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Preservation conditions at  
dipwells MB38 at Bellgården  
and MB39 at Bryggestredet,  
Bryggen, Bergen





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*Department of Conservation*

**Preservation conditions at  
dipwells MB38 at Bellgården  
and MB39 at Bryggestredet,  
Bryggen, Bergen**

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Report from the  
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Title:  
Preservation conditions at dipwells MB38 at Bellgården and MB39 at Bryggestredet, Bryggen,  
Bergen

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Summary:

In May and November 2011 two new dip wells, MB39 and MB38, were installed in the north-eastern part of Bryggen in order to acquire further information about the spatial variability of the preservation conditions of the cultural deposits. Soil samples from the installation were analysed, and groundwater was sampled on the 7<sup>th</sup> October and 22<sup>th</sup> December 2011 for a characterisation of the groundwater chemistry. The results are presented and commented on in this report, with special emphasis on the impact of water flow and drainage on preservation conditions around the dip wells. The results have shown that poor state of preservation is mainly found in the more permeable sandy layers containing some highly decomposed humus, as found in the upper soil layer at MB38 (down to 0.5 m asl). The more compact deposits at MB39 have maintained a medium state of preservation for deposits beneath 2.15 m asl (0.9 m below surface).

Conditions at MB39 have shown that processes occurring in the unsaturated zone may affect the groundwater and soil underneath by delivering dissolved redox-active species, e.g. sulphate. Laboratory experiments with soil material from MB39 and from an excavation at Bryggen have shown how the addition of sulphate could significantly increase the decay rate for organic material in the soil (Hollesen & Matthiesen, 2012). However, it is still not possible to evaluate the exact effect in situ on a quantitative scale, as the sulphate reduction will also depend on the supply rate, the temperature and the reactivity of the organic material.

The deeper deposits (beneath -2½ m asl) are in good to excellent state of preservation at MB38 and 39, and the preservation conditions are considered good to excellent.

These results document that a better understanding of the local hydrology and further investigations covering the unsaturated zone is necessary to fully understand and elucidate ongoing processes controlling organic matter decay.

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## Introduction

The conditions in the archaeological deposits underneath the World Heritage Site Bryggen in Bergen have been thoroughly monitored for the last decade in order to document their state of preservation and the impact of local drainage on decay rates of organic material. In some areas this drainage has caused settling rates as high as 6-8 mm/year (Jensen 2007).

To date close to 40 dip wells have been installed in the area. These ongoing investigations have documented considerable variation of preservation conditions described by a conceptual model based on hydrology, groundwater chemistry and preservation state which is concurrently refined (e.g. de Beer and Matthiesen, 2008, Matthiesen 2008a,b, - Figure 4a, b). In May and November 2011 two new dip wells, MB39 at Bryggestredet and MB38 at Bellgården, were installed to extend the observation network. The National Museum of Denmark has been contracted by Riksantikvaren to evaluate possible threats to the cultural layers at these dip wells based on results from analyses of soil and water samples.

## Site and methods

The positions of the new and existing dip wells on Bryggen are shown in Figure 1.

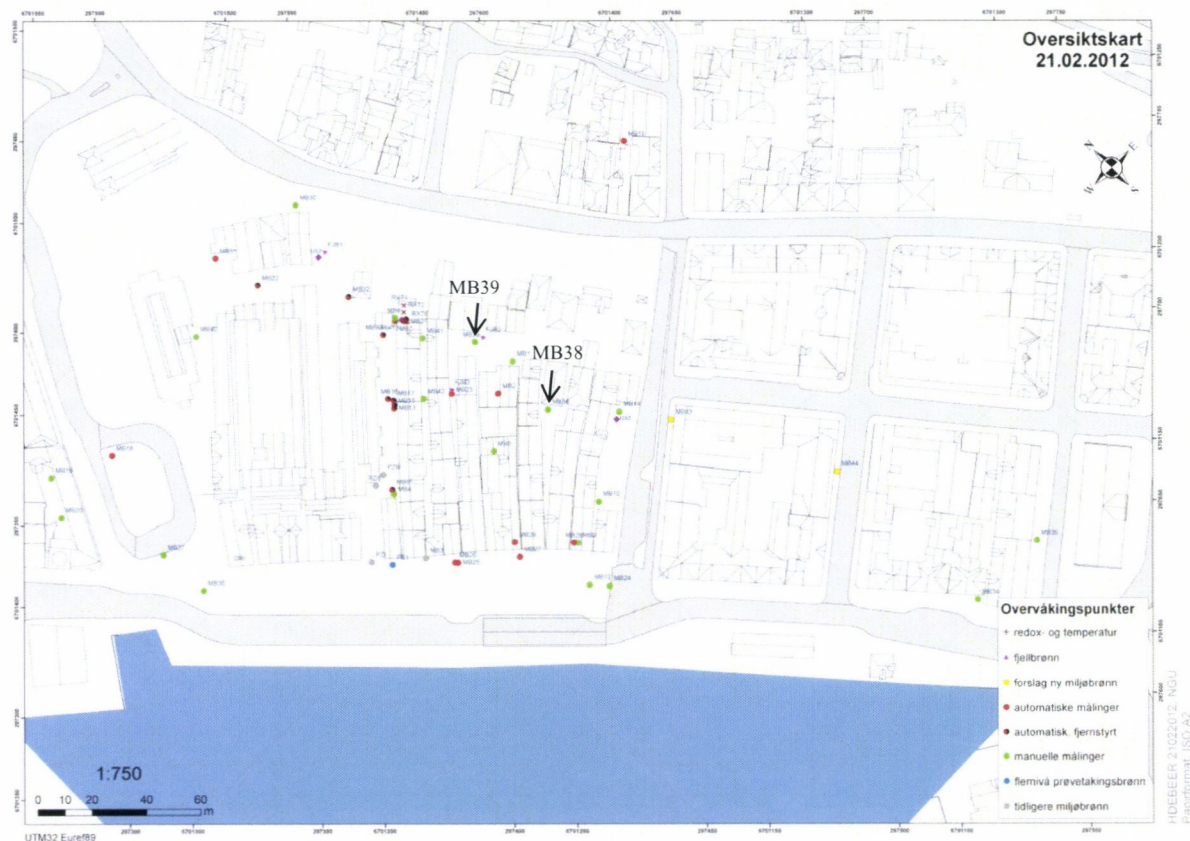


Figure 1: Map of Bryggen, showing the position of MB38 at Bellgården and MB39 at Bryggestredet (arrows) and other earlier installed dip wells. Dipwell numbers are best seen in the electronic version of the report. Graphics: Hans de Beer, NGU.

Drilling work and installation of the dip wells was done in May (MB39) and November 2011 (MB38) by Multiconsult and archaeologist Rory Dunlop from the Norwegian Institute for Cultural Heritage Research (NIKU). The soil stratigraphy is described in a report by Dunlop (2011). Seven soil samples from MB38 and eleven samples from MB39 were analysed at Eurofins for pH, dry matter content (i.e. the weight of the dried sample relative to the weight of the wet sample), loss on ignition (i.e. the weight loss when the dried sample is burned), water-soluble chloride and water-soluble sulphate. Three depths were also analysed for total phosphor, total nitrogen, total sulphur and total potassium. The laboratory reports are attached in Appendix 1. The position of the dip wells along with the level of their water intake is given in Table 1.

Dip well	Y-COORD.	X-COORD.	Soil surface (m asl)	Water intake – top (m asl)	Water intake – bottom (m asl)	Water level (measured on data)
MB38	297516.33	6701314.83	2.40	-2.60	-3.60	1,24 m asl (27/3/2012)
MB39	297514.87	6701351.31	3.00	0.00	-1.00	2.58 m asl (7/10/2011)

Table 1: Position and depth of water intake of dipwells MB38 and 39, as well as water level measured on two different dates. The positions have been taken from a report from NIKU (Dunlop 211), but need to be confirmed by Multiconsult.

Water sampling from the dip wells by Multiconsult was performed at MB39 on 7<sup>th</sup> October 2011 and at MB 38 on 22<sup>nd</sup> December 2011. The dip wells were emptied on the day before the actual sampling to ensure that fresh water from the cultural layers was sampled. Due to a misunderstanding the samples were not filtered in the field. The water samples preserved if required, then sent to the laboratory (Eurofins) where they were analysed for alkalinity, salt (sodium, chloride), nutrients (ammonium, nitrate, phosphate), redox active species (sulphate, nitrate, dissolved iron, dissolved manganese, sulphide, methane), and other major ions (calcium, magnesium, potassium). This spectrum of pore water components gives a good description of the chemical conditions in the ground-water. The reports from the laboratory are shown in Appendix 2.

## **Results**

The soil analysis results from MB38 and MB39 are presented graphically in Figure 2. It can be difficult to validate the quality of the data, but the results are in the range of earlier measurements in the cultural layers on Bryggen (these results are published in a range of reports for each individual dip well on Bryggen, and compiled in an unpublished database).

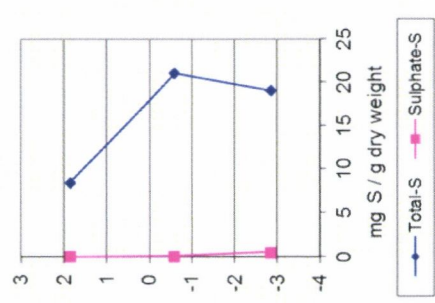
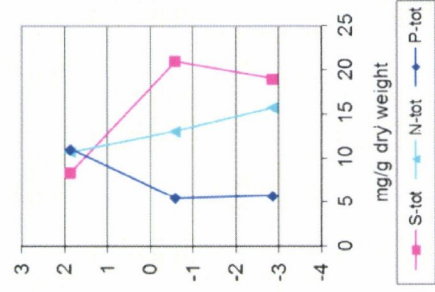
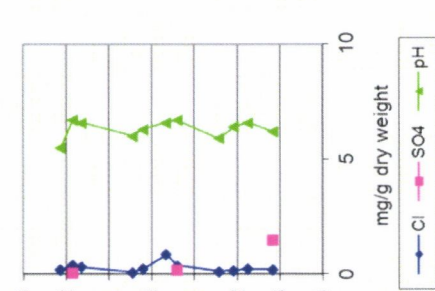
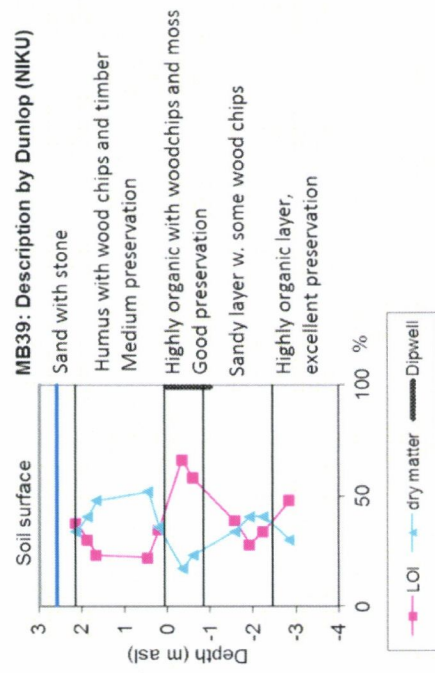
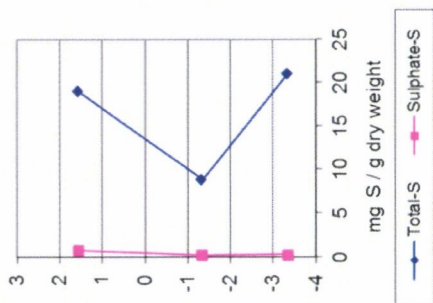
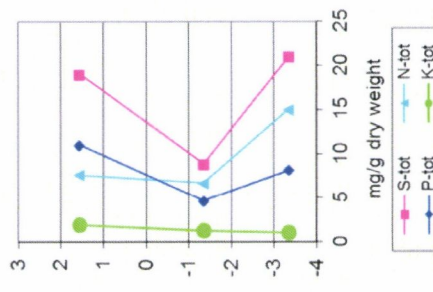
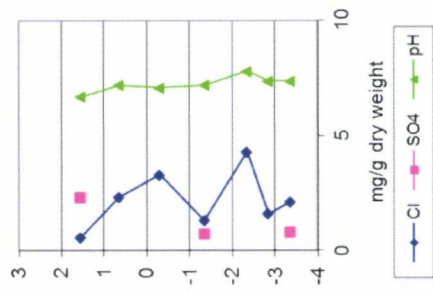
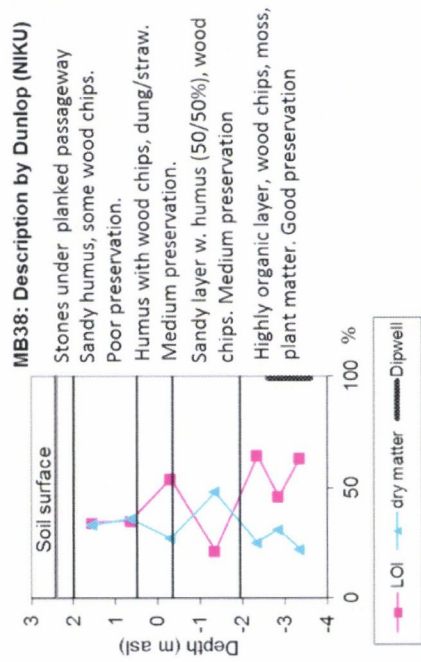


Figure 2: Description and soil analyses of drillings MB38 and MB39. The blue horizontal line marks the groundwater level as described in Table 1. LOI is the loss on ignition; Cl and SO<sub>4</sub> is water extractable chloride and sulphate. S-tot, N-tot, P-tot and K-tot is total amount of sulphur, nitrogen, phosphorus and potassium after total digestion of the sample. Sulphate-S is the water soluble fraction (calculated from SO<sub>4</sub>).



Results from groundwater analysis of samples taken in MB38 and MB39 in December and October 2011 are presented in Figure 3:

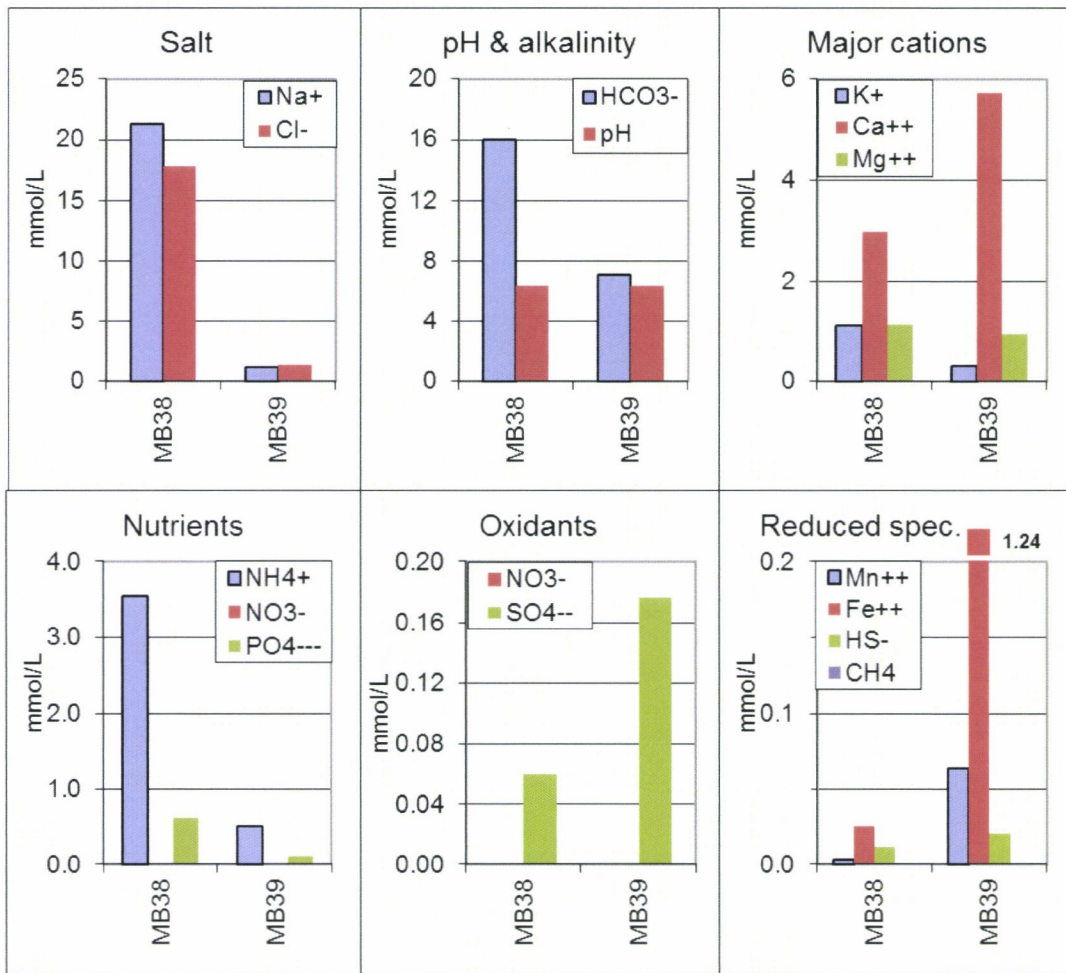


Figure 3: Groundwater composition from MB38 and MB39. Results for nitrate (NO<sub>3</sub><sup>-</sup>) were below detection limit (< 0.01 mmol/L). Results for methane data were below detection limit (< 0.3 μmol/L) for MB39 and not available for MB38 due to analysis error. Oxygen was measured with a dipping probe directly in the dip well at MB39 2 weeks after the sampling took place. This method gives a high risk of pollution; therefore a value below 0.05 mmol/L measured at MB39 has been disregarded.

The quality of the groundwater analyses is considered good for MB38 as demonstrated by a balanced sum of positive and negative charges (a difference of 0%), but there is a substantial difference of 35 % (anion deficit) for MB39. This is also confirmed by measurements of the residue after drying which is in reasonable correspondence with the ion concentrations measured at MB38 but is ~ 37% higher at MB39. Solid particles in the sample from MB39 could in theory explain both the error on the dry residue and the anion deficit (as the samples for cation analysis are preserved with acid, which may release iron, calcium and other ions from solid particles), but there is no laboratory note about observation of such particles in the sample. Alternatively, alkalinity might be

underestimated due to calcium-carbonate or Fe-oxide precipitation during sample handling, as the samples for alkalinity were not preserved. A medium to strong H<sub>2</sub>S smell observed in the soil at the filter depth suggests that additionally oxidation of dissolved sulphide to sulphur could have taken place. The methane results may be too low compared to in situ conditions, as it is very difficult to avoid degassing when pressure is lowered during the sampling although sampling directly into evacuated bottles was attempted. In 2011, pH, conductivity, oxygen content and temperature was not measured in-line during the sampling, as Multiconsult did not have a flow-through cell for these parameters available. Instead pH was measured in the laboratory and oxygen about 2 weeks later directly in the dip wells with dipping probes lowered into the wells. This procedure might have introduced oxygen into the dip well by the probe itself, thus all results below 0.05 mmol (1.5 mg) O<sub>2</sub>/L have been disregarded.

The two new dip wells are located in the outer region and the centre of area D of the above mentioned conceptual model, where until now the conditions have been considered stagnant and the preservation state very good. The new dip wells are compared to earlier installed dip wells in the adjacent areas A, B and D (Figure 4a,b).

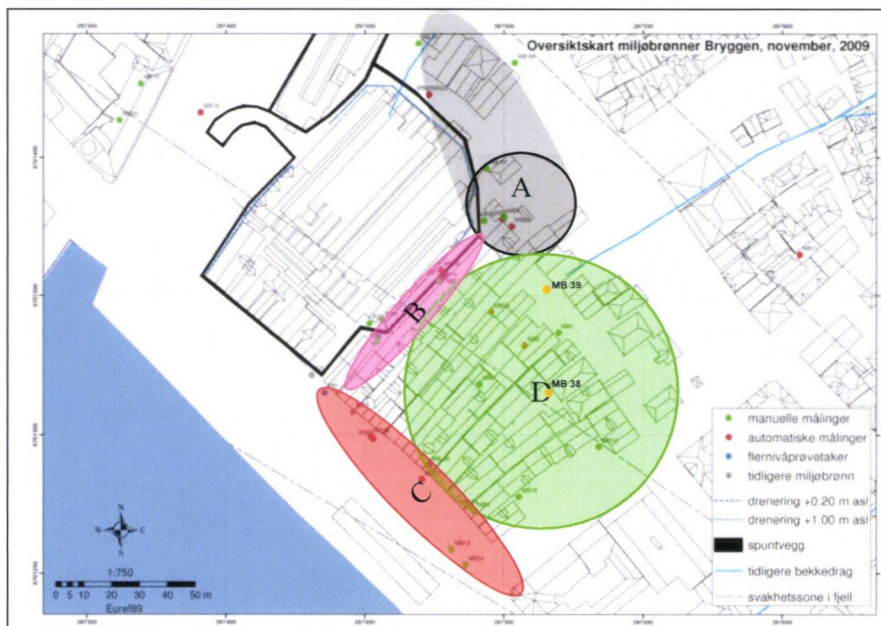


Figure 4a: Areas of Bryggen characterised by different preservation conditions:

- A: Drained area
- B: Rainwater influenced along sheet piling
- C: Seawater influenced
- D: Stagnant conditions
- E: Water from bedrock/natural deposits

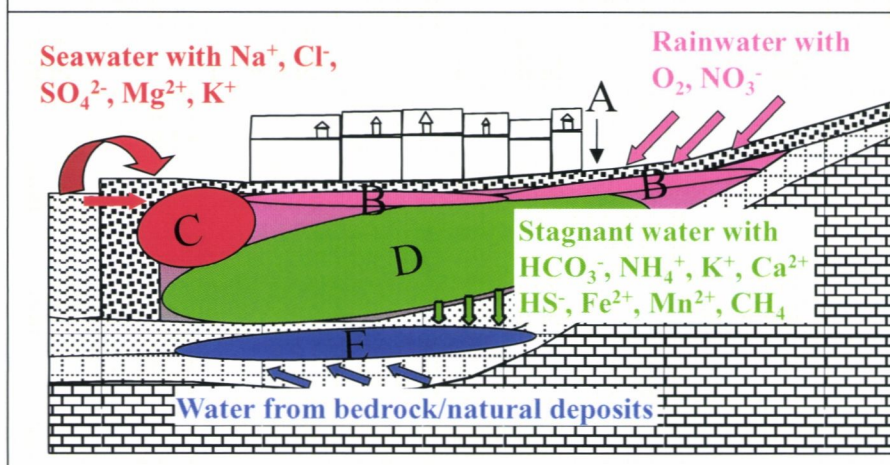


Figure 4b: Conceptual model of the groundwater formation in the different areas on Bryggen

Figure 5 shows a depth related comparison of the groundwater composition from MB38 and MB39 with groundwater from other dip wells on Bryggen sampled in autumn 2011. A detailed analysis of these results can be found in Matthiesen (2012). Here most dip wells from the drained area A have been assigned as being mainly (e.g. MB31, 32) and to some extent (e.g. MB8 and 21) impacted by processes in the unsaturated zone above.



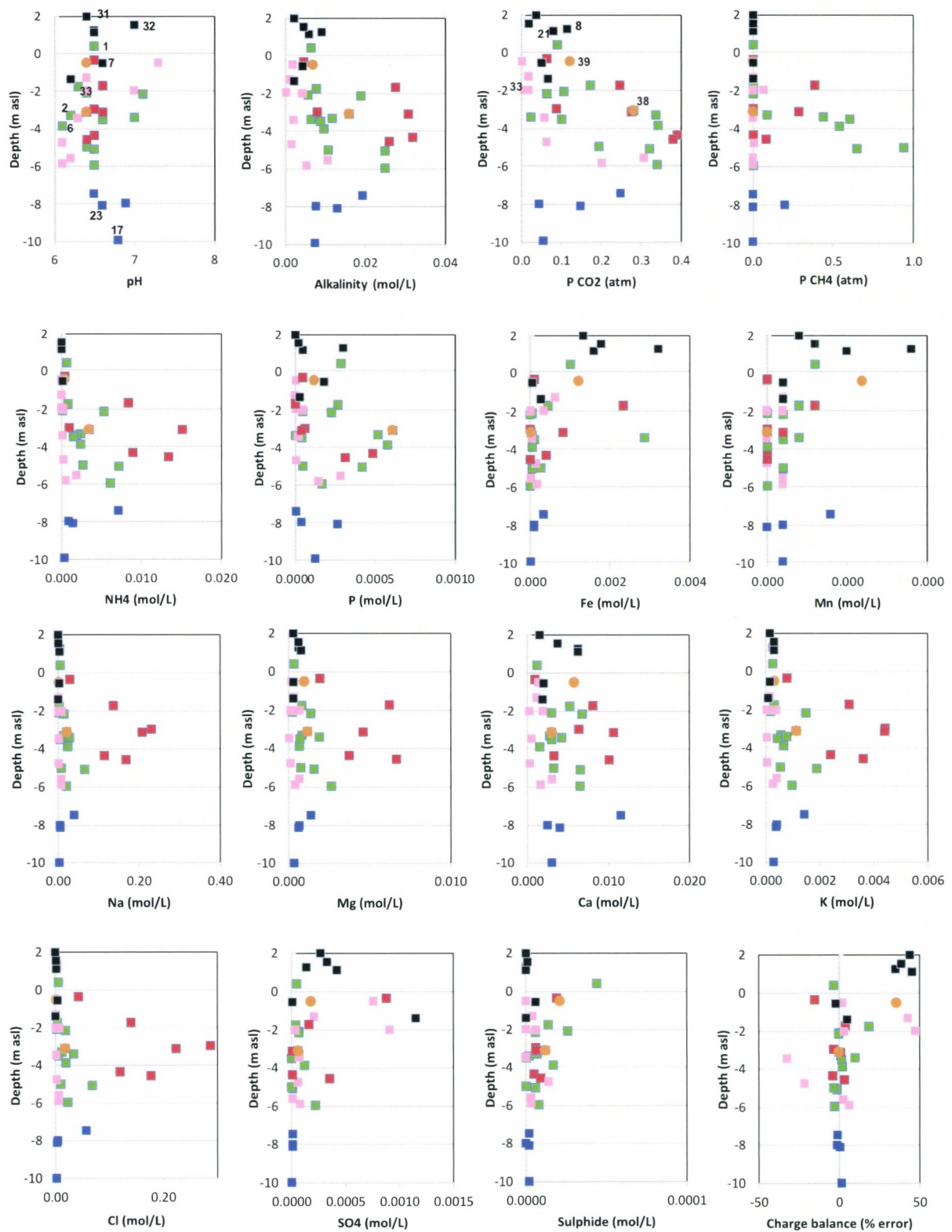


Figure 5: Comparison of groundwater data from MB38 and MB39 (orange points) with groundwater data from all other dip wells on Bryggen (sampled in autumn 2011). The different colours indicate: Black – water from the drained area; green – water from relatively stagnant conditions; red – dip wells near the quayfront influenced by seawater; pink – dip wells near the sheet piling diluted by rainwater; and blue – water from natural deposits underneath the cultural layers. Numbers indicate dip wells along a gradient from area A impacted by drainage to area D with stagnant conditions defined by a conceptual model of groundwater formation and chemistry (de Beer and Matthiesen 2008, Matthiesen 2012).

## **Discussion**

### **Soil characteristics**

Figure 2 (left) shows the loss on ignition (LOI) and dry matter content of soil samples from dip well MB38 and MB39, along with a brief description of the different soil strata (taken from Dunlop, 2011).

In MB38 the upper 0.7 m (down to 1.7 m asl) of the deposits are modern and post-medieval and comprise stones under a planked passageway surface and the fire layer from the 1702 fire. Medieval deposits start from 1.7 m asl. From 1.7 to 0.5 m asl these humic deposits are sandy, relatively porous (semi-compact, partly disturbed layering). The LOI is still reasonably high (34%), but the state of preservation is poor (State of Preservation Scale, SoPS 2). From 0.5 m asl to -1.95 m asl the preservation of the organic deposits increases to medium (SoPS 3) and an LOI of > 50% but the material is still semi-compact. From -0.35 m asl the mineral content increases to 50% which is reflected in a LOI minimum. Humus material is relatively loose. An intercalated layer with timber shows good preservation (SoPS 4). Also in the lowest part of the profile from -1.95 m to a depth of -3.6 m asl good preservation conditions prevail. This coincides with highest LOI reaching 64% and corresponding to a high organic content. At -3.6 m asl drilling was abandoned to avoid puncturing of the cultural deposits. The groundwater level was measured to 1.16 m below surface or 1.24 m asl on the 27<sup>th</sup> of March 2012.

In MB39 the upper 0.85 m are modern, and at 2.15 m asl possibly a disturbed medieval firelayer is encountered. Beneath this, medieval quite homogeneous and compact organic deposits of medium preservation (SoPS 3) are found from 2.1 m to 0.35 m asl, including layers of timber (e.g. from 1.4 to 0.55 m asl). Here, LOI decreases to a minimum of 22%. Highly organic layers follow from 0.35 m asl with a good state of preservation (SoPS 4) from 0.05 to -0.85 m. This is also reflected in a high LOI of up to 66%. Below -0.85 m to -2.45 m asl deposits mainly consist of porous sand with an organic content < 40%, and their state of preservation is poor (SoPS 2). Excellent state of preservation is found in compact highly organic material from -2.45 m asl (SoPS 5) where LOI with ca. 50% again is elevated. Drilling was abandoned at -3 m asl in order to minimize disturbance. The medieval archaeological deposits are in total a little in excess of 6 meters thick and are underlain by sand and bedrock. The groundwater level was measured to 0.42 m below surface or 2.58 m asl on the 7<sup>th</sup> of October 2011.

### **Redox conditions, nutrients and pH**

Both dip wells are situated in area D which in the conceptual model for Bryggen is characterized by relatively stagnant groundwater and very good preservation conditions (de Beer and Matthiesen 2008). The groundwater analyses (Figure 3) confirm an anoxic environment, where reduced species

( $\text{Fe}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{HS}^-$ ,  $\text{CH}_4$ , and  $\text{NH}_4^+$ ) accumulate and alkalinity is high. Oxygen has not been measured in water from MB 38, but accumulation of  $\text{NH}_4^+$  in high concentrations indicate anoxic conditions in the deeper part of the cultural deposits at the average filter depth of -3.1 m asl. At MB39 the high concentrations of dissolved  $\text{Fe}^{2+}$  exclude the presence of oxygen in the water. The only oxidant measured at a significant concentration in the water is sulphate. Compared to MB38, groundwater of MB39 is markedly depleted in dissolved salts (15 times), alkalinity (> 2 times), and dissolved nutrients (e.g.  $\text{NH}_4^+$  7 times). In contrast, concentrations of  $\text{Ca}^{2+}$ ,  $\text{SO}_4^{2-}$  and  $\text{Fe}^{2+}$  are considerably (2, 3 and ca. 50 times) elevated. The water intake (filter) at MB39 is placed from 0 to -1 m asl collecting water from both a highly organic layer and a more permeable sandy layer below, whereas the filter at MB38 is placed at -2.6 to -3.6 m asl in a highly organic layer. From these observations it appears, that conditions in the upper soil layers differ considerably from what is seen deeper in the soil. However, for further evaluation it also has to be taken into account that MB38 is placed in the centre of area D whereas MB39 is placed in the outskirts, next to area A which is influenced by drainage.

The pH measured for both locations is near neutral with pH 6.4 in the groundwater, but soil pH in the profile is on average 1 pH unit lower at MB 39 (pH 6.3) compared to MB38 (pH 7.3). There is a general trend to lower pH values in groundwater samples in 2011 compared to earlier sampling rounds (Matthiesen 2012), however, this might be an artefact as the pH was measured in the laboratory in 2011 and not directly in the field as in 2008.

The soil is relatively nutrient rich (N, P), and the concentrations reflect the different layering of sandy and organic-rich material at both locations. The C/N ratios of the soil samples are in the range 16-26 and consistent with the characteristic ratios for most of Bryggen. The C/N ratio of organic material is used to indicate the type of material and ease of decomposition; hard woody materials with a high C/N ratio being more resilient than soft leafy materials with a low C:N ratio. At a C/N ratio < 20 surplus nitrogen is released as  $\text{NO}_3^-$  or  $\text{NH}_4^+$  whereas at C/N ratios > 30 decay is slowed down as microbial growth is N limited. The C/N ratio normally increases with increasing decomposition, as more C than N is lost. At MB39, and at other locations in area D, e.g. MB6, total S concentrations increase with depth. The S concentrations are generally well correlated with the organic content of the soil.

Comparing the results from other dip wells, sampled in autumn 2011, Figure 5 shows that the concentrations measured in MB38 and MB39 (orange markers) generally fit with the trends observed for the stagnant area A (green markers). However, there are some exceptions for MB39, where groundwater composition shares some characteristic signs with dip wells of the drained area (black markers), e.g. relatively high concentrations of dissolved  $\text{Fe}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{SO}_4^{2-}$  and  $\text{Ca}^{2+}$ , and a large error in the ion balance. This is discussed below by setting the two dip wells in context to the surroundings.



## Spatial variability of soil characteristics

Loss on ignition of the soil samples varies considerably both above and below sea level and reflects differences in composition of the organic deposits. Most pronounced differences between the deposits are observed in soil pH and Cl content (Figure 5). High pH and Cl concentrations confirm a stagnant environment at MB38 where through-flow is low up to ca. 0.7 m asl. In contrast, at MB 39 lower soil pH and a decreased Cl content down to ca. -3 m asl indicate that the soil around this dipwell to a certain degree are affected by increased flushing with rain water an indirectly by drainage (as seen at MB7, 21, 31-33).

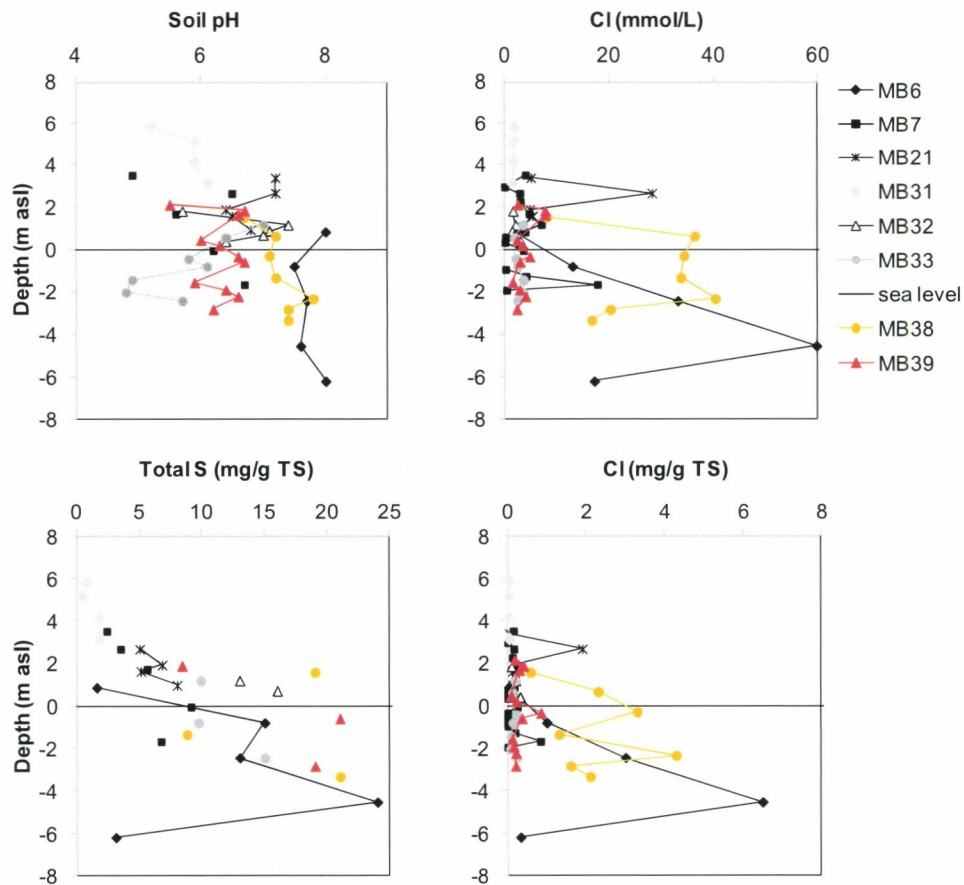


Figure 6: Comparison of selected soil characteristics from dip well drillings MB 38 and 39 with MB7, 21, 31-33 from the drained area A, partly also affected by the sheet piling, and MB6 representing a stagnant environment in area D.

## Spatial and temporal variability of groundwater composition

Regarding a gradient from MB31 in area A to MB38 in area D in 148 to 79 m distance from the coast (Figure 7, data from 2011), MB38 and 39 fit well in the trend showing an increase of Na, Cl, alkalinity ( $\text{HCO}_3^-$ ), K and  $\text{NH}_4$  towards the coast. In contrast,  $\text{Fe}^{2+}$ ,  $\text{SO}_4^{2-}$ , and  $\text{Mn}^{2+}$  are among the reaction products showing the opposite trend.

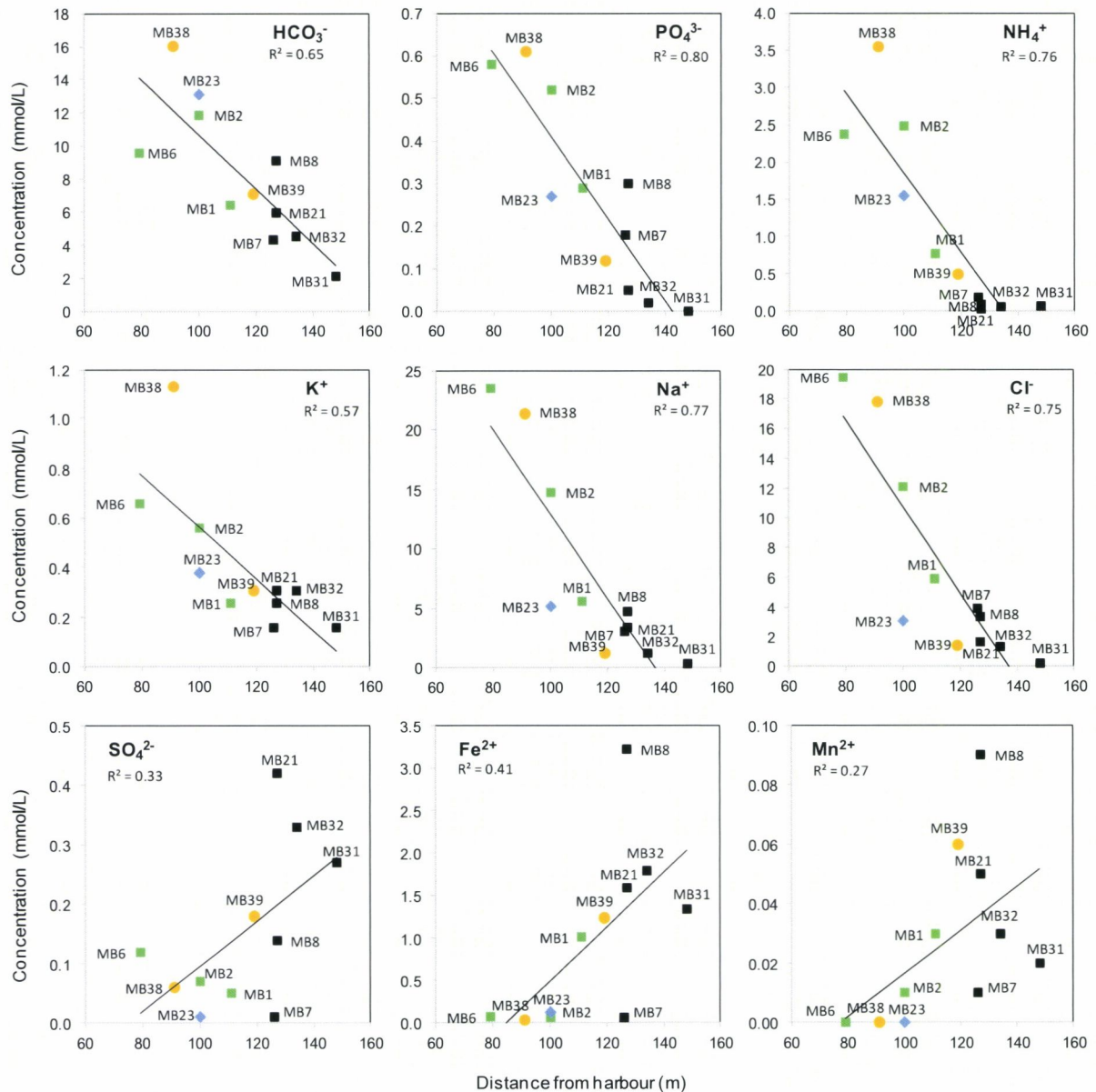


Figure 7: Spatial trends of groundwater chemistry vs. distance from the harbour, along a transect starting from dip well 31 in the drained area A to MB 6 in area D characterized by more stagnant conditions. MB 33 is strongly affected by the conditions at the sheet piling and therefore not included here. CH<sub>4</sub> is not shown as possibly some methane may have been lost during the sampling in 2011 underestimating the true concentrations.

In Figure 8 and 9 the development of the groundwater chemistry of the selected dip wells is presented over time and with sampling depth (depth of water intake is shown in the upper panel). Conditions at MB38 exhibit a very similar pattern and follow concentration ranges measured at MB2 and 6 having their water intake at approximately the same depth and representing stagnant conditions in area D. Dip wells MB17 and 23 in about the same distance from the harbour as MB38 go down into natural deposits and therefore have a mixed signature of rainwater and water coming from the organic rich cultural deposits with relatively stagnant conditions diluted by water with a low ion content running through the rock/natural deposits. This is expressed by a low salt, NH<sub>4</sub> and

SO<sub>4</sub> content but also a still elevated CH<sub>4</sub> concentration level. The importance of the local hydrology is visible at MB1 in area D where conditions have varied over the years between the presence of oxygen in 2002 (in the first year after installation) and a reducing environment with accumulation of Fe<sup>2+</sup> and some methane in the later sampling rounds. High Fe<sup>2+</sup> concentrations are found in several dipwells with water intake in the upper soil layers (MB39, 21, 32 and 31 – Figure 9) and these are also characterised by relatively high concentrations of SO<sub>4</sub> (which is not the case in MB1). Thus, MB1 can be regarded as the transition to MB39 and dip wells from the upper soil layers with higher Fe<sup>2+</sup> concentrations and occurrence of Mn<sup>2+</sup>.

Groundwater from MB 39 stems from the same depth (m asl) as MB7, but MB39 shares more common features with MB 21, 31 and 32 that have their filters right beneath the unsaturated zone in the drained area. These dip wells are all characterized by a high level of Fe<sup>2+</sup>, Mn<sup>2+</sup> and SO<sub>4</sub><sup>2-</sup>. Most dynamic conditions are found close to the sheet piling where the cluster of dip wells MB7, 8, 21 and 33 reflect the varying influence of drainage and a low water table (e.g. no water at MB8 and 21 in May '08 at the average filter depth of 1.26 and 1.11 m asl, respectively) and increased flow of rainwater in other periods. The ion concentrations were very low in MB33 in the sampling in 2011, indicating an increased rainwater input, which can be ascribed to the fact that 2/3 of the filter of MB33 collects water from a more permeable layer consisting of 50/50% fine sand and grey/brown humus. Also at the highest dip well MB31 a more permeable fine to medium sand layer may favour transport and with this draining or a generally fast reaction to changes in environmental conditions. Conditions at MB39 are clearly affected by processes above the ground water table, again a more porous sandy layer penetrated by the filter might contribute to the ground water composition and vertical exchange.



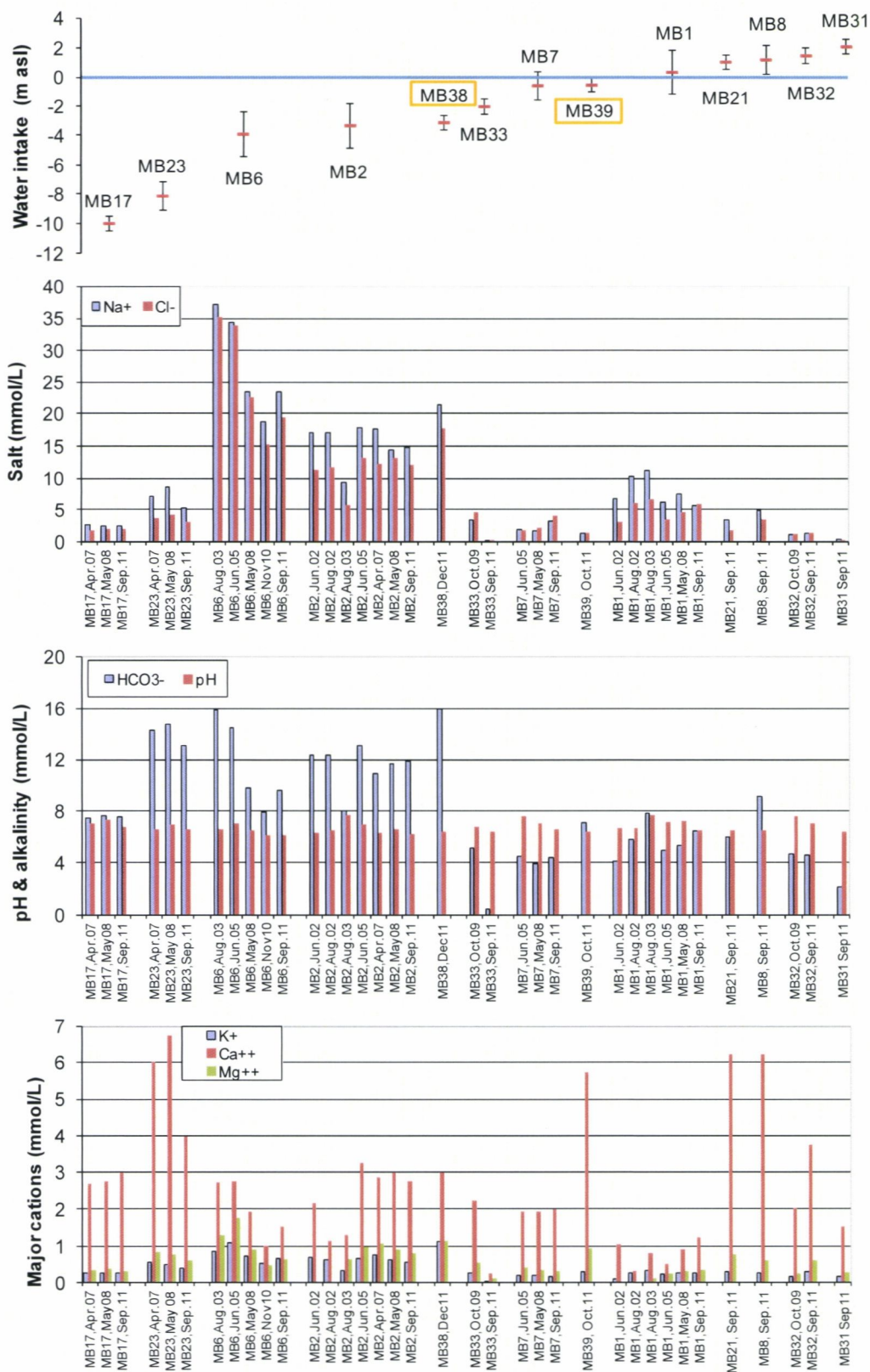


Figure 8: Concentrations of sodium ( $\text{Na}^+$ ) and chloride ( $\text{Cl}^-$ ), alkalinity ( $\text{HCO}_3^-$ ), pH, potassium ( $\text{K}^+$ ), calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ) in selected dip wells as time series arranged after depth of their water intake (upper diagram). The new dip wells MB38 and 39 are highlighted. To obtain results in mg/L the numbers in mmol/L must be multiplied by 22.99 for Na, 35.45 for Cl, 61.02 for  $\text{HCO}_3^-$ , 39.10 for K, 40.08 for Ca and 24.31 for Mg.

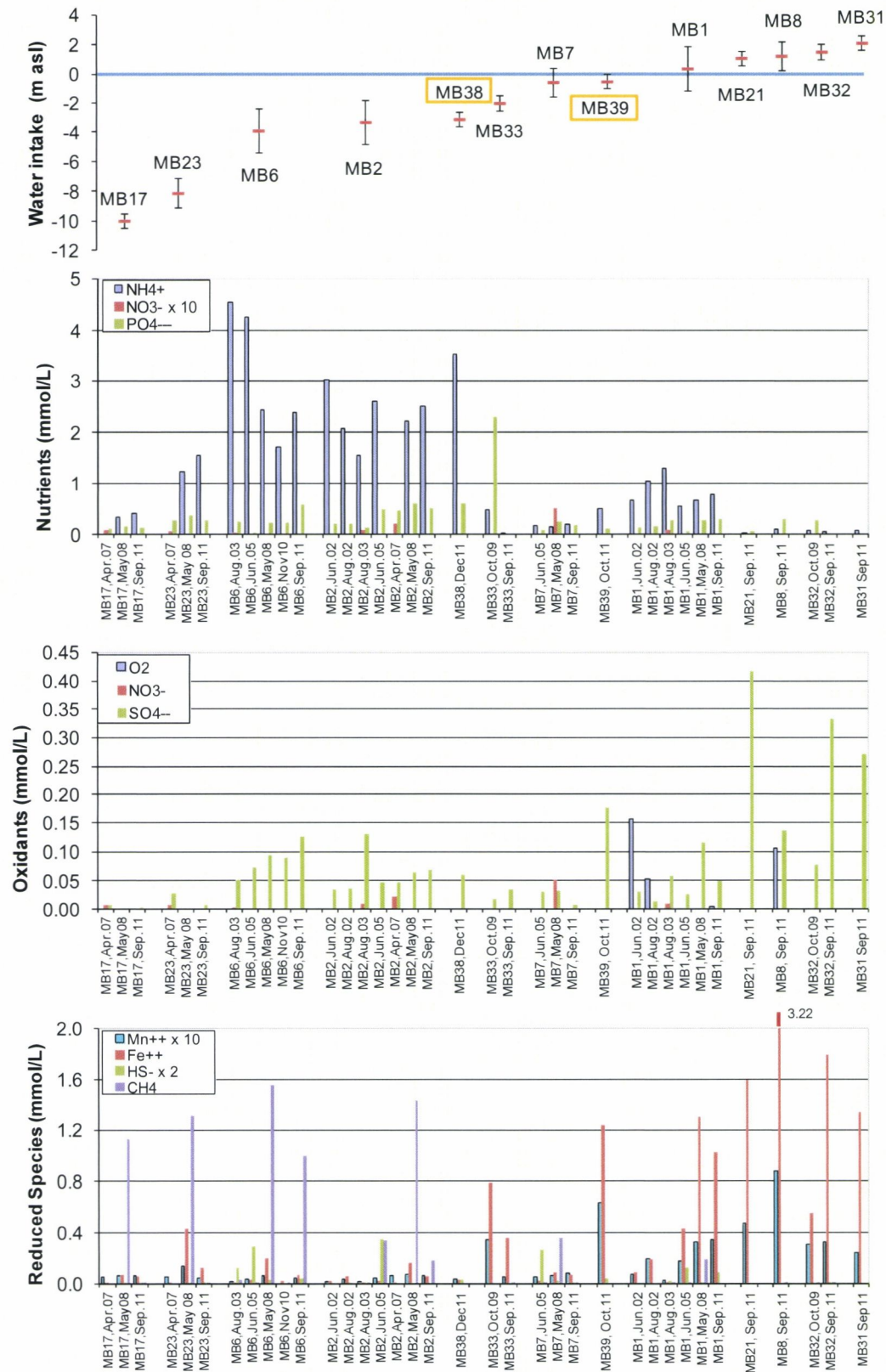


Figure 9: Concentrations of different nutrients, oxidants and reduced species in the dip wells as time series arranged after depth of their water intake (upper diagram). Note that for better visibility the concentration of NO<sub>3</sub> is multiplied by 10 (nutrient diagram) and the concentrations of Mn and HS are multiplied by 10 and 2 respectively (lower diagram). Sulphide was not analysed in 2002 or 2007, and in May '08 the results for MB2 were reported as "too high" for the analytical method applied. In May '08 dip wells 8 and 21 were dry. Due to pollution problems oxygen measurements

below 0.05 mmol/L have been discarded from the results and oxygen was not analysed at all in May '07. Methane was not measured in 2002, and in 2003, 2005 and possibly 2011 some methane may have been lost during the sampling resulting in too low values.

### **Preservation conditions at MB38 and MB39 and the influence of drainage and water flow**

Water level loggers in the drained area at the rear of Nordre Bredsgården have shown a low and fluctuating groundwater level, for instance in MB7 where the water level has varied between 0.7 and 2 m asl in the period 2006-2011 (data from de Beer). Monitoring in the unsaturated zone during 2011 has documented occasional O<sub>2</sub> penetration down to ca. 2.3 m asl (Matthiesen & Hollesen 2012) with very fluctuating conditions and a distinct (negative) correlation to the precipitation and water content of the soil: When it rains the water content of the soil increases and the conditions become anoxic, whereas during dry periods the water content decreases and the conditions become oxic in the upper soil layers. These recurrent oxidation and reduction changes can generate reactive amorphous Fe-hydr(oxides) fuelling reductive bacterial mineralization processes, along with reactive manganese oxides and sulphate as discussed in Matthiesen (2012). In the period 2006-2010 there was an overall tendency towards decreasing water content in the soil, probably due to natural variations in the precipitation (Matthiesen & Hollesen 2012). In 2011, the trend of 'drying out' of the uppermost soil did not seem to continue and the high Fe<sup>2+</sup> concentrations we see in 2011 could indicate on-going intensified reduction processes following rewetting. The filter of MB39 is placed just below sea level, and the groundwater composition with high concentrations of Fe<sup>2+</sup>, Mn<sup>2+</sup> and SO<sub>4</sub><sup>2-</sup> is clearly affected by the processes going on in the upper deposits.

The sulphate produced in the upper deposits may be transported downwards and used for sulphate reduction in the deeper deposits, whereas produced iron and manganese oxides are immobile and stays in the upper deposits. In a laboratory study using samples from MB39 (and other samples from Bryggen) sulphate reduction rates corresponding to a decay rate of 0.003 to 0.013 mg organic carbon per g dry soil per day were found (Hollesen and Matthiesen 2012). This would correspond to lousy or poor preservation conditions (PresCon 1-2), but it must be emphasized that the laboratory study was made at room temperature (23 °C) and using relatively high sulphate concentrations (0.4-1 mmol/L). The sulphate reduction rate in situ is expected to be lower due to lower temperatures and restricted transport in the compact organic deposits at MB39. At this stage we cannot give a quantitative estimate of the decay rate in situ, but a first guess would be that the preservation conditions are PresCon 2, 3 or maybe even 4 (poor, middle or good) in the deposits just beneath the unsaturated zone. Furthermore, it is estimated that the preservation conditions are lousy to poor in the unsaturated zone (PresCon 1-2), and good to excellent in the deepest deposits (PresCon 4-5).



The state of preservation of the organic layers at MB39 down to sea level is still at medium level (SoPS 3), and good deeper down (SoPS 4).

At the deeper dipwell MB38 we see lower concentrations of dissolved  $\text{Fe}^{2+}$ ,  $\text{Mn}^{2+}$  and  $\text{SO}_4^{2-}$  and the groundwater reminds of typical composition from the inner/deeper parts of peatlands. Beer et al (2008) describe how lack of transport and slow diffusive porewater movement in the saturated zone led to accumulation of dissolved inorganic carbon,  $\text{CH}_4$  and dissolved organic matter (DOM) slowing down any further decay by impeding or limiting the release of more easily degradable DOM and methanogenesis. This should guarantee good preservation conditions in the cultural layers in particular below sea level. Under these more stable conditions the soil can also become a sink for sulphur, which may be incorporated in insoluble  $\text{FeS}$  or  $\text{FeS}_2$ . Other processes that may be responsible for the low Mn and Fe concentrations in the ground water from MB38 include the precipitation of the dissolved  $\text{Fe}^{2+}$  and  $\text{Mn}^{2+}$  as Fe- and Mn carbonates (siderite, rhodochrosite).  $\text{Fe}^{2+}$  can also be bound to organic substance or precipitate as vivianite which is a possible sink for phosphate.

The groundwater composition in MB38 is similar to what is found in MB2 and MB6 as well as other dipwells from area D on Bryggen (green markers in Figure 5). This indicates excellent preservation conditions (PresCon 5) at the depth of the filter of MB38 (-2.60 to -3.60 m asl). The conditions in the higher soil strata are less clear, but the high chloride content and pH indicate relatively stagnant conditions up to ca. 0.5 m asl. The deposits above 0.5 m asl level at MB38 consist of semi compact layers of sandy humus, where the conditions may be less stagnant. The organic content in these deposits is high and reaches with 33-36%, however with a poor state of preservation (SoPS 2). At present, it is not clear if the poor state of preservation is a result of ongoing decay processes, or if the decay took place during the formation of the deposits.

### ***Conclusions and future work***

It has been shown that around dipwells MB38 and MB39:

- Local conditions such as permeability of the soil strongly determine the preservation state of the cultural deposits and their content of decomposed humus.
- The deposits just beneath the groundwater level can be affected by processes occurring in the unsaturated zone.
- Changes of the groundwater level and recurrent oxidation processes may control the decay rate in the surface layers, but also to a certain degree in the deeper soil where supply of dissolved sulphate via preferential flow paths and more permeable sandy layers is possible.

- At MB39 the preservation conditions are estimated to be PresCon 1-2 (Lousy to poor) in the unsaturated zone, PresCon 2-4 (poor to good) just beneath the groundwater level where dissolved sulphate is supplied from above, and PresCon 4-5 (Good to excellent) in the deepest deposits.
- At MB38 the conditions in the deeper deposits are estimated to be PresCon 5 (Excellent) based on groundwater data from -2.6 to -3.6 m asl. The preservation conditions in the upper soil layers are less clear.

Further studies may include

- Logging of water level, water saturation and oxygen content in the unsaturated zone in area D, to elucidate the possible causes of the poor to medium state of preservation of the upper deposits at MB 38.
- Further water samples should be collected to confirm if MB39 is indirectly or directly influenced by drainage and therefore marks a transition between area A and D or if the conditions observed reflect the development in the unsaturated zone in general.
- A test infiltration in the drained area with labelled rain water could shed further light on the connections between deposits above and below the groundwater level

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***Appendix 1***

Results from analysis of soil samples from MB38 and 39 (Eurofins)

Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C55010  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C5501001

Att.: Henning Matthiesen

Modt. dato: 2011.11.10

## ANALYSERAPPORT

Sidenr.: 1 af 7

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen overvågn. af kulturlag Bellgården/Jacobsfjorden MB38**  
Prøvetype.....: Jord  
Prøvemærke.....: **01**  
Prøveudtagning...:  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.: Nov. 11  
Analyseperiode...: 2011.11.11 - 2011.11.17

	Prøvenr.: C5501001			
	Prøve ID: MB38	Detekt.		Um
	Prøvemærke:	grænse	Metoder	(%)
pH	6.7 pH		*DS 287 mod.	
Tørstof	33 %	0.05	DS 204 mod.	10
Glødetab, total	11.3 %	0.002	DS 204	20
Glødetab på tørstof	34 % i ts.	0.10	DS 204	20
Kvælstof, total	2500 mg/kg	5	NF 1975	20
Phosphor, total	11000 mg/kg ts.	100	DS259/SM3120ICP	30
Chlorid, vandopløselig	580 mg/kg ts.	5	*SM 17.udg. 4500	20
Sulfat, vandopløselig	2300 mg/kg ts.	1	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.  
< : mindre end. i.p.: ikke påvist.  
> : større end. i.m.: ikke målelig.  
# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).  
Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C55010  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C5501002

Att.: Henning Matthiesen

Modt. dato: 2011.11.10

## ANALYSERAPPORT

Sidenr.: 2 af 7

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen overvågn. af kulturlag Bellgården/Jacobsfjorden MB38**  
Prøvetype.....: Jord  
Prøvemærke.....: **02**  
Prøveudtagning...:  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.: Nov. 11  
Analyseperiode...: 2011.11.11 - 2011.11.17

	Prøvenr.: C5501002			
	Prøve ID: MB38	Detekt.		Um
	Prøvemærke:	grænse	Metoder	(%)
pH	7.2 pH		*DS 287 mod.	
Tørstof	36 %	0.05	DS 204 mod.	10
Glødetab, total	12.6 %	0.002	DS 204	20
Glødetab på tørstof	35 % i ts.	0.10	DS 204	20
Chlorid, vandopløselig	2300 mg/kg ts.	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.





Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C55010  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C5501003

Att.: Henning Matthiesen

Modt. dato: 2011.11.10

## ANALYSERAPPORT

Sidenr.: 3 af 7

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen overvågn. af kulturlag Bellgården/Jacobsfjorden MB38**  
Prøvetype.....: Jord  
Prøvemærke.....: **03**  
Prøveudtagning...:  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.: Nov. 11  
Analyseperiode...: 2011.11.11 - 2011.11.17

Prøvenr.: C5501003  
Prøve ID: MB38  
Prøvemærke:

Detekt. Um  
grænse Metoder (%)

pH	7.1 pH		*DS 287 mod.	
Tørstof	27 %	0.05	DS 204 mod.	10
Glødetab, total	14.6 %	0.002	DS 204	20
Glødetab på tørstof	54 % i ts.	0.10	DS 204	20
Chlorid, vandopløselig	3300 mg/kg ts.	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



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2800 Kgs.Lyngby

Registrernr.: C55010  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C5501004

Att.: Henning Matthiesen

Modt. dato: 2011.11.10

## ANALYSERAPPORT

Sidenr.: 4 af 7

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen overvågn. af kulturlag Bellgården/Jacobsfjorden MB38**  
Prøvetype.....: Jord  
Prøvemærke.....: **04**  
Prøveudtagning...:  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.: Nov. 11  
Analyseperiode...: 2011.11.11 - 2011.11.17

Prøvenr.: C5501004  
Prøve ID: MB38  
Prøvemærke:

Detekt. Um  
grænse Metoder (%)

pH	7.2 pH		*DS 287 mod.	
Tørstof	48 %	0.05	DS 204 mod.	10
Glødetab, total	10.0 %	0.002	DS 204	20
Glødetab på tørstof	21 % i ts.	0.10	DS 204	20
Kvælstof, total	3200 mg/kg	5	NF 1975	20
Phosphor, total	4600 mg/kg ts.	100	DS259/SM3120ICP	30
Chlorid, vandopløselig	1300 mg/kg ts.	5	*SM 17.udg. 4500	20
Sulfat, vandopløselig	750 mg/kg ts.	1	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.  
< : mindre end. i.p.: ikke påvist.  
> : større end. i.m.: ikke målelig.  
# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).  
Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C55010  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C5501005

Att.: Henning Matthiesen

Modt. dato: 2011.11.10

## ANALYSERAPPORT

Sidenr.: 5 af 7

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen overvågn. af kulturlag Bellgården/Jacobsfjorden MB38**  
Prøvetype.....: Jord  
Prøvemærke.....: **05**  
Prøveudtagning...:  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.: Nov. 11  
Analyseperiode...: 2011.11.11 - 2011.11.17

Prøvenr.: C5501005  
Prøve ID: MB38  
Prøvemærke:

Detekt. Um  
grænse Metoder (%)

pH	7.8 pH		*DS 287 mod.	
Tørstof	25 %	0.05	DS 204 mod.	10
Glødetab, total	16.0 %	0.002	DS 204	20
Glødetab på tørstof	64 % i ts.	0.10	DS 204	20
Chlorid, vandopløselig	4300 mg/kg ts.	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).  
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Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C55010  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C5501006

Att.: Henning Matthiesen

Modt. dato: 2011.11.10

## ANALYSERAPPORT

Sidenr.: 6 af 7

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen overvågn. af kulturlag Bellgården/Jacobsfjorden MB38**  
Prøvetype.....: Jord  
Prøvemærke.....: **06**  
Prøveudtagning...:  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.: Nov. 11  
Analyseperiode...: 2011.11.11 - 2011.11.17

	Prøvenr.: C5501006			
	Prøve ID: MB38	Detekt.		Um
	Prøvemærke:	grænse	Metoder	(%)
pH	7.4 pH		*DS 287 mod.	
Tørstof	31 %	0.05	DS 204 mod.	10
Glødetab, total	14.3 %	0.002	DS 204	20
Glødetab på tørstof	46 % i ts.	0.10	DS 204	20
Chlorid, vandopløselig	1600 mg/kg ts.	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C55010  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C5501007

Att.: Henning Matthiesen

Modt. dato: 2011.11.10

## ANALYSERAPPORT

Sidenr.: 7 af 7

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen overvågn. af kulturlag Bellgården/Jacobsfjorden MB38**  
Prøvetype.....: Jord  
Prøvemærke.....: **07**  
Prøveudtagning...:  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.: Nov. 11  
Analyseperiode...: 2011.11.11 - 2011.11.17

Prøvenr.: C5501007  
Prøve ID: MB38  
Prøvemærke:

Detekt. Um  
grænse Metoder (%)

pH	7.4 pH		*DS 287 mod.	
Tørstof	22 %	0.05	DS 204 mod.	10
Glødetab, total	14.2 %	0.002	DS 204	20
Glødetab på tørstof	63 % i ts.	0.10	DS 204	20
Kvælstof, total	3300 mg/kg	5	NF 1975	20
Phosphor, total	8100 mg/kg ts.	100	DS259/SM3120ICP	30
Chlorid, vandopløselig	2100 mg/kg ts.	5	*SM 17.udg. 4500	20
Sulfat, vandopløselig	810 mg/kg ts.	1	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

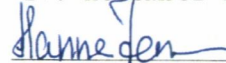
### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

- < : mindre end. i.p.: ikke påvist.
- > : større end. i.m.: ikke målelig.
- # : ingen af parametrene er påvist.

Kundecenter: tlf.70224267 Hanne Jensen  
Kontaktperson Godkendt af

17. november 2011

  
Hanne Jensen

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494401  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 1 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.:  
Analyseperiode...: 2011.06.17 - 2011.06.30

	Prøvenr.: <b>C3494401</b>		Detekt. grænse	Metoder	Um (%)
pH	5.5 pH			*DS 287 mod.	
Tørstof	34 %		0.05	DS 204 mod.	10
Glødetab, total	13.0 %		0.002	DS 204	20
Glødetab på tørstof	38 % i ts.		0.10	DS 204	20
Chlorid, vandopløselig	180 mg/kg ts.		5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.  
< : mindre end. i.p.: ikke påvist.  
> : større end. i.m.: ikke målelig.  
# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).  
Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.





Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494402  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 2 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger:  
Analyseperiode...: 2011.06.17 - 2011.06.30

Prøvenr.: C3494402  
Prøve ID:  
Prøvemærke: MB39 no 02

		Detekt. grænse	Metoder	Um (%)
pH	6.7 pH		*DS 287 mod.	
Tørstof	41 %	0.05	DS 204 mod.	10
Glødetab, total	12.1 %	0.002	DS 204	20
Glødetab på tørstof	30 % i ts.	0.10	DS 204	20
Kvælstof, total	4400 mg/kg	5	NF 1975	20
Phosphor, total	11000 mg/kg ts.	100	DS259/SM3120ICP	30
Chlorid, vandopløselig	400 mg/kg ts.	5	*SM 17.udg. 4500	20
Sulfat, vandopløselig	76 mg/kg ts.	1	*SM 17.udg. 4500	20
Svovl, total	8400 mg/kg ts.	50.0	DS259/SM3120ICP	30

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494403  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 3 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.:  
Analyseperiode...: 2011.06.17 - 2011.06.30

	Prøvenr.: C3494403	Detekt. grænse	Metoder	Um (%)
pH	6.6 pH		*DS 287 mod.	
Tørstof	48 %	0.05	DS 204 mod.	10
Glødetab, total	11.3 %	0.002	DS 204	20
Glødetab på tørstof	23 % i ts.	0.10	DS 204	20
Chlorid, vandopløselig	300 mg/kg ts.	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494404  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 4 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.:  
Analyseperiode...: 2011.06.17 - 2011.06.30

	Prøvenr.: <b>C3494404</b>	Detekt. grænse	Metoder	Um (%)
	Prøve ID:			
	Prøvemærke: <b>MB39 no 04</b>			
pH	<b>6.0 pH</b>		*DS 287 mod.	
Tørstof	<b>52 %</b>	0.05	DS 204 mod.	10
Glødetab, total	<b>11.5 %</b>	0.002	DS 204	20
Glødetab på tørstof	<b>22 % i ts.</b>	0.10	DS 204	20
Chlorid, vandopløselig	<b>80 mg/kg ts.</b>	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494405  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 5 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.:  
Analyseperiode...: 2011.06.17 - 2011.06.30

	Prøvenr.: C3494405	Detekt. grænse	Metoder	Um (%)
pH	6.3 pH		*DS 287 mod.	
Tørstof	36 %	0.05	DS 204 mod.	10
Glødetab, total	12.6 %	0.002	DS 204	20
Glødetab på tørstof	35 % i ts.	0.10	DS 204	20
Chlorid, vandopløselig	220 mg/kg ts.	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.





Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494406  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 6 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.:  
Analyseperiode...: 2011.06.17 - 2011.06.30

	Prøvenr.: C3494406	Detekt. grænse	Metoder	Um (%)
pH	6.6 pH		*DS 287 mod.	
Tørstof	17 %	0.05	DS 204 mod.	10
Glødetab, total	11.1 %	0.002	DS 204	20
Glødetab på tørstof	66 % i ts.	0.10	DS 204	20
Chlorid, vandopløselig	850 mg/kg ts.	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

- < : mindre end. i.p.: ikke påvist.
- > : større end. i.m.: ikke målelig.
- # : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).  
Rapporten må ikke gives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494407  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 7 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.:  
Analyseperiode...: 2011.06.17 - 2011.06.30

Prøvenr.: **C3494407**  
Prøve ID:  
Prøvemærke: **MB39 no 07**

		Detekt. grænse	Metoder	Um (%)
pH	6.7 pH		*DS 287 mod.	
Tørstof	23 %	0.05	DS 204 mod.	10
Glødetab, total	13.3 %	0.002	DS 204	20
Glødetab på tørstof	58 % i ts.	0.10	DS 204	20
Kvælstof, total	3000 mg/kg	5	NF 1975	20
Phosphor, total	5400 mg/kg ts.	100	DS259/SM3120ICP	30
Chlorid, vandopløselig	360 mg/kg ts.	5	*SM 17.udg. 4500	20
Sulfat, vandopløselig	190 mg/kg ts.	1	*SM 17.udg. 4500	20
Svovl, total	21000 mg/kg ts.	50.0	DS259/SM3120ICP	30

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494408  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 8 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.:  
Analyseperiode...: 2011.06.17 - 2011.06.30

Prøvenr.: **C3494408**  
Prøve ID:  
Prøvemærke: **MB39 no 08**

Detekt. Um  
grænse Metoder (%)

pH	5.9 pH		*DS 287 mod.	
Tørstof	34 %	0.05	DS 204 mod.	10
Glødetab, total	13.5 %	0.002	DS 204	20
Glødetab på tørstof	39 % i ts.	0.10	DS 204	20
Chlorid, vandopløselig	110 mg/kg ts.	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494409  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 9 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.:  
Analyseperiode...: 2011.06.17 - 2011.06.30

	Prøvenr.: C3494409	Detekt. grænse	Metoder	Um (%)
pH	6.4 pH		*DS 287 mod.	
Tørstof	41 %	0.05	DS 204 mod.	10
Glødetab, total	11.5 %	0.002	DS 204	20
Glødetab på tørstof	28 % i ts.	0.10	DS 204	20
Chlorid, vandopløselig	150 mg/kg ts.	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).  
Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.





Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494410  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 10 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger:  
Analyseperiode...: 2011.06.17 - 2011.06.30

	Prøvenr.: C3494410	Detekt. grænse	Metoder	Um (%)
pH	6.6 pH		*DS 287 mod.	
Tørstof	41 %	0.05	DS 204 mod.	10
Glødetab, total	13.7 %	0.002	DS 204	20
Glødetab på tørstof	34 % i ts.	0.10	DS 204	20
Chlorid, vandopløselig	210 mg/kg ts.	5	*SM 17.udg. 4500	20

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.



Nationalmuseet  
Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej  
2800 Kgs.Lyngby

Registrernr.: C34944  
Kundenr.: 82983  
Ordrenr.: 407823  
Prøvenr.: C3494411  
Sagsnr.: 11031266  
Modt. dato: 2011.06.17

Att.: Henning Matthiesen

## ANALYSERAPPORT

Sidenr.: 11 af 11

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi  
I.C.Modewegs vej, 2800 Kgs.Lyngby  
Prøvested.....: **Bryggen, overvågning af kulturlag**  
Prøvetype.....: Jord  
Prøveudtagning...: 2011.05.11  
Prøvetager.....: Rekvirenten  
Kundeoplysninger.:  
Analyseperiode...: 2011.06.17 - 2011.06.30

Prøvenr.: **C3494411**  
Prøve ID:  
Prøvemærke: **MB39 no 11**

Detekt. Um  
grænse Metoder (%)

pH	6.2 pH		*DS 287 mod.	
Tørstof	30 %	0.05	DS 204 mod.	10
Glødetab, total	14.5 %	0.002	DS 204	20
Glødetab på tørstof	48 % i ts.	0.10	DS 204	20
Kvælstof, total	4700 mg/kg	5	NF 1975	20
Phosphor, total	5700 mg/kg ts.	100	DS259/SM3120ICP	30
Chlorid, vandopløselig	200 mg/kg ts.	5	*SM 17.udg. 4500	20
Sulfat, vandopløselig	1500 mg/kg ts.	1	*SM 17.udg. 4500	20
Svovl, total	19000 mg/kg ts.	50.0	DS259/SM3120ICP	30

\*) Ikke omfattet af akkrediteringen.

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

- < : mindre end. i.p.: ikke påvist.
- > : større end. i.m.: ikke målelig.
- # : ingen af parametrene er påvist.

Kundecenter: tlf.70224267 Hanne Jensen  
Kontaktperson

30. juni 2011  
  
Godkendt af

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).  
Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

**Appendix 2**

Results from analysis of groundwater from MB38 and 39, sampled in autumn 2011.



Nationalmuseet, Bevaringsafdelingen

Registrernr.: C65956

I.C. Modewegs Vej  
2800 Kgs.Lyngby

Kundenr.: 602325

Ordrenr.: 813114

Prøvenr.: C6595601

Att.: Henning Matthiesen

Modt. dato: 2011.12.28

## ANALYSERAPPORT

Sidenr.: 1 af 1

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen  
I.C. Modewegs Vej, 2800 Kgs.Lyngby

Prøvested.....:

Prøvetype.....: Drikkevand

Prøvemærke.....: **Prøve nr 38**

Prøveudtagning...: 2011.12.22 kl. 11:30

Prøvetager.....: Rekvirenten (OS )

Kundeoplysninger:

Analyseperiode...: 2011.12.28 - 2012.01.10

	Prøvenr.: C6595601	Prøve ID:	**Grænseværdier		Um (%)
			Vejl.	Max.	
pH	6.4\$	pH	7.0-8.5	DS 287:1978	
Calcium (Ca)	120	mg/l		SM3120-ICP	30
Magnesium (Mg)	28	mg/l	50	SM3120-ICP	30
Kalium (K)	44\$	mg/l	10	SM3120-ICP	30
Natrium (Na)	490\$	mg/l	175	SM3120-ICP	30
Jern (Fe)	1.4\$	mg/l	0.2	SM3120-ICP	30
Mangan (Mn)	0.16\$	mg/l	0.05	SM3120-ICP	30
Ammonium	64\$	mg/l	0.05	SM 17.udg. 4500	10
Nitrat	<0.50	mg/l	50	SM 17.udg. 4500	10
Orthophosphat-P	19	mg/l		SM 17.udg. 4500	10
Chlorid	630\$	mg/l	250	SM 17.udg. 4500	10
Sulfat	5.7	mg/l	250	SM 17.udg. 4500	10
Hydrogencarbonat	978	mg/l	>100	DS/EN I 9963	10
Inddampningsrest	1900\$	mg/l	1500	DS 204:1980	12
Sulfid-S	0.39\$	mg/l	0.05	DS 278:1976auto	28

### Analysekommentarer:

Methan udgår pga. laboratoriefejl.

\*\*) Miljøministeriets bekendtgørelse nr. 1024 af 31. oktober 2011

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

\$) Resultater mærket \$ overholder ikke kravværdierne i Miljøministeriets bekendtgørelse nr. 1024 af 31. oktober 2011

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

Kundecenter: tlf.70224256 **Martin Hartlev Pedersen**

Kontaktperson

Godkendt af

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

10. januar 2012





Nationalmuseet, Bevaringsafdelingen

Registrernr.: C58945

I.C. Modewegs Vej  
2800 Kgs.Lyngby

Kundenr.: 602325

Ordrenr.: 813114

Prøvenr.: 10223759

Att.: Henning Matthiesen

Modt. dato: 2011.10.17

## ANALYSERAPPORT

Sidenr.: 1 af 1

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen  
I.C. Modewegs Vej, 2800 Kgs.Lyngby

Prøvested.....:

Prøvetype.....: Råvand - Andet

Prøvemærke.....: **MB39**

Prøveudtagning...: 2011.10.07 kl. 14:00

Prøvetager.....: Rekvirenten

Kundeoplysninger.:

Analyseperiode...: 2011.10.17 - 2011.10.26

Prøvenr.: **10223759**

Prøve ID:

Prøvemærke:

\*\*Grænseværdier

Vejl. Max. Metoder

Um

(%)

pH	6.4	pH	DS 287:1978	
Calcium (Ca)	230	mg/l	SM3120-ICP	30
Magnesium (Mg)	23	mg/l	SM3120-ICP	30
Kalium (K)	12	mg/l	SM3120-ICP	30
Natrium (Na)	28	mg/l	SM3120-ICP	30
Jern (Fe)	69	mg/l	SM3120-ICP	30
Mangan (Mn)	3.5	mg/l	SM3120-ICP	30
Ammonium	9.1	mg/l	SM 17.udg. 4500	10
Nitrat	<0.50	mg/l	SM 17.udg. 4500	10
Orthophosphat-P	3.6	mg/l	SM 17.udg. 4500	10
Chlorid	50	mg/l	SM 17.udg. 4500	10
Sulfat	17	mg/l	SM 17.udg. 4500	10
Hydrogencarbonat	433	mg/l	DS/EN I 9963	10
Inddampningsrest	1400	mg/l	DS 204:1980	12
Sulfid-S	0.66	mg/l	DS 278:1976auto	28
Methan	<0.005	mg/l	M0066 GC/FID	38

\*\*) Miljøministeriets bekendtgørelse nr. 1449 af 11. december 2007

Um(%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt [www.eurofins.dk](http://www.eurofins.dk), søgeord: Måleusikkerhed.

### Tegnforklaring:

RSD : Relativ Analyseusikkerhed.

< : mindre end. i.p.: ikke påvist.

> : større end. i.m.: ikke målelig.

# : ingen af parametrene er påvist.

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Kontaktperson

26. oktober 2011



Martin Hartlev Pedersen  
Godkendt af

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.