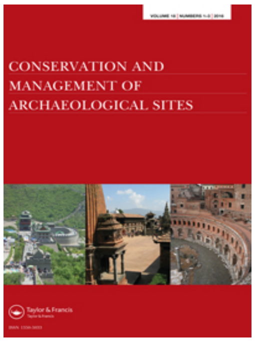

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Implementation of Sustainable Urban Drainage Systems to Preserve Cultural Heritage — Pilot Motte Montferland

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Implementation of Sustainable Urban Drainage Systems to Preserve Cultural Heritage — Pilot Motte Montferland

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The shallow subsurface in historic cities often contains extensive archaeological remains, also known as cultural deposits. Preservation conditions for naturally degradable archaeological remains are strongly dependent on the presence or absence of groundwater. One of the main goals at such heritage sites is to establish a stable hydrological environment. Green infrastructural solutions such as Sustainable Urban Drainage Systems (SUDS) can support preservation of cultural deposits. Several cases show that implementation of SUDS can be cost effective at preservation of cultural deposits. These include Motte of Montferland, City mound of Vlaardingen, Weiwerd in Delfzijl, and the Leidse Rijn area. In all cases, the amount of underground infrastructure is minimised to prevent damaging cultural layers. SUDS have been implemented to preserve cultural heritage. The first monitoring results and evaluation of the processes give valuable lessons learned, transnational knowledge exchange is an important element to bring the experiences across boundaries.

KEYWORDS: monitoring, SUDS, preservation conditions, guidelines for design, construction and maintenance, international knowledge exchange

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Introduction

Several studies have shown that groundwater quantity plays a crucial role in preservation conditions for archaeological deposits (e.g. de Beer, et al., 2012; Smit, et al., 2006; Tjelldén, et al., 2012; Harvold, et al., 2015). Be it degradable remains that need to stay in a permanently anoxic environment (e.g. Matthiesen, et al., 2015; Vorenhout, 2015), or be it materials that require low water flow such as bone (Hollund, et al., 2012; Huisman, et al., 2009). Urban areas are generally characterised as having large areas of solid surfaces, making it difficult for rainwater to infiltrate. Low infiltration results in lower groundwater tables as well as higher water flows along roads and structures, which in its turn can cause erosion. Implementing water management structures in archaeologically important areas can be challenging (de Beer, et al., 2012b). Any local water structure used to manage the water flow can potentially damage the archaeology located in the vicinity (de Beer, et al., 2012a). Most of these structures require groundworks, and some are placed completely under the surface. This trade-off requires special attention and experience (Rytter & Schonhowd, 2015).

Establishing a stable hydrological environment is thus a principal goal. Green and blue infrastructural solutions or Sustainable Urban Drainage Systems (SUDS) that infiltrate stormwater in unpaved areas (e.g. swales and rainwater gardens) are becoming popular applied methods for the preservation of cultural deposits. A number of Dutch pilot projects, with this goal and method, are described in this paper (Table 1). The pilot projects show that implementation of SUDS can be successfully performed in an archaeological setting and that they are, in general, cost effective. Subsurface green and blue solutions have been adapted in order to prevent the need to use underground infrastructure (storage volumes, pipes, cables etc.) and as such minimise the effect on archaeological layers.

First the solutions in water-management are discussed followed by an overview of the different case studies. As an example, the Motte Montferland case is described in more detail. At Montferland, a variety of SUDS have been implemented to preserve the water balance and thus the archaeological heritage.

Solution in water management

Infiltration and drainage can be used to create a soil–water balance that is beneficial for *in situ* preservation in areas with archaeological remains and a changing water management environment. A disturbance in the water balance can be the result of anthropogenic causes (paving areas, extracting of groundwater etc.) or climate change (longer dry periods, more intensive rainfall). Systems that differ from conventional stormwater drainage by providing alternative infiltration and drainage possibilities are known under several terms, such as best management practices (BMPs); green infrastructure (GI); integrated urban water management (IUWM); low impact development (LID); low impact urban design and development (LIUDD); source control; stormwater control measures (SCMs); water sensitive urban design (WSUD). Sustainable Urban Drainage Systems (SUDS) is the most commonly used name (Boogaard, 2015). Ten examples of SUDS that are used to preserve cultural deposits in several pilots are (Fletcher, et al., 2013):

- pervious pavements (Figure 1, right): a permeable surface that is paved and drains through voids between solid parts of the pavement;

Table 1
SUMMARY OF CASE STUDIES WITH IMPLEMENTED SUDS. ARCHAEOLOGY WAS PRESENT IN ALL CASES; IN SOME IT WAS THE MAIN CAUSE FOR THE PROJECT. LOCATIONS ARE SHOWN IN FIGURE 3.

	Motte Montferland	City mound Vlaardingen	Vondelpark (Van Eeghenstraat) Amsterdam	Leidse Rijn area	Church and houses, Echten, Friesland	Weiwerd in Delfzijl
Main reference	Boogaard, 2012	Vorenhout, 2013	Verhoog, 2007	STOWA, 2007	Bootsma & Bouma, 2008	Snoek, 2014
Era	Medieval, >1000 AD	Roman period	>1800	Roman period	>1900	
Object to preserve	Motte	Mound on top of sand ridge	Building on wooden piles	Area where Roman ship was found	Monumental building	Wierde/terp
(*In situ*) preservation of	Shape of the mound	Underground organic cultural deposits	(Wooden foundation of) monumental buildings	Preservation of archaeology in general	(Wooden foundation of) monumental buildings	Preservation of wierde, layers and possible artefacts
Implemented SUDS and measures	Subsurface runoff, bioswales, IT drainage and rainwater gardens	Advice for maintenance and extension of permeable pavement and local runoff of roof water	IT drainage, swale, constructed wetland, sheetpiling	Swales, permeable pavement, crates, subsurface runoff	IT drainage and crates	No dig/gully free area, subsurface runoff

- bioretention as rainwater gardens: a planted basin design to collect and clean runoff (normally from a roof, or hardstanding with low risk of pollution);
- infiltration device: a device specifically designed to aid infiltration of surface water into the ground;
- grassed swales (dry) and (wet) (Figure 1, left): shallow vegetated channel with filter in the base to convey surface runoff to the sewer network or infiltrate into the surrounding soils;
- infiltration trench: a trench, usually filled with permeable granular material, designed to promote infiltration of surface water to the ground;
- filter drains (Figure 1, middle): a linear drain consisting of a trench filled with a permeable material, often with a perforated pipe in the base of the trench to assist drainage;
- infiltration basins: a basin specifically designed to store water and to aid infiltration of (storm) water into the ground;
- (vegetated) detention ponds: permanently wet depression designed to retain stormwater and permit settlement of suspended solids and biological removal of pollutants. Detention occurs when the pond has a lower outflow than inflow. Often used to prevent flooding;
- wetland: flooded area in which the water is shallow enough to enable the growth of bottom-rooted plants;
- combination of SUDS in a 'treatment train': the management of runoff in stages as it drains from a site. A range of SUDS components are used to maximise the hydraulic and water quality management benefits.

Green infrastructural solutions such as these SUDS can facilitate restoration and upholding of the soil moisture content and water balance, thereby supporting preservation of archaeological layers (Figure 1). Six Dutch cases (Figure 3) that have been implementing green and blue solutions with infiltration of stormwater to get a more stable (ground-) water balance are given in Table 1, and locations in Figure 3:

(1) Motte Montferland: preservation of a medieval mound;
(2) Weiwerd in Delfzijl: reconstruction of a mound;
(3) Leidse Rijn: implemented SUDS in an area where cultural deposits are found and conserved;
(4) City mound of Vlaardingen: old centre with archaeology finds;
(5) Vondelpark Amsterdam: monumental buildings and implementation of SUDS;
(6) Friesland with wooden foundation of churches and houses being preserved by stormwater infiltration.

Some examples of SUDS implemented at locations with cultural deposits are visualized in Figure 2. The Motte Montferland case is further described in the next paragraph, as it serves well as an integrated approach.

Motte Montferland

The Motte Montferland is the highest man-made hill in the Netherlands. It is surrounded by a double canal system. Since 1000 AD, it has been inhabited by royals, and was used as a fortified living place. The Motte is a listed monument (ARCHIS ID 511162), and its shape has been defined as its most interesting feature. This shape is quite remarkable. A physical calculation study showed that in fact the sides of the hill are basically unstable as they are too steep. There is a small road on the side of the motte, going up to the plateau. The report by Boogaard (2012) details the following circumstances and decisions. In the 1990s, cracks were noticed on this road, as well as several small landslides on the roadsides. Several parties have reviewed the problems and they all agree that the increasing amount of rain over time is the largest threat. It was known that the hill slopes were protected by the roots of the dense vegetation; however the many trees that covered the mound were seen as undesirable because the form of the mound was obstructed. The ideal situation would be a coverage of shorter, grass-type vegetation.

It was evident that the risk of erosion of the hill slopes would increase when the vegetation density was reduced, especially during the period of woodcutting. Several consultants proposed ways to divert the water flow caused by rain from the slopes and road towards local storage. The initial plan entailed a large-scale stormwater storage and infiltration at one central place in the higher area. This however would mean ground disturbances below the first archaeological layers, thus greatly increasing costs for installation. It would require a relatively large excavation of the area and therefore a considerable loss of *in situ* preserved remains. Due to the high total costs and possible damage to cultural layers, the plan was halted.

(a)
(b)
(c)

FIGURE 1 SUDS applied in areas with cultural deposits: swales in Leidse Rijn area (a), filter drains (b) and permeable pavement (c) implemented to preserve the cultural heritage site in Bergen (Norway).

New problem assessment

The motte is located in a forested area (Figure 4) and the encroachment of this tall, dense vegetation was seen as unacceptable by those who managed the

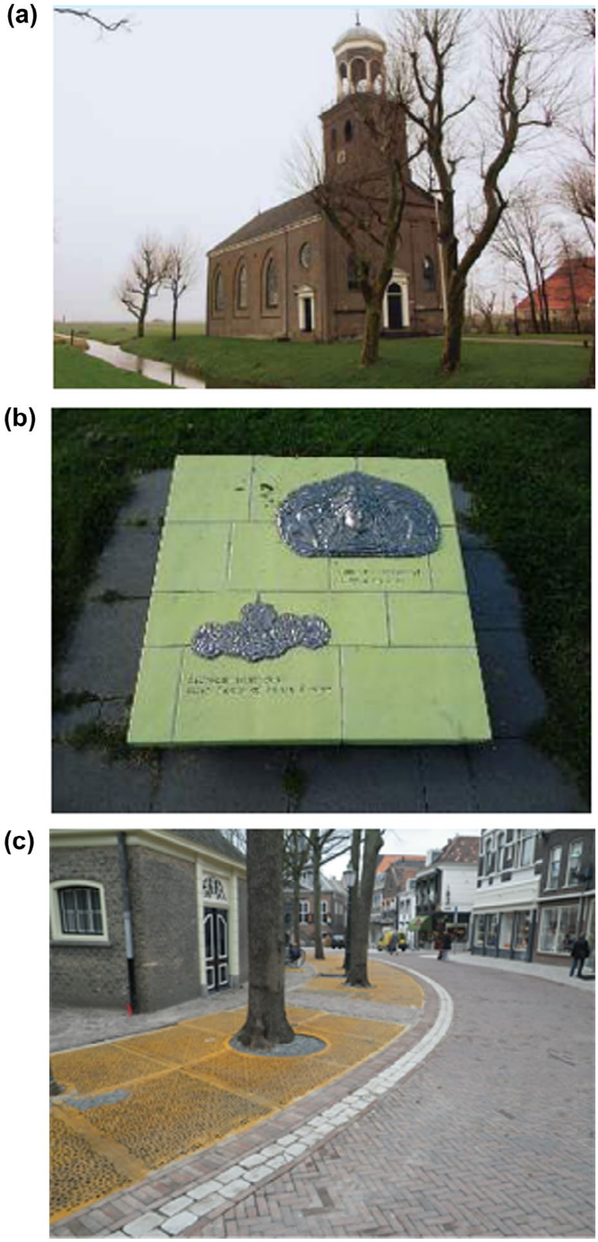


FIGURE 2 Impression of pilot cases: church in Friesland with wooden foundation (a), Roman coins found in Leidse Rijn area, infiltration surface near church in Vlaardingen (c).
Photographs after Bootsma & Bouma, 2008 and by Floris Boogaard and M. Vorenhout

monument (Boogaard, 2012). The preferred situation was that the motte would stand out in the landscape and have a good visibility from a distance. Removal of the trees would however create areas of bare soil that would be susceptible

FIGURE 3 Background: height model of the Netherlands (CC License, Jan-Willem van Aalst). Locations of sites as per Table 1. A: Amsterdam, D: Delfzijl, E: Echten, Friesland, LR: Leidsche Rijn, M: Motte Montferland, V: Vlaardingen.

to local gully formation by water erosion. Due to the steepness of the hill, the general use of the upslope road by cars and small sized lorries is detrimental to the general stability of the hill. This use is however very difficult to change as the motte is in use by a small hotel and restaurant, which in turn generates a need for maintenance.

The current runoff of water is significant and future predictions show an increased intensity of rain events due to climate change. The main problem therefore in good preservation of the motte is the rapid water runoff and a lack of storage of rainwater on the plateau. After flood modelling of this area (Figure 4), it was decided that the runoff should be halted as much as possible and any intervention should not involve deep excavation, thus preventing the need for an archaeological investigation. Rainwater should be stored on the plateau and other areas allowing infiltration on decentralised level. It was recommended that local infiltration should not take place too close to the sides of the plateau. That would decrease the stability of the top layer on the mound sides following the removal of the trees and before the replaced grass layer had a chance to grow. Excess water on the eastern side would be directed along the current road into the original canal. The road would also be equipped with enforced sides. The several SUDS methods that have been implemented to follow this

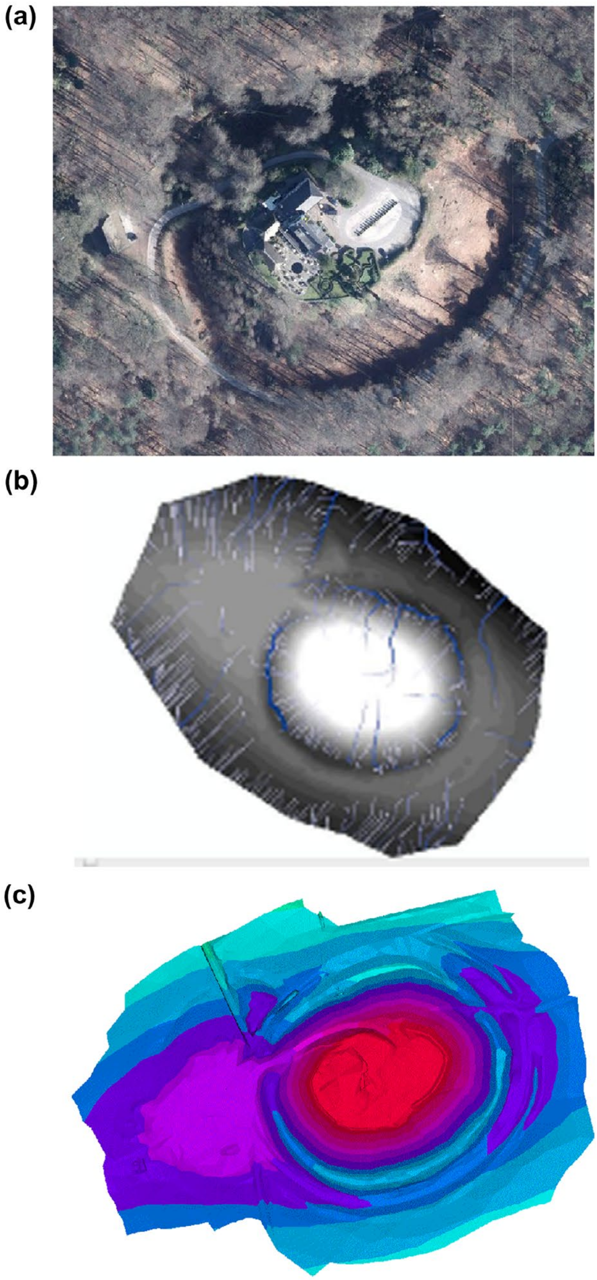


FIGURE 4 Aerial photograph of the Motte Montferland (source: Globespotter) and mapping of heights and waterflow in this area to construct structural measures for a decentralised stormwater storage and infiltration.
Photographs after Boogard (2012)

plan are mapped in Figure 5. The different SUDS that are used are (corresponding with numbers in Figure 5(a)):

- surface discharge to the canal downhill;
- swales;
- discharge to an infiltration basin, north;
- discharge to an infiltration basin, west;
- storage and infiltration of stormwater in grassed swales.

In the next years the implemented measures will be monitored and evaluated to optimise the water management system. Lessons learned of the design, construction, and maintenance will be exchanged with several sites in the Netherlands where cultural deposits should be preserved to stimulate the implementation of cost effective measures with several stakeholders.

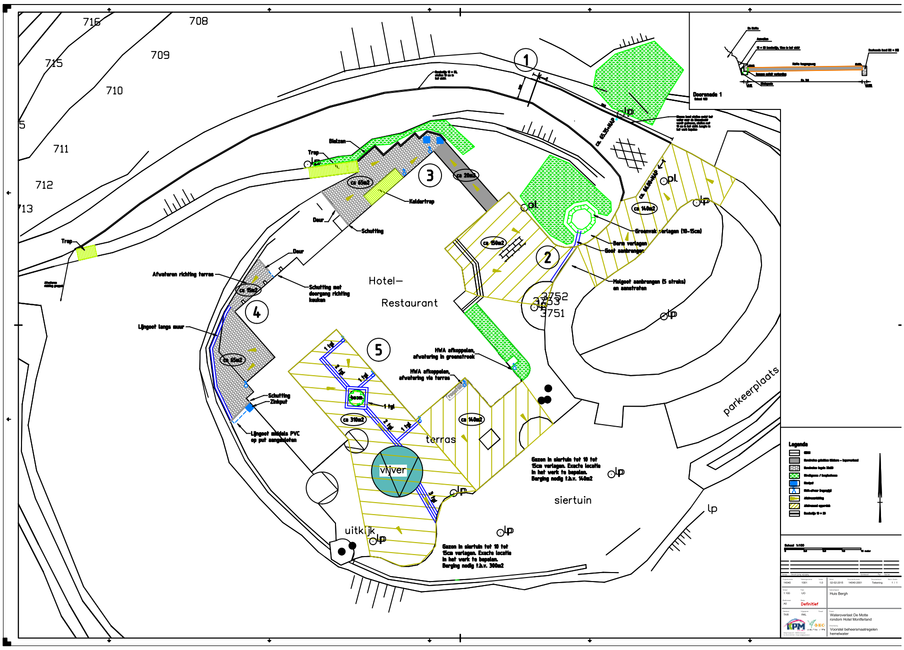
International knowledge exchange

Collaboration among stakeholders as water professionals, urban planners, and archaeologists is essential for more sustainable water management and preservation of cultural deposits. For a better understanding, visualisation and interaction play important roles, and innovative interactive tools can be used as communication aids to promote engagement with stakeholders in the field of climate change and related environmental issues. Examples of tools (Figure 6) that are used on international scale are 2D/3D flood and drought visualisations (e.g. Blanksby, et al., 2011; Verlaat, et al., 2015); 'serious' games (Jefferies, et al., 2012, augmented reality; Boogaard, et al., 2012); and a recently developed online application 'Climatescan.nl' (Tipping, et al., 2015).

Climatescan (Figure 7) is an interactive Web-based map application that provides an entry point to gain detailed information of various 'blue-green' projects with or without elements of preservation of cultural deposits. Currently, all the data points are categorised into twelve sub-groups which are each assigned a different colour on the webpage. Most of the categories relate to sustainable urban drainage systems (SUDS) including constructed wetlands, swales, green roofs, settlement basins, and permeable pavements. The Web tool climatescan.nl (discussed in Tipping, et al., 2015) also provides projects that use SUDS for specific purposes. For example there is a category named 'cultural heritage' which identifies locations where innovative techniques are being used at a local level to protect buildings and the environment.

The website has proved to be helpful not only for practitioners working in this field but also as a useful tool for students, lecturers and researchers. The Web tool is used for international fieldtrips around the Netherlands with countries such as Denmark, Australia, the UK, Sweden, Norway, and the United States. A survey among international project partners showed that the ease that projects can be found and viewed is highly advantageous when compared with more traditional data retrieval methods (Tipping, et al., 2015).

a)



b)

FIGURE 5 Mapping and implementing of decentralised solutions for preservation of the motte. *Photographs by F. Boogaard*

(a)
(b)
(c)


FIGURE 6 Examples of interactive tools to promote engagement with stakeholders: serious gaming (with case study Bergen, Norway), touch tables used in interactive workshops with mapping and 3D visualizations and augmented reality for virtual tools.
Photographs after Jefferies, et al. (2012) and by F. Boogaard

FIGURE 7 Snapshot of climatescan.nl, Netherlands with category 'cultural deposits' (left), and project page for Motte Montferland with documentation, photographs, and video impressions. *Photographs after Tipping (2015)*

Conclusions

The use of SUDS in water management for *in situ* preservation of archaeology is a relatively simple option, particularly when the special rules of conduct associated with archaeology are taken into account. There are a large number of methods available that are both cost effective and sustainable. These water management tools can be a good addition to *in situ* preservation plans. Research needs are present in the monitoring of the systems with regard to performance in an archaeological context, and in maintenance of the systems in the long run. The online tool climatescan.nl can help in sharing the knowledge gained and serve as a database of case studies; researchers are invited to add their projects to the database.

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