Abstract for oral presentation at PARIS5 conference

For theme no 6: (Monitoring) and Mitigation

Title: **Monitoring mitigation measures and their effects on in-situ preservation conditions**

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Abstract:

During the last decade, unique multidisciplinary investigations have been carried out to understand and document the environmental conditions that have led to the observed worsening state of preservation of archaeological deposits at Bryggen in Bergen. Current results of these investigations have already been presented and published at Paris3 and Paris4 conferences in 2006 and 2011. In 2011, a large-scale mitigation project was started. This presentation focuses on the monitoring of the long-term performance and effectiveness of different mitigation measures that have been implemented at Bryggen, with particular regard to determining if an improvement in environmental conditions for the in-situ preservation of archaeological deposits can be observed.

Since September 2011, numerous mitigation measures have been implemented to improve conditions for the preservation of organic cultural deposits at Bryggen in Bergen. The main mitigation target is to create a hydrological divide between the area where urban development has disturbed the local water balance and the affected areas at Bryggen that are characterized by poor preservation conditions. The mitigation measures were selected to comply as far as possible with sustainable water-management principles, and are focused on increasing and stabilizing groundwater-levels and soil moisture content in affected areas. The use of sustainable water-management solutions specifically targeted on improving in-situ archaeological preservation conditions is an innovative approach with multiple benefits. A long-term environmental monitoring programme will document the solutions' performance and effects. The monitoring plan, target parameters and preliminary results are briefly discussed, including a quick future outlook on the use of interferometric synthetic aperture radar (InSAR) as a non-destructive monitoring method.

Keywords: mitigation, monitoring, sustainability, preservation conditions

Bryggen World Heritage Site

Monitoring mitigation measures and their effects on preservation conditions

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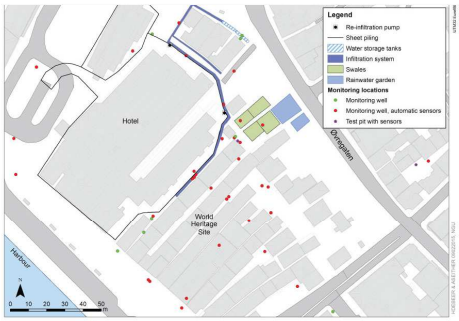
Documentation of archaeological deposits and constructions in a section at Bryggen.
Photo: Universitetsmuseet i Bergen, UiB



Overview map of mitigation measures carried out by the Groundwater Project, including locations of monitoring wells for measurement of groundwater level, temperature and sampling. Mitigation measures consist of a "treatment train" made up by rainwater gardens, green swales, permeable pavement and a subsurface infiltration/transport system with storage facility and re-infiltration of groundwater.
Map: Anna Seither, Geological Survey of Norway.

MONITORING

The initial baseline study at Bryggen included measurements of oxygen, groundwater levels, subsidence rates, soil and groundwater temperatures, redox-potential as well as soil - and stormwater chemistry. After risk assessment and mitigation, a long-term environmental monitoring programme will now document the solutions' performance and their effects on the preservation conditions.

The long-term monitoring consists of a selection of parameters, with primary focus on monitoring subsidence rates, groundwater levels and groundwater chemistry. Monitoring and maintenance is described in the management plan for the site.

CONCLUSIONS

The use of sustainable water management solutions specifically targeted on improving in-situ archaeological preservation conditions is an innovative approach with multiple benefits.

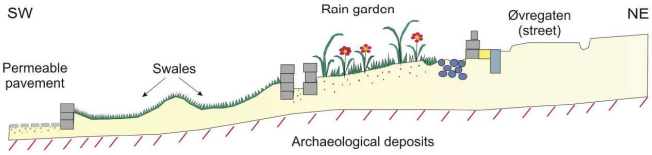
The methods that have been employed are designed to be resilient in the face of climate change, and can easily be modified for implementation in other Norwegian centres and abroad.

Reference: Monitoring, Mitigation, Management - The Groundwater Project - Safeguarding the World Heritage Site of Bryggen in Bergen. Riksantikvaren, 2015. ISBN 978-82-7574-084-5.

During the last decade, unique multidisciplinary investigations have been carried out to understand and document the environmental conditions that led to the worsening state of preservation of archaeological deposits at Bryggen in Bergen, Norway. Results of these investigations were presented and published at Paris3 and Paris4 conferences in 2006 and 2011.

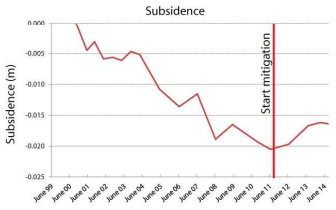
MITIGATION

In september 2011, a large-scale mitigation project was started. A range of mitigation measures have been implemented to improve conditions for the preservation of the organic archaeological deposits. The main mitigation target is to create a hydrological divide between the area where urban development has disturbed the local water balance and the affected areas at Bryggen that are characterized by poor preservation conditions. The mitigation measures at Bryggen were selected to comply as far as possible with sustainable water management principles, and are focused on increasing and stabilizing groundwater levels and soil moisture content in affected areas.

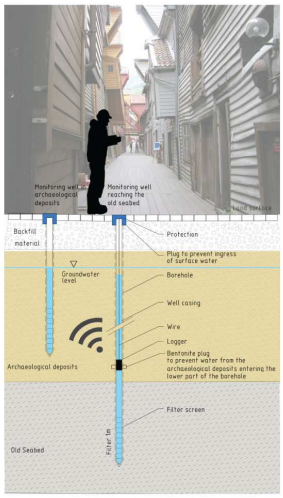


Section of the sustainable water management "treatment train", with rain garden, swales and permeable pavement.
Drawing: Johannes de Beer, Geological Survey of Norway.

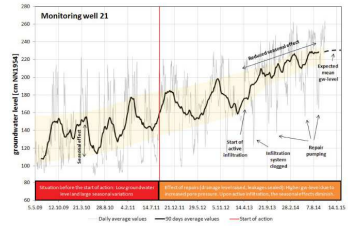
Permeable pavement and adjustment of the terrain surface stimulates local infiltration of storm water runoff. On the left hand side, green swales are visible that actively store and infiltrate rainwater.
Photo: Johannes de Beer, Geological Survey of Norway.



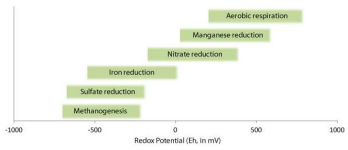
Development of subsidence at point near monitoring well MB21 at the back of Bredsgården/Bugården., downstream of swales.
Graph: Jann Atle Jensen, Multiconsult AS



Schematic representation of monitoring wells within archaeological deposits and below.
Drawing: Inger Hageberg, Multiconsult AS



Groundwater level in monitoring well MB21. The grey line shows daily variations of the groundwater level. The black curve gives a simplified impression of the groundwater level, by showing average values over three-month intervals.
Graph: Anna Seither, Geological Survey of Norway.



Overview over oxidation / reduction processes that control degradation of organic archaeological deposits, in relation to the Redox Potential (Eh) range in which they occur. At Bryggen, the Redox Potential is measured in conjuction with oxygen content to assess if the environment has become more stable.
Graph: Michel Vorenhout, MvH Consult.

Biography (max 50 words/person):

Hans de Beer is a hydrogeologist and leader for the Groundwater and Urban Geology group at the Geological Survey of Norway. He has 20 years' of experience in groundwater research, particularly in urban areas. Research on groundwater and in-situ preservation of cultural heritage is a primary focus area since 2005.

Henning Matthiesen is a senior researcher at the National Museum of Denmark, where he is working with the in situ preservation of archaeological remains. His research is focused on urban deposits, wetlands and frozen sites.

Floris Boogaard is professor Spatial Transformations at the Centre of Applied Research and Innovation on Area Development at the Hanze University of Applied Sciences in Groningen. His research fields include stormwater drainage and infiltration, complex monitoring, design of drainage facilities and urban water management planning.

Jann Atle Jensen is a geotechnical engineer and senior consultant at Multiconsult AS. He has 16 years' experience on geotechnical engineering in soil and rock. Is responsible for planning, implementation and analysis of subsidence monitoring at Bryggen since 2000 and coordinates the technical planning and construction of groundwater mitigation measures.

Rory Dunlop is an urban archaeologist working at NIKU's Bergen office, with more than 30 years' experience of all kinds of archaeological investigations. He has become increasingly specialized in aspects of archaeological monitoring since 2001, particularly in connection with the work at Bryggen.

Michel Vorenhout is an affiliate researcher at the University of Amsterdam (UvA) and specialises on redox processes in soils. He is involved in various archaeological monitoring projects through his company MVH Consult.

Ann Christensson was a senior advisor at the Directorate of Cultural Heritage. Has since 2001 been in charge of the monitoring project concerning the archaeological deposits at World Heritage Site Bryggen in Bergen. Since 2011 we have been working to establish the groundwater situation to improve conditions for in-situ preservation.