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Preservation conditions at dipwells MB34 and MB35 at Finnegården, Bryggen, Bergen

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Report from the
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Case: 11031261
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Title:
Preservation conditions at dipwells MB34 and MB35 at Finnegården, Bryggen, Bergen

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Summary:
In September 2010 two new dipwells, MB34 and MB35, were installed in the southeasternmost part of the original Bryggen area, in order to acquire baseline information on underground conditions in advance of a proposed railway development project. Soil samples from the installation were analysed, and groundwater was sampled on the 24th November 2010 for a full groundwater analysis. The results are presented and commented on in this report, with special emphasis on the actual preservation conditions around the dipwells.
The results have shown that the upper soil layers are sandy with a low organic content. Sandy soil drains rapidly allowing ingress of oxygen, and the preservation conditions above the groundwater level are therefore not very good. However, as these deposits are modern or mainly inorganic, it only has a limited effect on the cultural layers.
The deposits beneath the groundwater level are more organic and susceptible to decay. The proximity to the harbour means that decay through sulphate reduction could be a risk, as has earlier been shown for other dipwells at the quay front on Bryggen. High concentrations of sulphur and pyrite in the soil at MB34 and 35 indicate that this has already taken place to some extent. The present-day decay rate for the deposits depends on the supply of sulphate. During groundwater sampling in November there were only minor amounts of sulphate present, but the dynamics and supply are still unknown.
The first estimate of the preservation categories is PresCon 1 (Lousy) down to the groundwater level, and PresCon 3-4 (Medium to Good) beneath the groundwater level; these estimates may be modified when more data is available.
Effects from future building activity in the area may include changes in the groundwater flow, which could increase (or decrease) the sulphate supply. Continuous data logging and/or repeated groundwater sampling is necessary if this shall be further elucidated.

Henning Matthiesen	David Gregory
Author	Control

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Introduction

The conditions in the archaeological deposits underneath the World Heritage Site Bryggen in Bergen have been thouroughly monitored for the last decade, and more than 30 dipwells have been installed in the area since 2001. In September 2010 two new dipwells, MB34 and MB35, were installed in the southeasternmost part of the original Bryggen area, in order to acquire baseline information on underground conditions in advance of a proposed railway development project (Bybane Nord). Furthermore, the information provided from these new dipwells may help shed light on the causes of the settling of the Hanseatic Museum. Finally, the new dipwells may be used to evaluate if the preservation conditions found in the central Bryggen area (discussed in previous Bryggen reports) are representative of a larger area.

The National Museum of Denmark has been contracted by Riksantikvaren to evaluate the conditions of and threats to the cultural layers at these dipwells based on results from analyses of soil and water.

Site and methods

The new and old dipwells on Bryggen are shown in Figure 1.

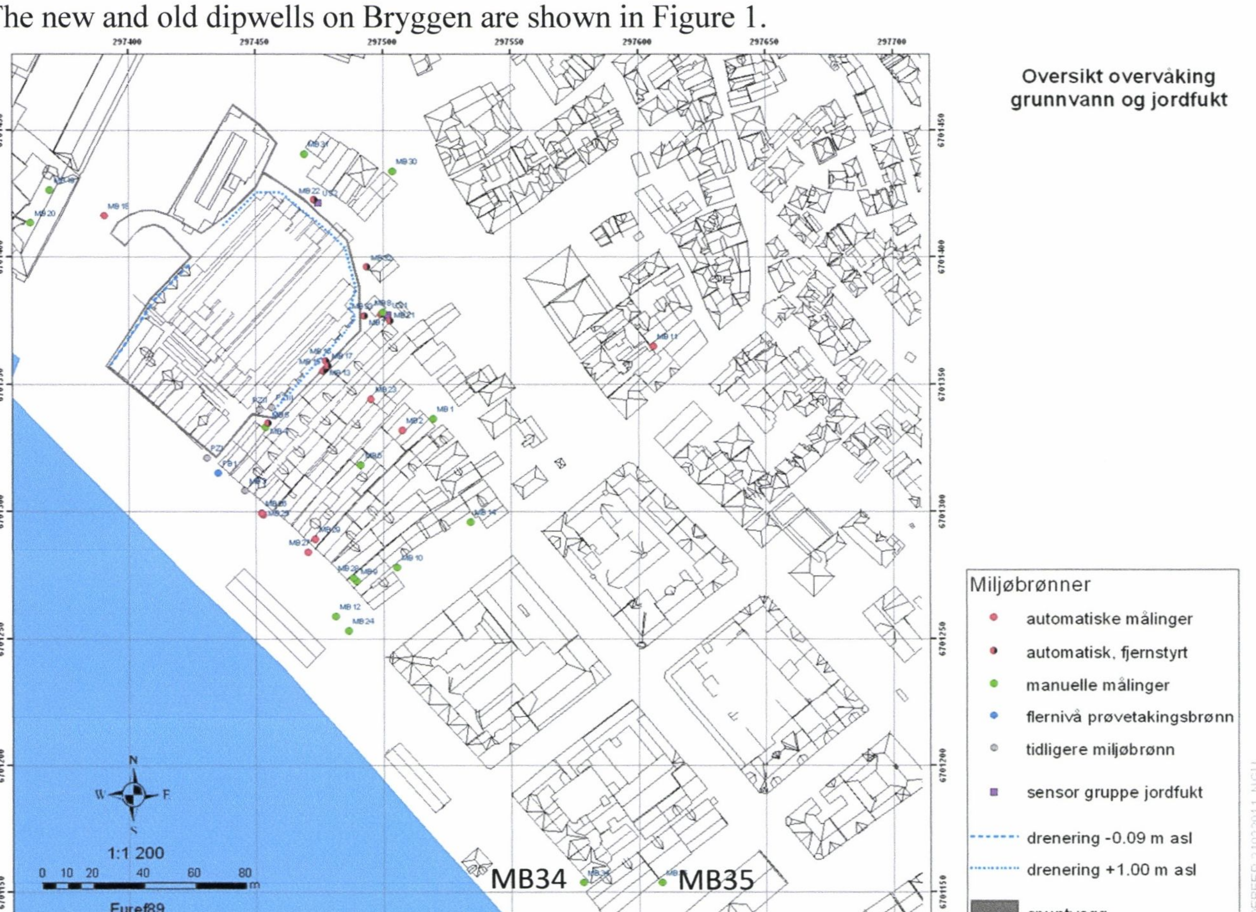


Figure 1: Map of Bryggen, showing the position of MB34 and MB35 at Finnegården in the southern part of Bryggen (green circles). Other dipwells are marked as well. Map from Hans de Beer, NGU.

In September 2010 the drilling work was made 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 (2010). Nine soil samples from MB34 and MB35 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, water-soluble sulphate, total sulphur, total phosphor and total nitrogen, and two of the samples were also analysed for pyrite (measured as iron extracted in boiling HNO_3 after removal of non-pyritic iron). The laboratory reports are given in Appendix 1. Further soil samples were analysed for dry matter content and loss on ignition by Multiconsult.
The position of the dipwells along with the level of their water intake is given in Table 1.

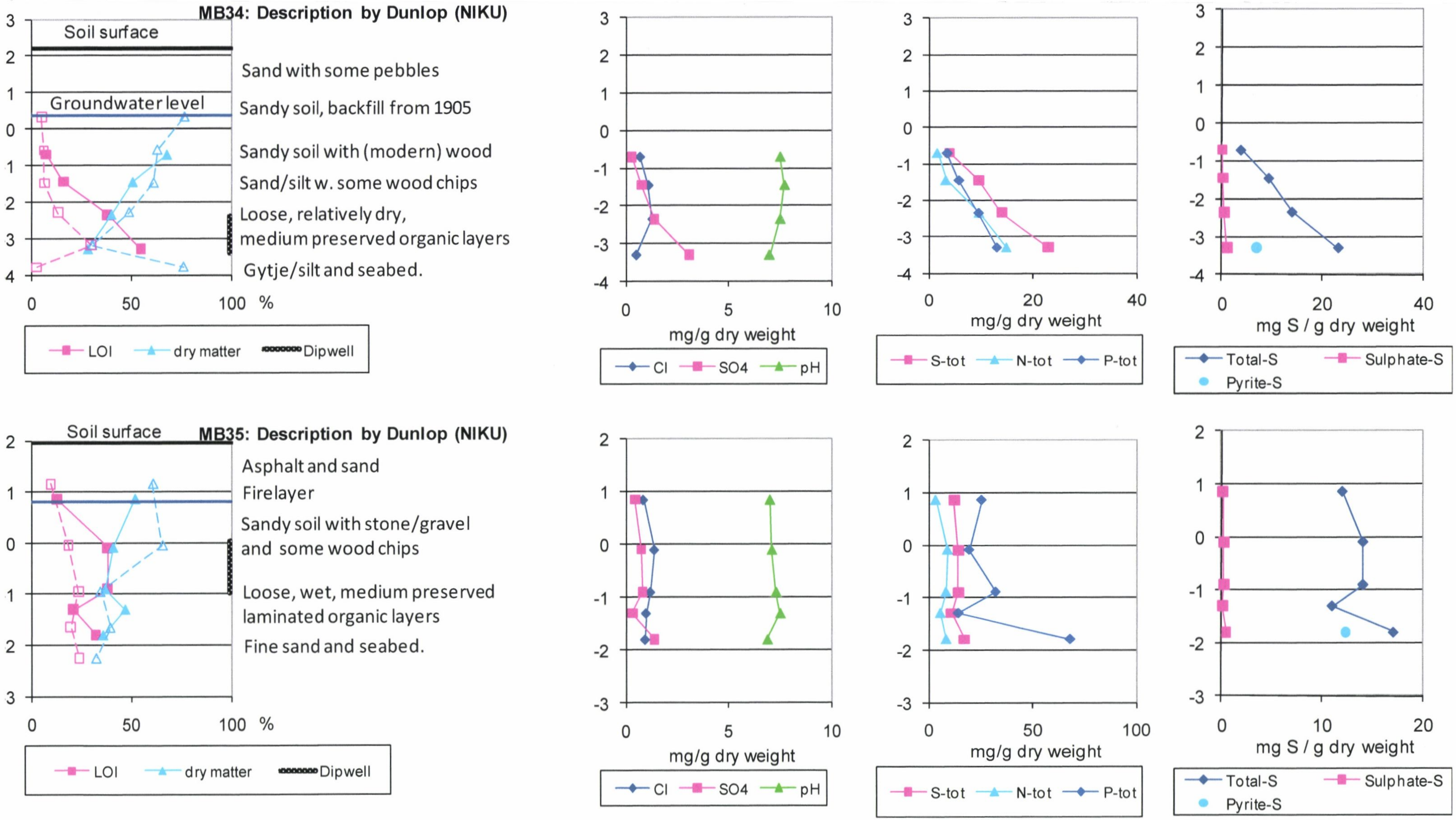
Dipwell	Y-COORD.	X-COORD.	Soil surface (m asl)	Top of dipwell (m asl)	Water intake – top (m asl)	Water intake – bottom (m asl)
MB34	297578.49	6701153.64	2.21	2.18	-2.39	-3.39
MB35	297609.40	6701153.89	1.96	1.93	0.03	-0.97

Table 1: Position of dipwells (data from Multiconsult/NGU).

On the 24th of November 2010 water was sampled from the dipwells by Multiconsult. The dipwells were emptied before the actual sampling, to ensure that fresh water from the cultural layers was sampled. The water samples were filtered in the field (0.45 μm Gelman high capacity in-line filter). The samples were sent to the laboratory (Eurofins) and 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), which gives a good description of the chemical conditions in the ground-water. The reports from the laboratory are shown in Appendix 2.

Results

The results from analysis of soil from MB34 and MB35 are presented graphically in Figure 2. It can be difficult to validate the quality of the data, but the results are similar to what has earlier been measured in the cultural layers on Bryggen (these earlier results are published in a range of reports for each individual dipwell on Bryggen, and compiled in an unpublished database). The only exception is the nitrogen content in sample MB34-2: in the report from Eurofins it is given as 330000 mg/kg dry weight (Appendix 1) but this is considered a typing error as it is 100 times higher than the realistic content. Furthermore, it took more than a month between sampling of the soil (9th September) to analysis in the laboratory (21st – 28th October) – the soil was kept refrigerated at 5°C during this period, but still it cannot be excluded that some oxidation of pyrite or sulphide-S has taken place during storage, giving a production of sulphate-S. Thus these data should be interpreted with some caution.



e 2: Description and soil analyses of drillings MB34 and MB35. LOI is the loss on ignition; filled symbols are data from Eurofins and open symbols data from Multiconsult. Cl and SO_4 is water :table chloride and sulphate, S-tot, N-tot and P-tot is total amount of sulphur, nitrogen and phosphor after total destruction of sample, sulphate-S is water soluble fraction (calculated from SO_4), and -S is calculated from the measured pyritic Fe.

Results from groundwater analysis of samples taken in MB34 and MB35 in November 2010 are presented in Figure 3:

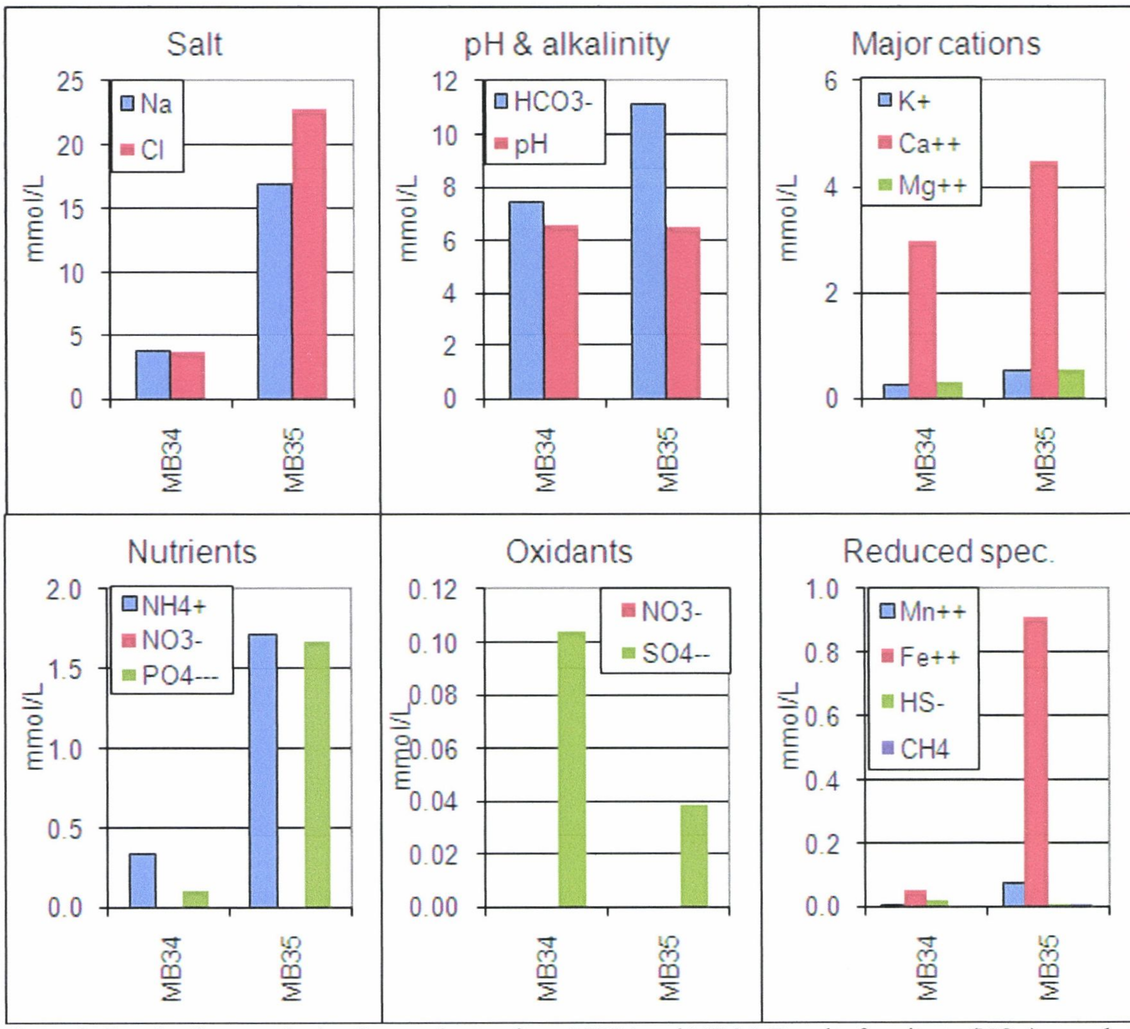


Figure 3: Results from analysis of groundwater from MB34 and MB35. Results for nitrate (NO_3^-) were below the detection limit of the method (< 0.01 mmol/L). The samples were not analysed for oxygen.

The quality of the groundwater analyses has been checked in terms of ion balance, where the sum of positive charges should equal the sum of negative charges. This gives a good result for MB34 (a deviation of only 1%) but some deviation for MB35 (7% more negative ions compared to positive ions). There may be several explanations for such a difference (for instance oxidation or precipitation processes during transport and storage of samples), and some deviation is common for the groundwater samples from Bryggen. The laboratory has measured the conductivity of the samples as well as the residue after drying (data in Appendix 2), both of which are in reasonable correspondence with the ion concentrations measured. It is thus concluded that the laboratory measurements are fairly accurate, even if the results from MB35 may have some bias. The methane results may be too low compared to in situ conditions, as it is very difficult to avoid degassing during the sampling.

Figure 4 shows a comparison of the groundwater analyses from MB34 and MB35 with earlier analyses of groundwater from Bryggen.

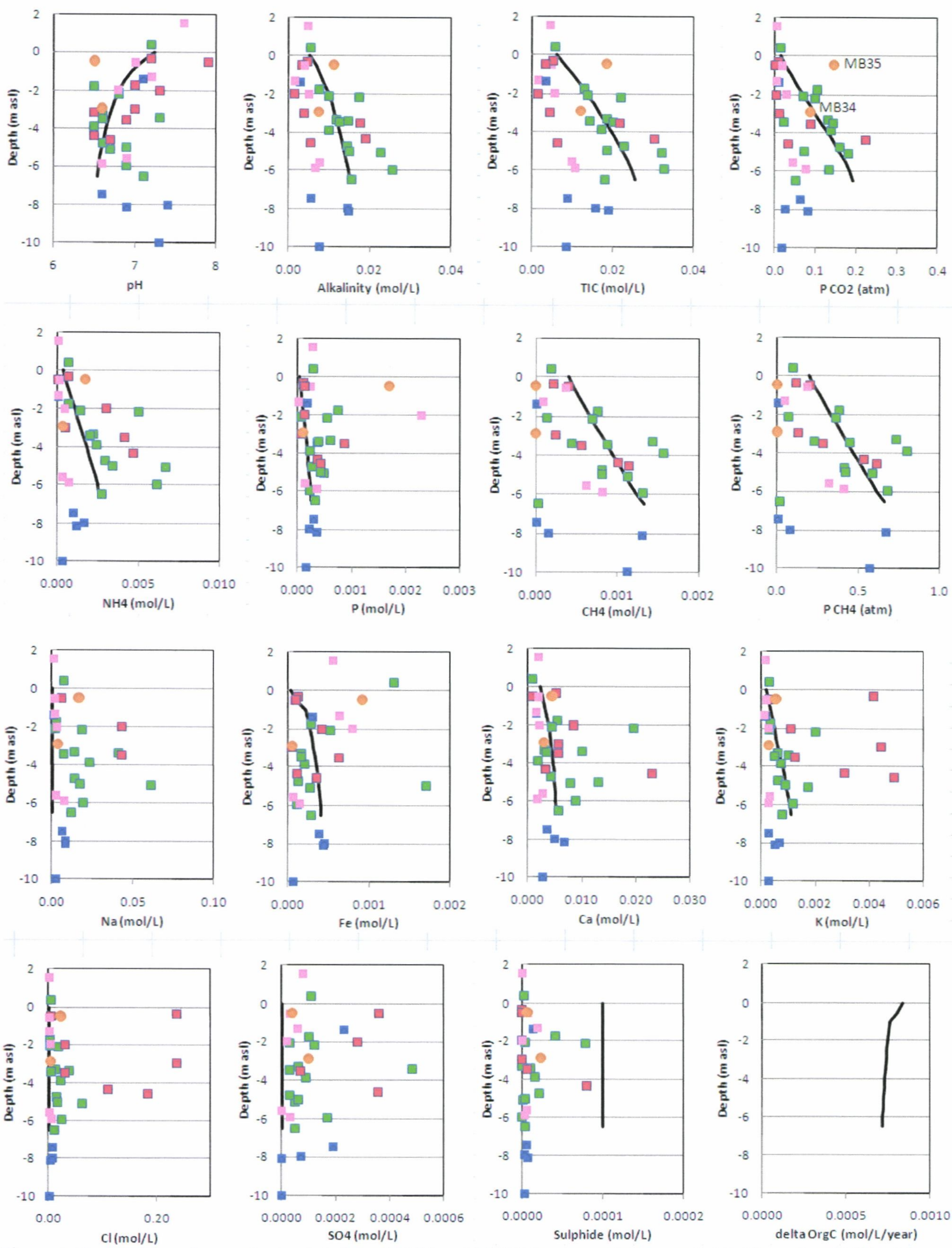


Figure 4: Comparison of groundwater data from MB34 and MB35 (orange points, sampled in November 2010) with groundwater data from all other dipwells on Bryggen (sampled in 2008 or 2009). The different colours indicate: Green – water from relatively stagnant conditions; red – dipwells near the quayfront influenced by seawater; pink – dipwells near the sheet piling diluted by rainwater; and blue – water from natural deposits underneath the cultural layers. The black lines are the output from a numerical groundwater geochemistry model made in PHREEQC attempting to model the stagnant condition (using a moderate vertical flow of 0.1 m/year through organic deposits). It must be emphasized that the model still needs validation and the numbers should not be over-interpreted. Updated from Matthiesen (2010).

Discussion

Organic content, water content and porosity

Figure 2 (left) shows the loss on ignition (LOI) and dry matter content of soil samples from dipwell MB34 and MB35, along with a brief description of the different soil strata (taken from Dunlop, 2010).

In MB34 the upper 3 m (down to -1.1 m asl) of the deposits are modern, most probably backfill from the construction pit from the building of Finnegården in 1905. These deposits are sandy, relatively porous and have a low LOI, corresponding to a low organic content. From -1.1 m asl to -3.5 m asl postmedieval and medieval deposits are found - the organic content increases with depth (reaching >50% LOI), the deposits become more compact, and the state of preservation increases from PresCon 2 to PresCon 3/4. At -3.5 m asl natural deposits and seabed are found. The groundwater level was measured to 0.37 m asl the 29th November 2010.

In MB35 only the upper 0.8 m are modern, and at 1.15 m asl a medieval firelayer is encountered. Beneath this is found sandy soil down to 0 m asl, the deposits are porous, have a low organic content, and their state of preservation is bad (PresCon 2). Between 0 and -2 m asl medium preserved (PresCon 3) organic deposits (LOI between 20 and 40%) with layers of more coarse, sandy soil in between are found. At -2 m asl the natural deposits and seabed are found. The groundwater level was measured to 0.79 m asl the 29th November 2010.

Redox conditions, nutrients and pH

The ground water analyses (Figure 3) indicate a reduced environment, where the concentration of reduced species (Fe^{2+}, Mn^{2+}, HS^-, CH_4, NH_4^+) are higher than the concentrations of oxidised species (NO_3^-, SO_4^{2-}). The water samples were not analysed for oxygen, but the high concentrations of dissolved iron indicate that there is no oxygen in the water. The only oxidant measured at a significant concentration in the water is sulphate, which is discussed later.

In some areas of Bryggen groundwater data have been used to estimate the decay rate for organic material in the soil, based on the supply of oxidants (Matthiesen 2010). It is not yet possible to estimate this at MB34 and MB35, as it requires knowledge of the local groundwater flow velocity. Comparing the results from other dipwells (Figure 4) shows that the concentrations measured in MB34 and MB35 are not extraordinary.

The pH measured for both groundwater (pH 6.5-6.6) and soil (pH 7-7.5) are in the neutral region, which is the case for almost all samples from Bryggen. The pH of 6.5 measured in groundwater from MB35 is relatively low compared to other dipwells of the same depth (Figure 4); this leads to relatively high PCO_2 and TIC as they are both calculated from the measured alkalinity and pH.

The groundwater and soil is relatively nutrient rich (N, P species). There is a strong correlation between the nutrients and the loss on ignition measured in the soil, indicating that the nutrients are connected to the organic material. The C/N ratio of the soil samples are in the range 18-24, which is normal for Bryggen.

Salt and seawater intrusion

The sodium and chloride in the water (Figure 3) indicates that there is a marine contribution to the groundwater (possibly combined with a contribution from the use of de-icing salt in the area). On the other hand, the relatively high concentrations of calcium and bicarbonate show that there is also a large fresh-water contribution. This may be better demonstrated in a so-called Piper diagram (Figure 5).

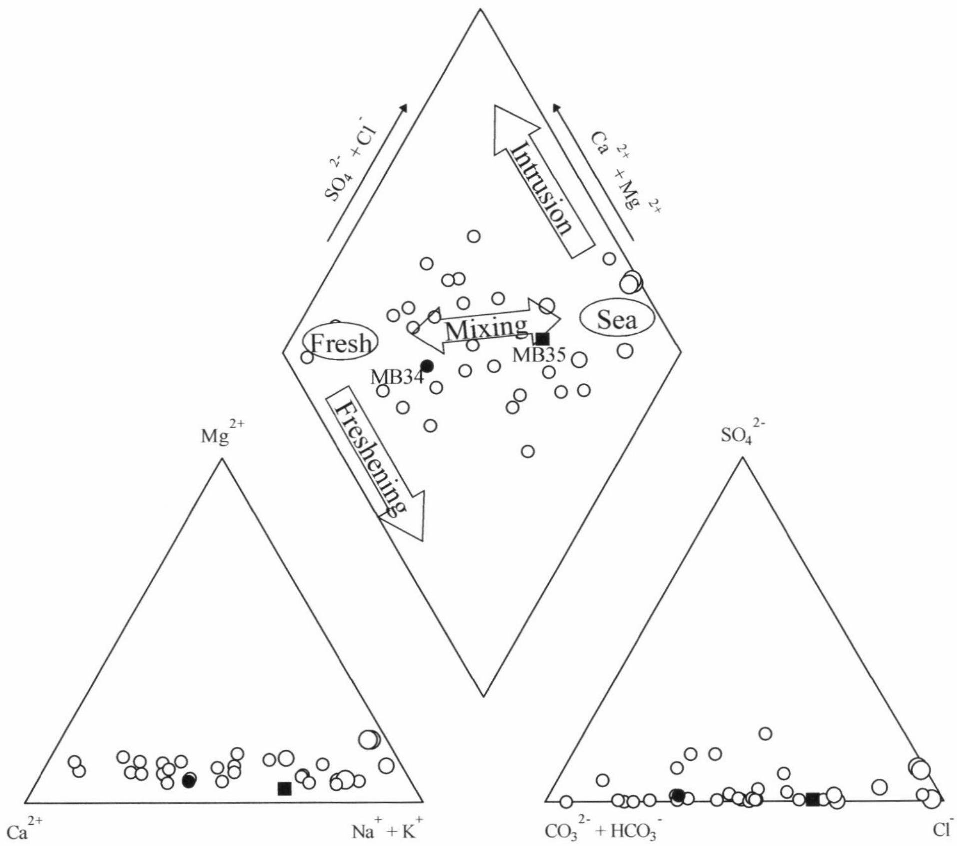


Figure 5: Piper diagram showing the groundwater analyses from MB34 (filled circle) and MB35 (filled square), along with data from other dipwells on Bryggen sampled in 2008 (open circles). On the construction and interpretation please refer to Matthiesen 2008.

The Piper diagram is used to get a quick idea of the origin of groundwater. Typical compositions of fresh groundwater and of seawater are shown with ellipses. Ion exchange reactions during seawater intrusion or freshening of sediment will change the composition of the groundwater as indicated by arrows in the diagram. Groundwater that results from conservative mixing (i.e. mixing without ion

exchange reactions) is presented by the arrow “mixing”. Both dipwell MB34 and MB35 are close to the arrow “mixing”, maybe slightly on the “freshening” side.
As for the ratio between fresh and sea water, the chloride content of dipwells MB34 and MB35 is 4 and 23 mmol/L respectively. For comparison the chloride content in seawater is 545 mmol/L, i.e. a contribution of only 1-5 % of seawater is sufficient to explain the chloride content found in the two dipwells. The chloride content in MB34 and MB35 is significantly lower than in some of the other dipwells close to the quay front (red squares in Figure 4).

Figure 6 shows in more detail how water-soluble chloride (and sulphate) was distributed in the soil samples from MB34 and MB35, where the results have been recalculated to mmol/L using the watercontent of the samples. For comparison the content measured in the dipwells in November 2010 (shown as thick vertical lines, corresponding to the 1 m filter where groundwater can enter the dipwell) is shown. Lower Cl concentrations were found in dipwell MB34 (4 mmol/L) compared to MB35 (23 mmol/L), but Figure 6 demonstrates that this is mainly due to the deeper filter position in MB34. In the higher soil strata the Cl concentrations in soil from MB34 are actually slightly higher (up to 41 mmol/L) than in MB35, which could also be expected as MB34 is closer to the quay front. The chloride profile from MB34 indicates that the chloride comes from the upper soil strata, for instance from seawater flowing through the porous upper soil layers, or from occasional flooding.

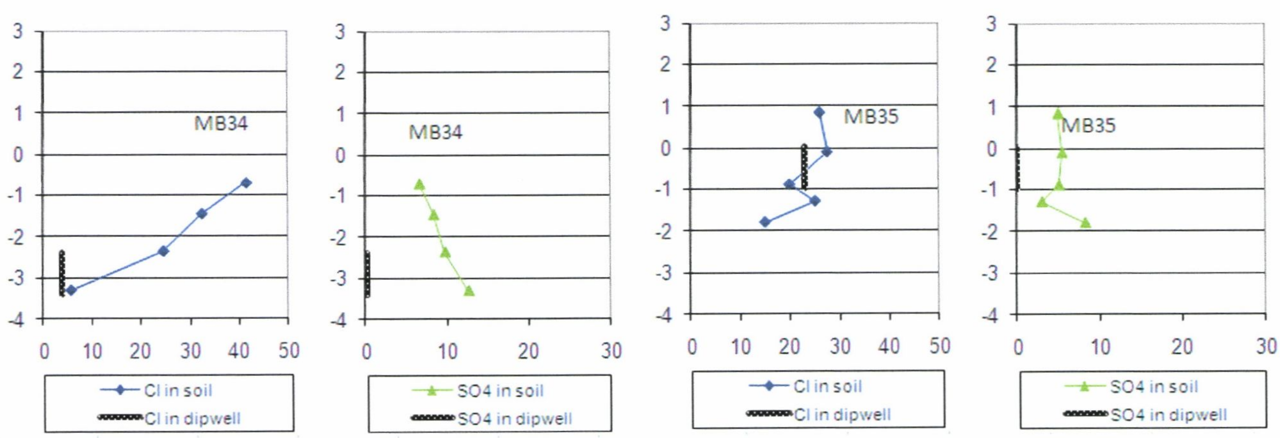


Figure 6: Measurements of water-soluble chloride and sulphate in soil samples from MB34 and MB35. Recalculated to mmol/L using the water content of the soil. The concentrations measured in groundwater from the dipwells are shown for comparison, using the length of the filter where groundwater enters the dipwell as “sample depth”.

Sulphate reduction

The effect of sulphate reduction has already been discussed in Matthiesen (2010). Very briefly it is the process where sulphate is used by bacteria to oxidise organic material:

$SO_4^{2-} + 2\ CH_2O \rightarrow HS^- + 2\ HCO_3^- + H^+$

presented here as a complete oxidation of organic matter (with the brutto formula CH_2O) all the way to bicarbonate/carbon dioxide. Seawater contains both chloride and sulphate, at a fixed molar ratio of 0.052 SO_4:Cl (28 mmol/L SO_4 and 546 mmol/L Cl at a salinity of 35 ‰). This means that whenever seawater enters the groundwater, sulphate is added to the system along with the chloride. It is possible to calculate a theoretical sulphate concentration from the chloride content and compare this with the measured sulphate content. The difference between these numbers gives the sulphate depletion, which may be used as an indicator for the extent of sulphate reduction (assuming that there are no other sources or sinks of chloride and sulphate).

In dipwell MB34 the groundwater contains 3.67 mmol/L Cl, which corresponds to a theoretical sulphate concentration of 0.052*3.67 = 0.19 mmol/L if it stems from seawater. For comparison 0.10 mmol/L SO_4 was measured, or a depletion of 0.09 mmol/L. In dipwell MB35 the groundwater contains 22.9 mmol/L Cl, which corresponds to a theoretical sulphate concentration of 0.052*22.9 mmol/L = 1.19 mmol/L. For comparison 0.04 mmol/L SO_4 was measured or a depletion of 1.15 mmol/L. This indicates that some sulphate reduction has been going on. However, the actual sulphate concentrations measured in the groundwater are relatively low compared to other dipwells near the quay front (Matthiesen 2010), and the sulphate reduction will have a limited extent if there isn't a new supply of seawater. Frequent analysis of groundwater from the two dipwells may help elucidate the dynamics.

The sulphate concentration measured in the soil is significantly higher than in the groundwater, and much higher than would be expected from the chloride content (Figure 6). This could indicate that there is an alternative sulphate source in the soil (for instance solid sulphate salts such as gypsum), but it cannot be excluded that the extra sulphate is an artefact that stems from oxidation of the soil sample during storage, as it took 1½ months from sampling before it was analysed in the laboratory.

As for the accumulated effect over time, sulphate reduction leads to formation of sulphide, and parts of this sulphide will normally precipitate as acid volatile sulphide or as pyrite, as already discussed in Matthiesen (2010). As with the other dipwells from the quayfront the soil samples from MB34 and MB35 have low C/S ratios (between 5 and 14) which could indicate accumulation of reduced sulphur. The pyrite content has been measured in the two deepest samples, showing contents of 7 and 12 g pyrite-S per kg dry soil, which is a substantial percentage of the total sulphur in the soil (Figure 2). It is possible that this accumulation of pyrite took place a long time ago in periods with a higher sulphate supply, as these deep layers were originally deposited in the harbour.

Preservation conditions

The preservation conditions above the groundwater table are often critical, due to an increased access of oxygen that may degrade organic material in the soil. This is especially the case for sandy, porous deposits that cannot retain soil water but drain off readily. The unsaturated zone has not been studied in any detail here, where only a few soil samples have been taken above or at the groundwater level as measured in November (Figure 2). All these samples were described as sandy and analysis showed moderate organic contents (LOI 5-13%). From the visual description it seems that the other deposits above the groundwater level are even more sandy and have even lower organic contents. Sandy, porous deposits point towards a freely draining soil with a high oxygen access. On the other hand, the low organic content means that little damage is done by the oxygen, and that the soil only has a limited settling potential. It is therefor estimated (admittedly on a limited data basis) that the preservation conditions are Lousy (PresCon 1), but that it only causes a limited damage to the cultural deposits. The data are not sufficient to give an unambiguous explanation of the settling problems of the Hanseatic Museum. A more thorough evaluation would require measurements of the water content and oxygen concentration in the unsaturated zone (as is currently being done behind Bredsgården - Matthiesen & Hollesen, 2011) but first of all it needs to be verified if the two drillings and the groundwater levels measured in November are representative for this area.

As for the deeper deposits they are more organic rich and thus more susceptible to oxidation. A future lowering of the groundwater would threaten these deposits, but as they are mainly found below the sealevel a complete drainage of the layers is considered unlikely. As long as they are waterlogged, degradation by sulphate reduction is probably the main risk. The high content of sulphur and pyrite in the soil indicates that some sulphate reduction has taken place previously. At the groundwater sampling in November relatively low sulphate concentrations were found in the water, enabling only a limited decay of organic matter, and the present day sulphate reduction depends on whether the conditions are stable or dynamic with frequent groundwater exchange. This needs to be validated by data logging and/or future groundwater sampling. The organic cultural deposits are surrounded by porous layers, which could allow a fast groundwater exchange.

Using the numerical scale of preservation conditions (PresCon) introduced in NS9451 (2009) the conditions in the unsaturated zone are at this stage estimated to be Lousy (PresCon 1), and in the saturated zone they are estimated to be medium or good (PresCon 3-4) depending on the sulphate supply. These estimates may be re-evaluated when more information is available on the variations in groundwater level, the variations in sulphate content of the water, the water flow through the deposits, and the soil temperature.

On the current information it is not possible to evaluate the effects from the existing building (Finnegården) on the preservation conditions at the site – for instance there have been no measurements of the soil temperature yet, so it is unknown if the building causes heating of the soil. As for future building activities in the area it is considered unlikely that they will result in direct drainage of the deposits, as the organic cultural deposits are found beneath the sea level. However, waterflow patterns (and thus supply of seawater and sulphate) could possibly change.

Conclusions and future work

It has been shown that around dipwells MB34 and MB35:

- The upper soil layers are sandy with low organic content. The preservation conditions above the groundwater level are not very good, but as these deposits are modern or mainly inorganic it has a limited effect on the cultural layers.
- The deposits beneath the groundwater level are more organic and susceptible to decay. High contents of sulphur and pyrite in the soil indicate that some decay by sulphate reduction has taken place.
- The present day decay rate for the deposits depends on the supply of sulphate. During groundwater sampling in November there were only minor amounts of sulphate present, but the dynamics and supply are still unknown.
- The first estimate of the preservation categories is PresCon 1 (Lousy) down to the groundwater level, and PresCon 3-4 (Medium to Good) beneath the groundwater level, but these estimates may be modified when more data is available.
- Effects from future building activity in the area may include changes in the groundwater exchange, which could increase (or decrease) the sulphate supply.

Further studies may include

- Automatic logging of the salinity in the dipwells for a period
- If a change in salinity indicates seawater intrusion, new measurements of chloride and sulphate content in the dipwells should be made
- Logging of temperature in the soil, to examine influence from Finnegården.
- Logging of water and oxygen content in the unsaturated zone, to elucidate the causes of the settling of Hanseatic Museum

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NS9451: Norsk Standard: Kulturminner. Krav til miljøovervåking og -undersøkelse av kulturlag, 2009.

Appendix 1

Results from analysis of soil samples from MB34 and 35 (Eurofins)

Eurofins Miljø A/S
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CVR/VAT: DK-2884 8196

ilac-MRA DANAK TEST Reg.nr. 168

eurofins

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

Att.: Henning Matthiesen

Registernr.:	C14428
Kundenr.:	82983
Ordrenr.:	408224
Sagsnr.:	27290001
Modt. dato:	2010.10.18
Sidenr.:	1 af 3

ANALYSERAPPORT

Rekvirent........: Nationalmuseet, Bevaringsafdelingen, Arkæologi
I.C.Modewegs vej, 2800 Kgs.Lyngby
Prøvested........: **Finnegården**
Prøvetype........: Sediment
Prøveudtagning...:
Prøvetager.......: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2010.10.21 - 2010.10.28

Prøvenr.:	C1442801	C1442802	C1442803	C1442804				
Prøve ID:						Detekt.		RSD
Prøvemærke:	MB34-1	MB34-2	MB34-3	MB34-4	Enheder	grænse	Metoder	(%)
pH	7.5	7.7	7.5	7.0	pH		DS/EN 12176	
Tørstof	68	51	40	28	%	0.05	DS 204 mod.	5
Glødetab på tørstof	7.6	16	38	55	% i ts.	0.10	DS 204	5
Kvælstof, total	1200	170000	3800	4100	mg/kg	5	NF1975:6/59/VKI	10
Kvælstof, total	1700	330000	9600	15000	mg/kg ts.	300	Beregning	10
Phosphor, total	3400	5600	9400	13000	mg/kg ts.	100	DS259/SM3120ICP	15
Phosphor, total	2300	2800	3800	3700	mg/kg		Beregning	
Chlorid, vandopløselig	690	1100	1300	510	mg/kg ts.	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	300	770	1400	3100	mg/kg ts.	1	*SM 17 udg. 4500	10
Svovl, total	3900	9400	14000	23000	mg/kg ts.	50.0	DS259/SM3120ICP	15
Pyrit, FeS2				1.3	% i ts.	0.01	*SM3120 mod.	

*) Ikke omfattet af akkrediteringen.

RSD: Den ekspanderede måleusikkerhed er lig 2 x RSD%, se i øvrigt 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.

Eurofins Miljø A/S
Ladelundvej 85
6600 Vejen
Telefon: 7022 4266
CVR/VAT: DK-2884 8196

ilac-MRA DANAK TEST Reg.nr. 168

eurofins

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

Att.: Henning Matthiesen

Registernr.:	C14428
Kundenr.:	82983
Ordrenr.:	408224
Sagsnr.:	27290001
Modt. dato:	2010.10.18

ANALYSERAPPORT

Rekvirent........: Nationalmuseet, Bevaringsafdelingen, Arkæologi
I.C.Modewegs vej, 2800 Kgs.Lyngby
Prøvested........: **Finnegården**
Prøvetype........: Sediment
Prøveudtagning...:
Prøvetager.......: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2010.10.21 - 2010.10.28

Prøvenr.:	C1442805	C1442806	C1442807	C1442808				
Prøve ID:						Detekt.		RSD
Prøvemærke:	MB35-1	MB35-2	MB35-3	MB35-4	Enheder	grænse	Metoder	(%)
pH	7.0	7.1	7.3	7.5	pH		DS/EN 12176	
Tørstof	52	41	37	47	%	0.05	DS 204 mod.	5
Glødetab på tørstof	13	38	38	21	% i ts.	0.10	DS 204	5
Kvælstof, total	1800	3800	3100	2700	mg/kg	5	NF1975:6/59/VKI	10
Kvælstof, total	3500	9200	8500	5800	mg/kg ts.	300	Beregning	10
Phosphor, total	25000	19000	32000	14000	mg/kg ts.	100	DS259/SM3120ICP	15
Phosphor, total	13000	7700	12000	6400	mg/kg		Beregning	
Chlorid, vandopløselig	850	1400	1200	1000	mg/kg ts.	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	440	750	820	320	mg/kg ts.	1	*SM 17 udg. 4500	10
Svovl, total	12000	14000	14000	11000	mg/kg ts.	50.0	DS259/SM3120ICP	15

*) Ikke omfattet af akkrediteringen.

RSD: Den ekspanderede måleusikkerhed er lig 2 x RSD%, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

Tegnforklaring:
RSD : Relativ Analyseusikkerhed.
< : mindre end. i.p.: ikke påvist.
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Eurofins Miljø A/S
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6600 Vejen
Telefon: 7022 4266
CVR/VAT: DK-2884 8196

ilac-MRA DANAK TEST Reg.nr. 168

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

Att.: Henning Matthiesen

Registernr.:	C14428
Kundenr.:	82983
Ordrenr.:	408224
Sagsnr.:	27290001
Modt. dato:	2010.10.18

ANALYSERAPPORT

Rekvirent........: Nationalmuseet, Bevaringsafdelingen, Arkæologi
I.C.Modewegs vej, 2800 Kgs.Lyngby
Prøvested........: **Finnegården**
Prøvetype........: Sediment
Prøveudtagning...:
Prøvetager.......: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2010.10.21 - 2010.10.28

Prøvenr.:	**C1442809**				
Prøve ID:			Detekt.		RSD
Prøvemærke:	**MB35-5**	Enheder	grænse	Metoder	(%)
pH	**6.9**	pH		DS/EN 12176	
Tørstof	**36**	%	0.05	DS 204 mod.	5
Glødetab på tørstof	**32**	% i ts.	0.10	DS 204	5
Kvælstof, total	**3100**	mg/kg	5	NF1975:6/59/VKI	10
Kvælstof, total	**8600**	mg/kg ts.	300	Beregning	10
Phosphor, total	**6800**	mg/kg ts.	100	DS259/SM3120ICP	15
Phosphor, total	**2400**	mg/kg		Beregning	
Chlorid, vandopløselig	**950**	mg/kg ts.	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**1400**	mg/kg ts.	1	*SM 17 udg. 4500	10
Svovl, total	**17000**	mg/kg ts.	50.0	DS259/SM3120ICP	15
Pyrit, FeS2	**2.3**	% i ts.	0.01	*SM3120 mod.	

*) Ikke omfattet af akkrediteringen.

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: ingen af parametrene er påvist.

28. oktober 2010

N Weibel

Kundecenter: tlf.70224267 Kontaktperson

Niels Weibel
Kvalitetssikring

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

Appendix 2

Results from analysis of groundwater from MB34 and 35, sampled on the 24th of November 2010.

Eurofins Miljø A/S
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eurofins

Multiconsult A/S
Postbox 265

N-0213 Oslo
Norge
Att.: Jann Atle Jensen

Registernr.:	B05195
Kundenr.:	623294
Ordrenr.:	810153
Prøvenr.:	B0519501
Sagsnr.:	11031261
Modt. dato:	2010.11.30
Sidenr.:	1 af 1

ANALYSERAPPORT

Rekvirent........: Multiconsult A/S, Postbox 265
N-0213 Oslo, Norge
Prøvested........: **Bryggen Prosjekt Bryggen nr. 27290001 - /4173101000**
Prøvetype........: Råvand - Udvidet kontrol
Prøveudtagning...: 2010.11.24
Prøvetager.......: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2010.11.30 - 2010.12.15

Prøvenr.:	**B0519501**		**Grænseværdier Vejl.	Max.	Metoder	RSD (%)
Prøve ID:						
Prøvemærke:	**Brønn 34**					
pH	**6.6**	**pH**			DS 287:1978	
Ledningsevne	**110**	**mS/m**			DS/EN 27888	5
Hårdhed, total	**18.6**	**H grader**			SM3120-ICP	4.3
Calcium (Ca)	**120**	**mg/l**			SM3120-ICP	15
Magnesium (Mg)	**8.2**	**mg/l**			SM3120-ICP	15
Kalium (K)	**11**	**mg/l**			SM3120-ICP	15
Natrium (Na)	**88**	**mg/l**			SM3120-ICP	15
Jern (Fe)	**2.9**	**mg/l**			SM3120-ICP	15
Mangan (Mn)	**0.24**	**mg/l**			SM3120-ICP	15
Ammonium	**6.1**	**mg/l**			SM 17.udg. 4500	5
Nitrit	**<0.005**	**mg/l**			SM 17.udg. 4500	5
Nitrat	**<0.50**	**mg/l**			SM 17.udg. 4500	5
Total-P	**3.1**	**mg/l**			DS/EN I 6878aut	10
Chlorid	**130**	**mg/l**			SM 17.udg. 4500	5
Fluorid	**0.51**	**mg/l**			SM 17.udg. 4500	5
Sulfat	**10**	**mg/l**			SM 17.udg. 4500	5
Aggressiv kuldioxid	**<2**	**mg/l**			DS 236:1977	10
Hydrogencarbonat	**453**	**mg/l**			DS/EN I 9963	5
Turbiditet	**6.3**	**FTU**			DS/EN I 7027	10
Farvetal, Pt	**18**	**mgPt/l**			DS/EN I 6271-2	5
Inddampningsrest	**640**	**mg/l**			DS 204:1980	6
NVOC, ikke flygt.org.carbon	**5.0**	**mg/l**			DS/EN 1484	5.0
Sulfid-S	**0.74**	**mg/l**			DS 278:1976auto	14
Methan	**<0.005**	**mg/l**			M0066 GC/FID	19

Kopi af rapporten er sendt til:

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

**) Miljøministeriets bekendtgørelse nr. 1449 af 11. december 2007
RSD: Den ekspanderede måleusikkerhed er lig 2 x RSD%, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

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\# : ingen af parametrene er påvist.

15. december 2010

Annette Vendel

Kundecenter: tlf.70224256 Annette Vendel
Kontaktperson Kvalitetssikring

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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Prøvenr.:	B0519601
Sagsnr.:	11031261
Modt. dato:	2010.11.30

ANALYSERAPPORT

Rekvirent........: Multiconsult A/S, Postbox 265
N-0213 Oslo, Norge
Prøvested........: **Bryggen Prosjekt Bryggen nr. 27290001 - /4173101000**
Prøvetype........: Råvand - Udvidet kontrol
Prøveudtagning...: 2010.11.24
Prøvetager.......: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2010.11.30 - 2010.12.15

Prøvenr.: **B0519601**
Prøve ID:
Prøvemærke: **Brønn 35**

			**Grænseværdier Vejl.	Max.	Metoder	RSD (%)
pH	**6.5**	**pH**			DS 287:1978	
Ledningsevne	**360**	**mS/m**			DS/EN 27888	5
Hårdhed, total	**28.9**	**H grader**			SM3120-ICP	4.3
Calcium (Ca)	**180**	**mg/l**			SM3120-ICP	15
Magnesium (Mg)	**13**	**mg/l**			SM3120-ICP	15
Kalium (K)	**21**	**mg/l**			SM3120-ICP	15
Natrium (Na)	**390**	**mg/l**			SM3120-ICP	15
Jern (Fe)	**51**	**mg/l**			SM3120-ICP	15
Mangan (Mn)	**4.2**	**mg/l**			SM3120-ICP	15
Ammonium	**31**	**mg/l**			SM 17.udg. 4500	5
Nitrit	**0.006**	**mg/l**			SM 17.udg. 4500	5
Nitrat	**<0.50**	**mg/l**			SM 17.udg. 4500	5
Total-P	**52**	**mg/l**			DS/EN I 6878aut	10
Chlorid	**810**	**mg/l**			SM 17.udg. 4500	5
Fluorid	**0.37**	**mg/l**			SM 17.udg. 4500	5
Sulfat	**3.7**	**mg/l**			SM 17.udg. 4500	5
Aggressiv kuldioxid	**<2**	**mg/l**			DS 236:1977	10
Hydrogencarbonat	**681**	**mg/l**			DS/EN I 9963	5
Turbiditet	**38**	**FTU**			DS/EN I 7027	10
Farvetal, Pt	**22**	**mgPt/l**			DS/EN I 6271-2	5
Inddampningsrest	**2100**	**mg/l**			DS 204:1980	6
NVOC, ikke flygt.org.carbon	**10**	**mg/l**			DS/EN 1484	5.0
Sulfid-S	**0.19**	**mg/l**			DS 278:1976auto	14
Methan	**0.016**	**mg/l**			M0066 GC/FID	19

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15. december 2010
Annette Vendel

Kundecenter: tlf.70224256
Kontaktperson

Annette Vendel
Kvalitetssikring