rich set of data. This data is, however, not much use to site managers and employees or volunteers, many of whom will not be experienced enough to interpret the large quantity of data. STORM provided a way for sites to take in these vast sums of information and convert this into real-world, real-time, useful information. In the event the weather stations record data in excess of a pre-defined range of values, the STORM service would inform the site that action needed to be taken to mitigate damage or prevent any damage and significantly prevent loss of life. Moreover, the STORM service provided a platform whereby the site manage who received the alert (Figure 4) would be able to pass on responsibility of the first-responder to the nearest available volunteer or staff member. The platform would be pre-loaded with expert advice from the site, CH experts, scientific and technical experts, and regional and local governance and law experts, for which the user of the app would be able to follow clear guidelines and respond, knowing which assets must be protected in the first instance and how they should go about their task. This provides an excellent use-case example for UK based volunteer-reliant organisations where often the person or people who ought to respond to events may not be based in the vicinity of the cultural heritage site. Ordinarily, pre-STORM this would be an issue which would result in response times extending over days, as opposed to hours, damage occurring to the assets, and potentially greater costs being incurred by the organisation.

Figure 4: Volunteer-led use of the STORM platform in action. Top left: Site manager informed of hazard. Top right: First responder follows guidelines delivered by the STORM application. Bottom left: Photographs of damage are recorded in a diary. Bottom right: Volunteers are briefed and follow mitigation strategies to deal with immediate issues.

The STORM platform provided an excellent, easy to use service to the Mellor pilot site which required minimal training for volunteers. The Sensory Map was useful for site management, volunteers and on-site employees to understand the location of sensors across the site as well as gathering quick information from an instantaneous reading of, for example, the weather data from the Mellor Archaeological Trust office. The online and offline sensors could be viewed meaning the site could also review past offline data collection and analysis conducted across the site's assets. A great example of this would be the ability for site management to view the scientific analysis uploaded to the service by the University of Salford after detailed laser scans of the assets had been conducted and assessed. Further, the ability for site experts to view longer-term data through the Visual Analytics component proved a great addition to the site. Not only did this data aid the site in monitoring it could provide useful teaching elements to site visitors from the general public to wider audiences like local schools. The STORM platform effectively amalgamated data from a variety of sources and relayed the useful element from that data no non-experts to enable them to successfully monitor the pilot site. Before the onset of the STORM project, this would not have been possible.

3. Feedback and Conclusions

The STORM project has brought a number of positives to the management of our volunteer-led Cultural Heritage site. Prior to the STORM project climate-related risk information was minimal and this led to a reactive approach to both slow and fast onset scenarios. This meant that protective and restorative decisions were often taken without any reference to documented processes. STORM has given site managers the tools, using cutting edge technology, to analyse the situation against predetermined and rehearsed disaster scenarios. STORM has given the volunteers the opportunity to be proactive in their approach, keep accurate records and produce mitigation plans against the effects of climate change. This interactive service, linking volunteer person power to expert advice and technical partners ensures that the site is doing the most it can to monitor, mitigate, prevent and respond to hazard situations. Furthermore, through this project Mellor has been able to share 'best practice' across the five, Europe wide, Cultural Heritage sites and other expert partners involved. Mellor volunteers are also now more aware of what new potential disasters may occur as climate change progresses.

In running the experiments, we demonstrated how the platform could be successful in two different situations: one where experts and volunteers were able to quickly respond, and one in which only volunteers were in a position to respond. The first, a flooding situation at Mellor Mill, provided excellent

proof of concept and the second, the aftermath of an electrical storm with high winds, was a great demonstration on how volunteers of CH sites would be able to respond and follow predefined guidelines to ensure the preservation of the most important assets. The second scenario was attended by national organisations who expressed great need for such a service – utilising huge numbers of volunteers as opposed to smaller number of trained experts. The benefit of having the STORM application for experts to relay information to volunteers, as opposed to the volunteers having to await the arrival of experts before first aid can begin, was shown to be of great benefit to a UK volunteer-based organisation regardless of its size. Not only could organisations utilise STORM with only a small outlay, the ability to utilise volunteers with such effectiveness could bring large savings. In an industry which relies heavily on subsidies and charity, this outcome could help ensure the on-going preservation of CH assets. Where such an organisation may struggle to employ disaster management, STORM could potentially lead to this cost being pooled across involved organisations, thus ensuring the longevity of the site management company. The benefits are evidenced by the use of the STORM services at Mellor. Mellor would not be able to fund, long-term, employees specifically hired to preserve the heritage in response to hazards. This leads to a choice – preserve assets at a cost which could risk the collapse of the organisation involved – or less focus on preservation and potential accepting loss of assets as and when disasters occur. STORM solves this problem, a problem that the vast majority of CH sites in the UK will face.

Unfortunately, some of the sensors and tools which had a lot of promise; for example, the WASN and mobile phone application were presented towards the end of the project so, although tested, perhaps a longer implementation period would have been ideal for developing more thorough analysis of how such data collection could feedback to pilot site managers and become a big part of what drives the Mellor prevention and mitigation strategies. The idea behind the use of these sensors should give hope that future projects and interventions develop similar tools that this proof of concept appears to indicate will be extremely useful for diagnosis and play a critical role in the prevention strategies of Europes CH. This is especially true for the Gamification app which has endless potential for not only providing information as a sensor, but also acting as a tool with citizen science. The results of testing at just one small pilot shows the ability to enable the user to inform the site of issues as they play along. Crucially this could act as a learning experience for newer generations of visitors who may perhaps not have shown interest in protecting CH prior to such novel engagement methods.

Volunteer feedback was also sought about use of the STORM platform and the following conclusions were given:

- Photographs. A useful feature to have available to record key events, but the use of the camera is not as intuitive as it might be. It would ideally work like a smartphone camera and save all images automatically without the need for follow-up actions. This would be especially helpful in a fast-moving emergency when there would not be time to save each image separately. If this is not possible within the app. then the 'save' button in the top right-hand corner needs to be much more obvious. Currently it is too small, and white letters on a black background - so not at all obvious as it merges with the image - so is not noticeable. Smartphone screen design would normally place this image in the centre of the image so that you can't move on to the next action without acting (so 'Save Image - Yes/No' placed centrally). If this is not possible then the Yes/No buttons need to be white with black lettering - and larger.
- The notes page was a really useful feature - where the detail of actions (or variations from pre-planned actions) can be recorded. Users should be encouraged to use this feature as fully as possible as it is in these notes that post-event analysis of actions will be reviewed.
- The volunteers acted/reacted well on the day and followed instructions well thanks to the STORM application, and this would not have been achieved without the implementation of the STORM platform.

STORM was a hugely beneficial experience for the Mellor Pilot site. Giving the site a great understanding of how technical experts, conservationists, archaeologists, and site management can come

together to create something that is useful for the end-user. Bringing together many industries to create a service that will help preserve CH assets across Europe and produce an example that has been keenly welcomed across the CH industry in the UK. The idea of STORM is scalable – the novel technologies such as UAVs, Acoustic Sensors as well as more widespread technologies such as in advancing over-the-counter weather stations, can be applied thoroughly, sparsely, or not at all allowing sites with different budgetary requirements to be supported. This shows that STORM or similar technologies will play a huge role in the ongoing preservation of Europes, and wider, archaeology, cultural, built, and natural heritage.

References

[1] Pachauri, R. K. & Reisinger, A., (eds.), 2007, Climate Change 2007: The physical science basis. Contribution of Working Group I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC.

[2] Croft, A., 2013, Assessment of Heritage at Risk from Environmental Threats. Key Messages Report for English Heritage. Research report by Atkins Heritage for English Heritage.

[3] Daly, C., 2010, *Monitoring Impacts of Climate Change in Built Heritage.* Dublin: Report of the ICOMOS Ireland Climate Change Sub-Committee.

[4] Nevell, M Williamson R & Wit R, 2019, 'STORM: Managing cultural heritage sites in the face of environmental and climate change' in Dawson M, James E & Nevell M, eds, 2019, *Heritage Under Pressure: Threats and Solutions. Studies of Agency and Soft Power in the Historic Environment.* Oxford: Oxbow Publications, 298-316.

[5] N. Redhead, "Mellor: its local and wider archaeological significance". In *Mellor: Living on the edge. A regional study of an Iron Age and Romao-British upland settlement.* Edited by M. Nevell and N. Redhead, Manchester, University of Manchester Archaeological Unit, 2005, 145-157

[6] J. Roberts "Archaeology" in *Mellor Through the Ages,* edited by J. Hearle, Loughbourgh Mellor Archaeological Trust 2011, 89-107

[7] J. Hearle (ed.) "the Story unfolds" in *Mellor Through the Ages* Mellor Archaeological Trust, 2011, 0-80

[8] J. Hearle, A. Hearle. "An Introduction to Archaeology and Mellor 1998-2004", in *Mellor: Living on the Edge, A Regional Study of an Iron Age and Romao-British Upland settlement.* Edited by M. Nevell and N. Redhead, Manchester, University of Manchester Archaeological Unit, 2005, 11-16

[9] P. Noble, A. Thompson. "The Mellor Excavations 1998-2004", in *Mellor: Living on the edge, A Regional study of an Iron Age and Romao-British Upland Settlement.* Edited by M. Nevell and N. Redhead, Manchester, University of Manchester Archaeological Unit, 2005, 44-48