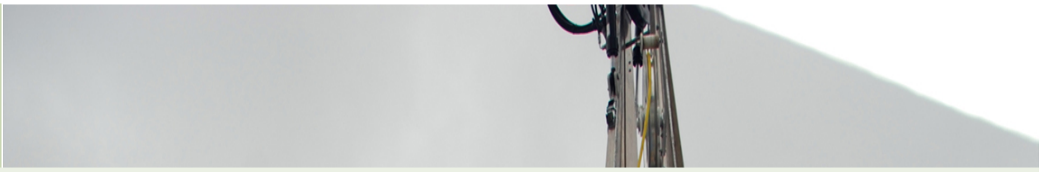
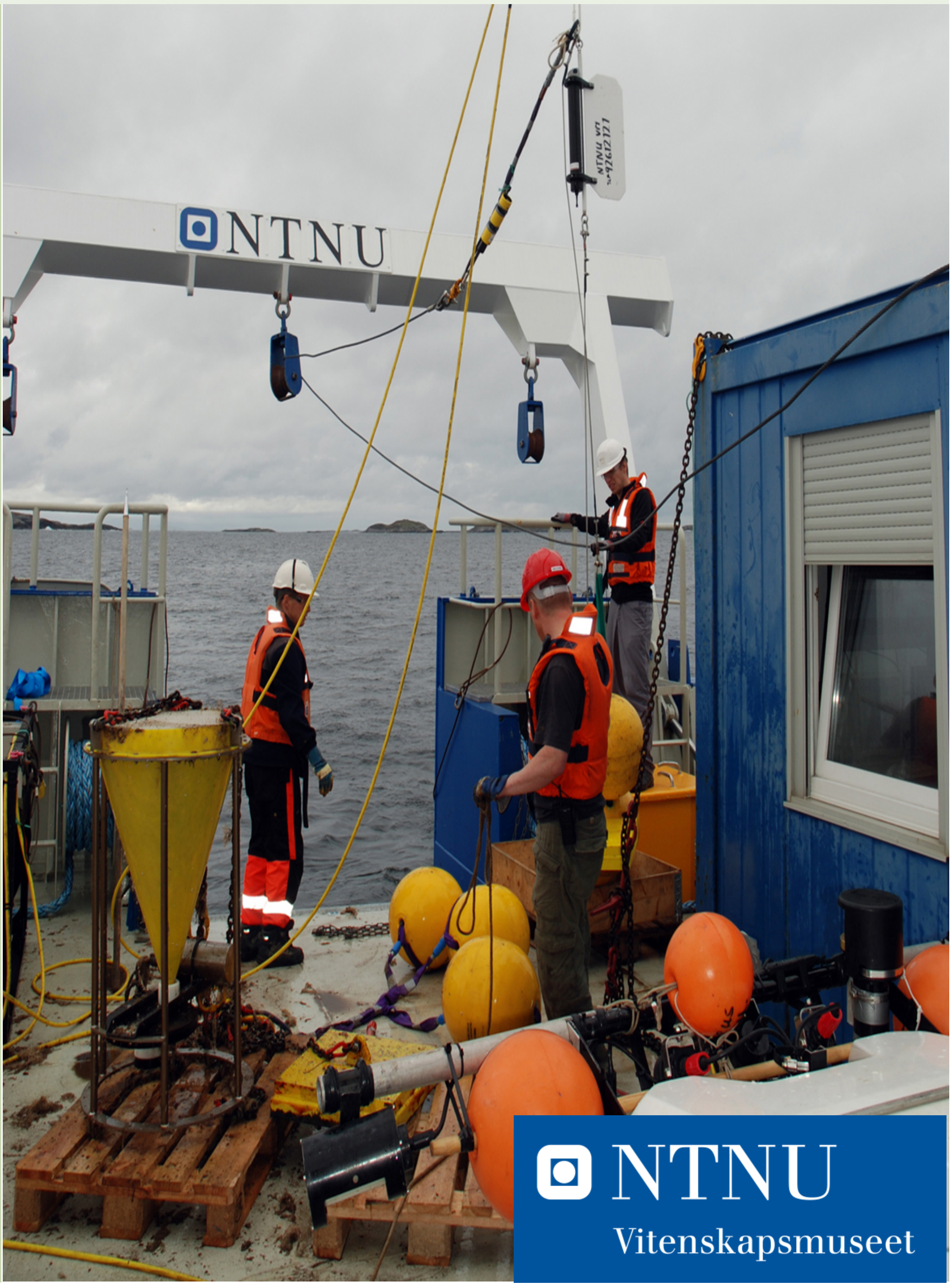


Fredrik Skoglund

Ormen Lange Shipwreck: Environmental Monitoring Project - Final Report



NTNU Vitenskapsmuseet
Arkeologisk rapport 2014-5

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Sammendrag

Skoglund, F. 2014: NTNU Vitenskapsmuseet arkeologisk rapport 2014/5. Ormen Lange Shipwreck: Environmental Monitoring Project – Final Report.

I 2003 ble det under marinarkeologisk survey påvist et eldre skipsvrak i traséen til Ormen Lange gassrørledninger (Askeladden ID: 91448) på 170m dyp. Ormen Lange gassfeltet ligger ca. 120 km nordvest for Kristiansund i Møre og Romsdal, skipsvraket ble påtruffet i nærheten av traseen til hjelperørledningene. Skipsfunnet er eldre enn 100 år og dermed vernet i medhold av Lov om Kulturminner av 9. juni 1978 nr. 50 § 14.

I henhold til dispensasjonsvedtak fra Riksantikvaren ble det i tidsperioden 2004-2005 gjennomført marinarkeologiske undersøkelser av vraklokaliteten. Undersøkelsene viste at det dreide seg om et skipsvrak sannsynligvis bygget på slutten av 1700-tallet, og som sank i første halvdel av 1800-tallet. Vraklokaliteten omfatter bunnseksjonen av et seilførende fartøy, samt omfattende uorganisk gjenstandsmateriale, primært keramikk og flasker av ulik europeisk proveniens og datering. Vraket virker ikke å ha blitt brukket opp i deponeringsprosessen. I etterkant av deponeringstidspunkt er vraket primært utsatt for biologisk nedbrytning, hvor særlig de deler av skroget som ikke har vært dekket av sedimenter har blitt nedbrutt, primært grunnet pælemark. Det er lite som tyder på at vraket er skadet som følge av menneskeskapt påvirkning.

Som et ledd i Riksantikvarens dispensasjonsvedtak ble det stilt som vilkår at det skulle gjennomføres en miljøovervåking av lokaliteten for å dokumentere om tiltaket med rørledningene påvirket bevaringsforholdene ved vraklokaliteten. Det ble gjennomført miljøovervåkingstokt i perioden mellom 2006 og 2012. Toktet i 2012 ble det siste da man mener at de innsamlede datasett fra de gjennomførte miljøovervåkingstokt tilstrekkelig dokumenterer tiltakets (dvs. rørlednings traséens) konflikt med kulturminnelokaliteten, og at tiltakshavers (dvs. Shell) plikter knyttet til kulturminneloven og Riksantikvarens dispensasjonsvedtak ansees som oppfylt.

Nøkkelord: skipsvrak – miljøovervåking – nedbrytning – bevaring – kulturminnevern under vann

Fredrik Skoglund, NTNU Vitenskapsmuseet, Seksjon for arkeologi og kulturhistorie, NO-7491 Trondheim

Abstract

Skoglund, F. 2014: NTNU Vitenskapsmuseet arkeologisk rapport 2014/5. Ormen Lange Shipwreck: Environmental Monitoring Project – Final Report.

The Ormen Lange gas field is located approximately 120 km northwest of Kristiansund in central Norway. In 2003, during the archaeological surveys, a late 18th century shipwreck was discovered close to the proposed pipeline routes Bjørnsund near the onshore facility at Nyhamna, Aukra. The water depth at the wreck site is approximately 170 m. The shipwreck is protected under §14 of the Act concerning the cultural heritage No.50 of 1978.

Archaeological excavations were carried out on the shipwreck site in the period between 2004 and 2005 (Bryn, Jasinski and Søreide 2007). After the excavations, and in accordance with guidelines from the Directorate for Cultural Heritage, an environmental monitoring project was established. Annual surveys were carried out between 2006 and 2012 in order to monitor the site after the establishment of the adjacent pipelines, and to see whether the pipelines had any subsequent influence on the continued stability and preservation of the wreck site. In 2012 the Directorate for Cultural Heritage concluded, based on the data from the previous surveys, that the level of conflict had been satisfactory documented and that the obligations of the developer (i.e. Shell) towards the Cultural Heritage Act had been fulfilled.

Key words: Environmental monitoring – shipwreck – degradation – preservation - UCHM

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Kommune	Fræna

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2. Abbreviations

ADCM	Acoustic Doppler Current Meter
AUR-lab	Applied Underwater Robotics laboratory
DP	Dynamic Positioning
HiPAP	High Precision Acoustic Positioning
HSE	Health, Safety and Environment
LARS	Launch and Recovery System
MBES	Multi Beam Echo Sounder
NGU	Norwegian Geological Survey
NTNU	Norwegian University of Science and Technology
NTNU DMT	NTNU Department of Marine Technology
NTNU IAR	NTNU Institute of Archaeology and Religious Studies
NTNU University Museum	NTNU Vitenskapsmuseet
NTNU Vitenskapsmuseet	NTNU University Museum, Section for Archaeology and cultural history
PPE	Personal Protective Equipment
ROV	Remotely Operated Vehicle

3. Relevant information

3.1. The site

The Ormen **Lange** Gas Field is located in the Norwegian Sea, approximately 120 km southwest of Kristiansund in central Norway (Figure 1). The development of the Ormen Lange Gas Field included installation of a subsea production system, which is piped directly to an onshore process and export plant in Nyhamna, Aukra. The main pipelines consist of:

• 42” Gas Export Pipeline
• 30” Gas Production Pipeline A
• 30” Gas Production Pipeline B

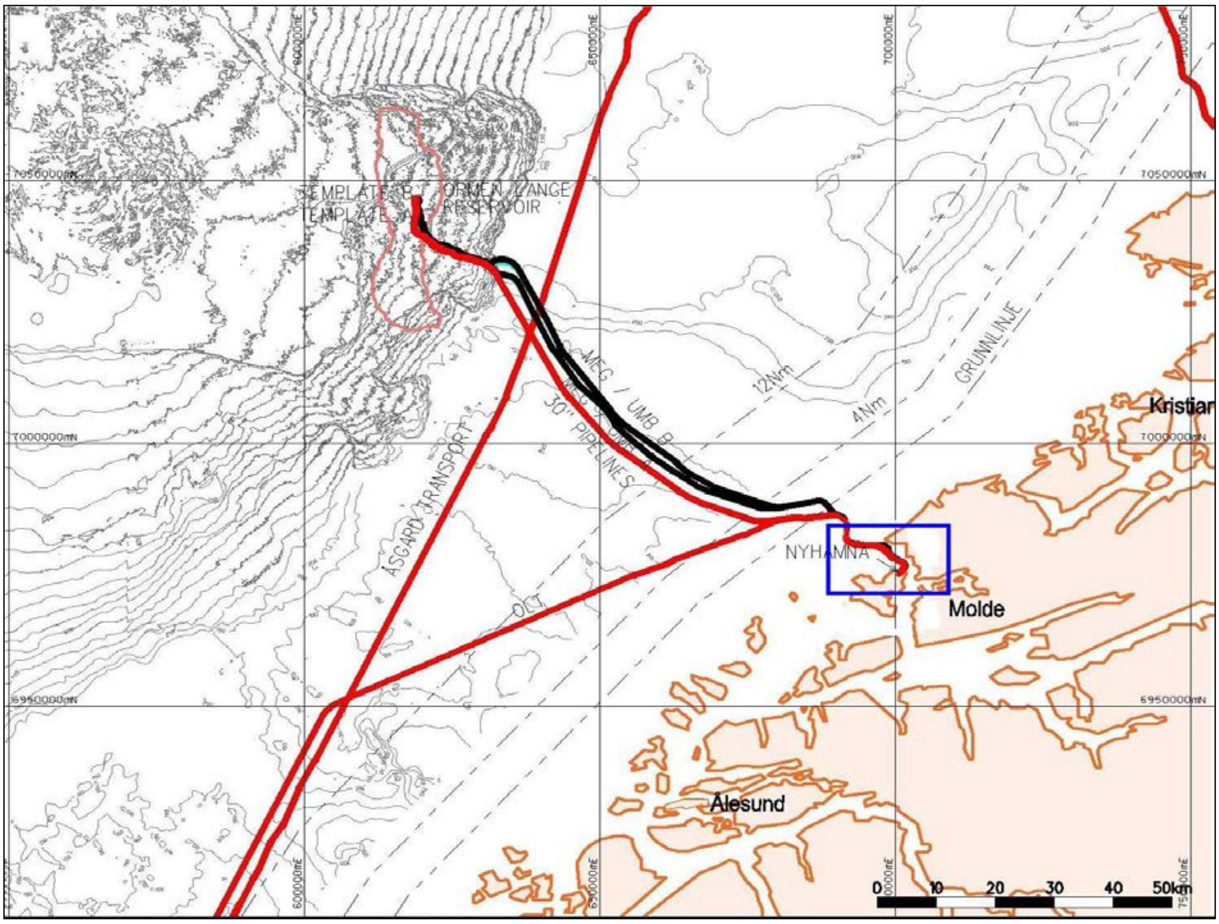

Figure 1 - Site location showing the pipeline routes from Nyhamna to the Ormen Lange reservoir. Illustration: Hydro

Due to the narrow underwater valley in the near shore area close to Bud, the gas pipelines were planned in a separate corridor to that of the small diameter service lines, consisting of:

• 6” MEG Line A (antifreeze)
• 6” MEG Line B (antifreeze)
• Umbilical A (control cable)
• Umbilical B (control cable)

It was in close proximity to the route of the service lines that the wreck was dicovered in 2003 (see Figure 2 and Figure 3) in Bjørnsundet southwest of Bud. The narrow underwater valleys and rugged terrain proved difficult for finding other adequate solutions for the pipeline routes that would avoid the shipwrecks discovered during the 2003 survey. Archaeological investigations were thus carried out in 2004 and 2005 to document the extent of the site, and to ascertain that no parts of wreck structure were buried beneath the sediments and would thus be in direct contact with the planned pipeline trenches.

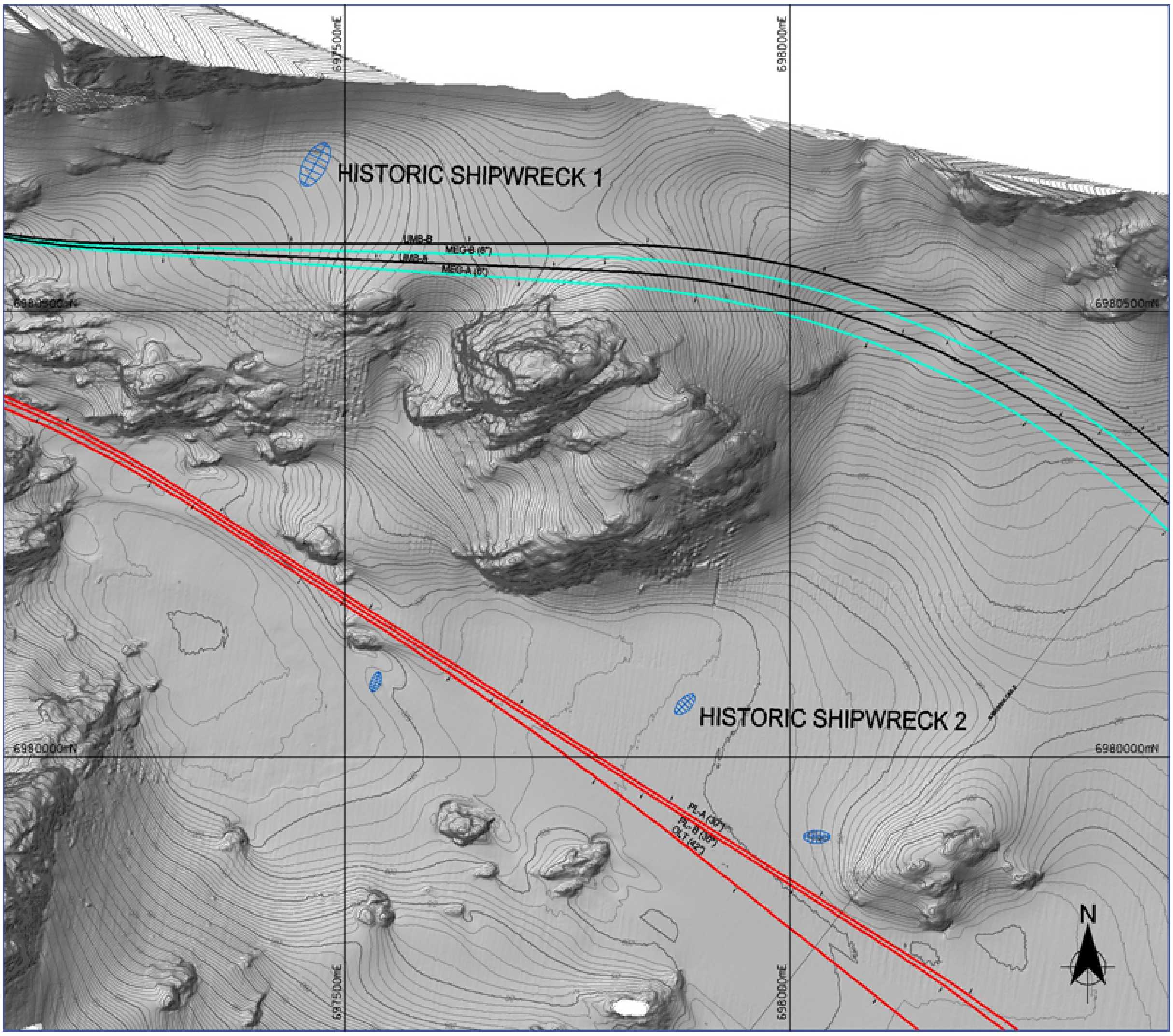

Figure 2 – Pipelines and shipwrecks. The environmental monitoring has been conducted on what on this illustration is called "Historic Shipwreck 1". Shipwreck 2 has also been visually documented during some of the surveys, but neither that nor the other two wrecks in this illustration has been part of the environmental monitoring project. All these wrecks and other finds during the survey can be found in the publication "Pipelines and Shipwrecks" from 2007. Illustration: Hydro

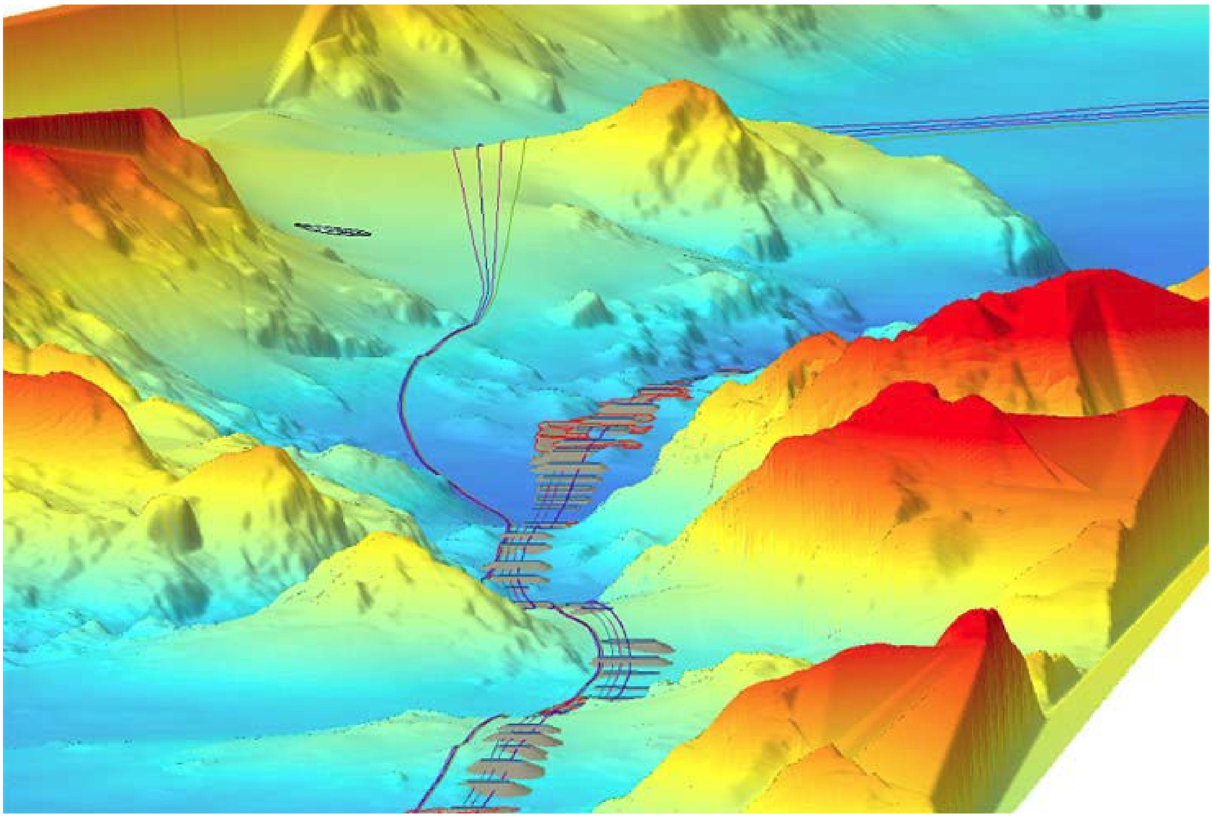

Figure 3 – 3D terrain model showing the wreck site (upper left corner) and pipeline routes. Illustration: Hydro

3.2. Background material

The NTNU University Museum has carried out the project using consultancy help from the Institute of Archaeology and Religious Studies and from the Department of Marine Technology. Marek Jasinski and Fredrik Søreide (both IAR) and Martin Ludvigsen (DMT) have been instrumental in carrying out the main part of the project. Only from 2012/13 the University Museums own staff (Fredrik Skoglund and Øyvind Ødegaard) have been involved.

This report is primarily based on the individual reports from the annual environmental monitoring surveys. The report summarizing the measurements of currents from 2005 – 2008 (Ludvigsen, Jasinski and Søreide 2009) has in addition been important. As well as the brief details of and plan behind the project which are detailed in the 2007-contract between AS Norske Shell and NTNU University Museum, and is presented in Chapter 7.1.

The present report is based on the available material and annual reports delivered by the primary project group. Reports from the 2011 and 2012-I (spring) surveys have not been made available to us writing this report, neither has the data from those surveys nor associated data from some of the other surveys. A specific report following the 2012-II (autumn) survey was not produced, because, as the last survey of the project, the information would be incorporated directly into this final report.

One major challenge has been that the final excavation report from the 2004 and 2005 excavations of the shipwreck has not been completed. The University Museum is still awaiting this final report from the external consultants. Consequently there is little available information on various specified aspects of the site prior to and after the intrusive excavations. This information is critical in order to fully understand the state of preservation of the shipwreck and site itself. Several smaller reports have been available, but they are not detailed enough regarding the environmental parameters, or hull structures, focusing mainly on technical achievements and work description of the excavations. One publication is worth mentioning: «Pipelines and Shipwrecks” (Bryn, Jasinski and Søreide 2007). This is however not a final archaeological report, as it focuses mainly on the background for the pipelines, and the methodology needed to undertake an excavation at 170m depth. Its archaeological section deal mainly with methodological aspects such as technology, and it mentions the wreck itself only briefly.

3.3. Rock dumping in 2007

One of the main reasons for establishing the environmental monitoring project was due to the great uncertainty as to whether the adjacent pipelines would come into conflict with the shipwreck site. The pipeline trenches themselves were dug at a distance from the shipwreck site that they did not physically interfere with it (approx. 60m). The uncertainties were directed towards whether the open trenches (1 - 2m deep) would influence the underwater currents, and thus contribute to unwanted erosion on the site. Such erosion could in a worst case scenario result in exposure of shipwreck materials and thus degradation and destruction of the shipwreck and vulnerable artefacts.

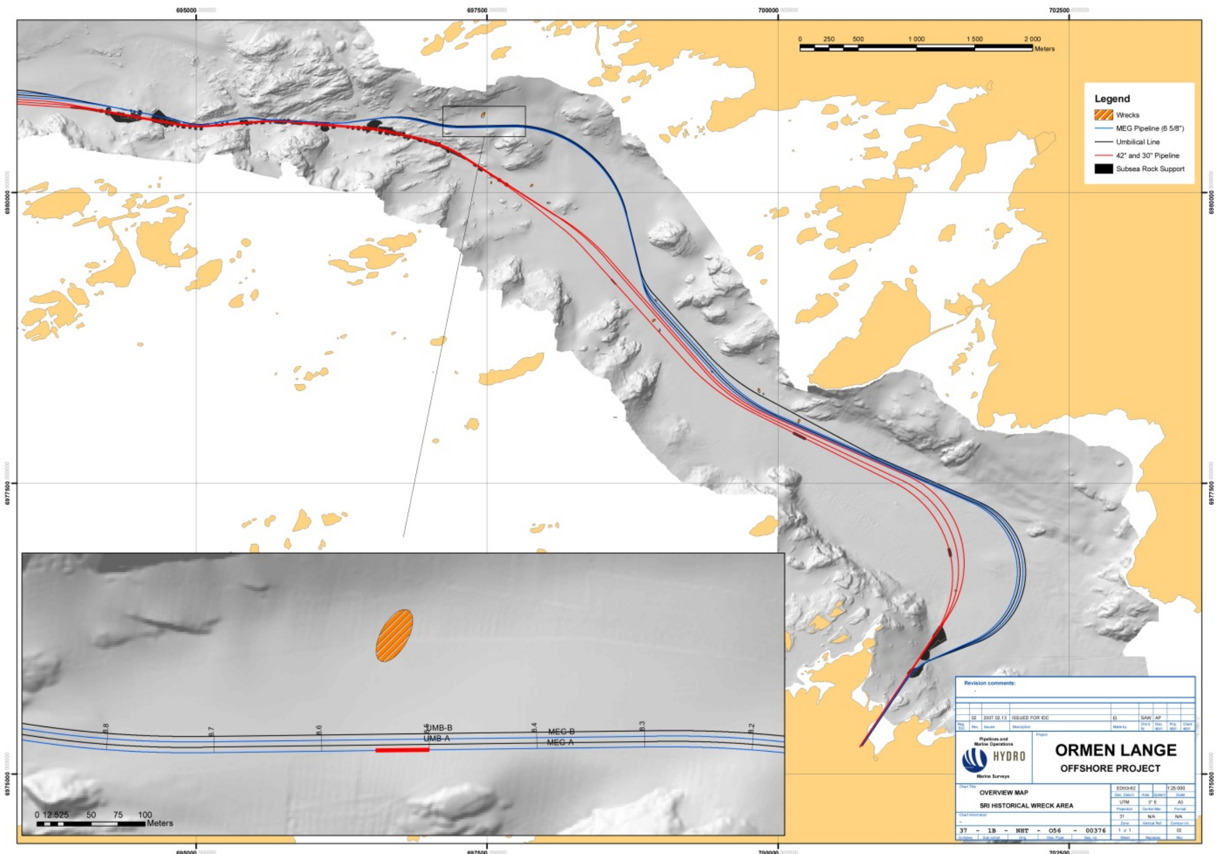

Figure 4 – Map of area covered with rocks in 2007. Illustration: Hydro

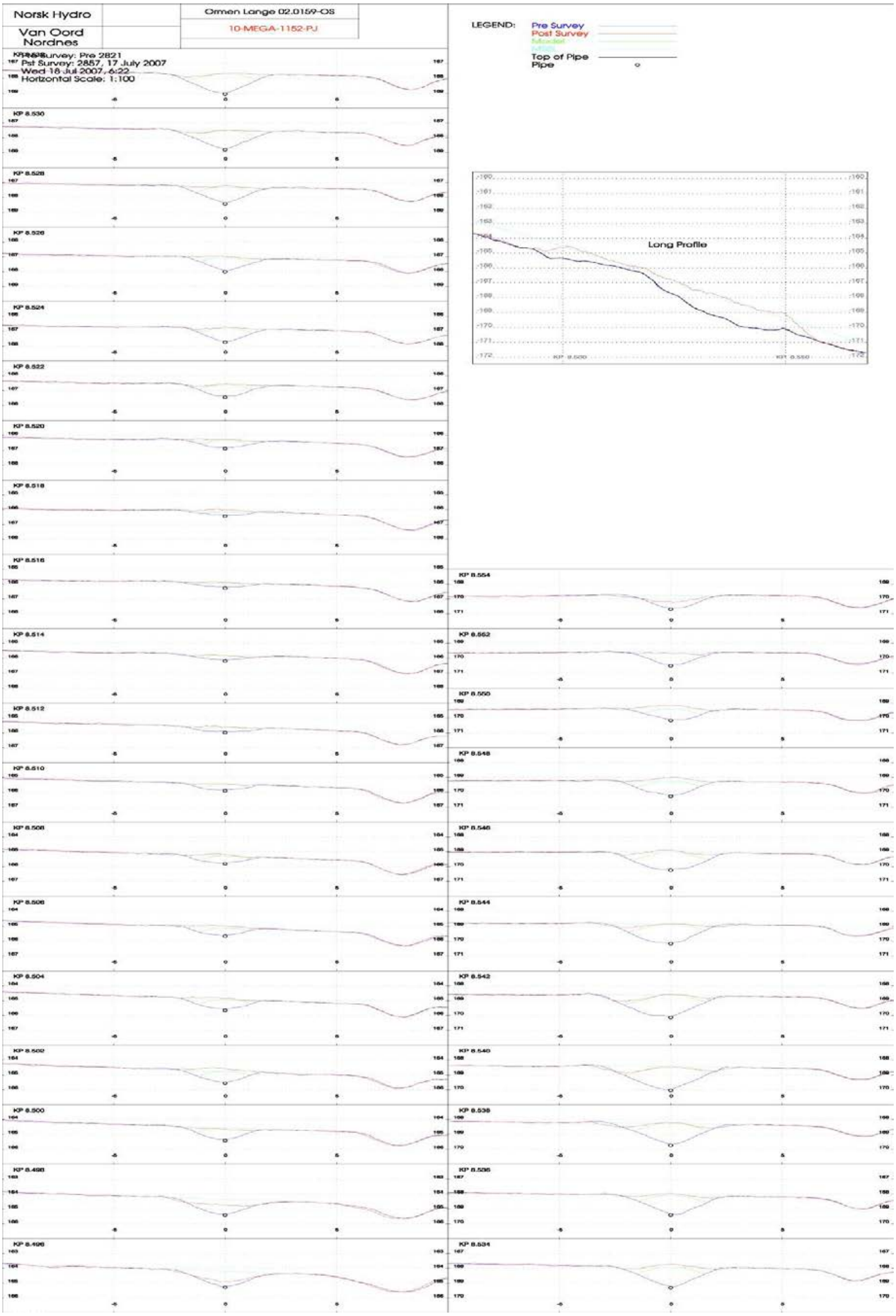

Figure 5 - Cross sections of profiles in pipeline trench, before and after rock dumping in July 2007. Illustration: Hydro

In 2007, Hydro wanted to cover parts of the 6” MEG-A pipeline to better preserve it. Hydro wished to fill the trench with stones over a distance of 50 m (See Figure 4), between KP 8.500 and KP 8.550. This initially came into conflict with the Directorate for Cultural Heritage’s letter of exemption, where they stated that establishment of rock fillings in this specified area was not permitted. It was however thought that if the trench was covered

properly, it could contribute to stabilizing the locally caused underwater currents rather than increase the risk of current contributed erosion. NTNU University Museum therefore wrote to the Directorate for Cultural Heritage proposing terms for the work. These terms were in agreement with Hydro determined to be a rock fillings that would not protrude above the seabed, but be laid flush with it.

The Directorate for Cultural Heritage agreed to the rock dumping on the specified terms, and the rock dumping was carried out on July 17th 2007, using the vessel FFPV *Nordnes.* A fall pipe system was utilized with an ROV at the end of the pipe to fully control the movement of the fall pipe. A total of 282 tons of rocks were used, but the rock size differed from 1” to 5” in order to make it as smooth as possible, and it was dumped during 6 runs. The ROV had an MBES that made continuous measurements before and after the dumping. The post-survey data shows that the trench was smoothly covered (see Figure 5).

The reason for putting such emphasis on this particular event in this report is that the event could have made an impact on the ongoing sediment-samplings and measurements of currents. But more importantly, that this action possibly improved the on-site preservation conditions for the shipwreck, by levelling the seabed and minimizing the risk for current-caused erosion.

4. Monitoring project - Background

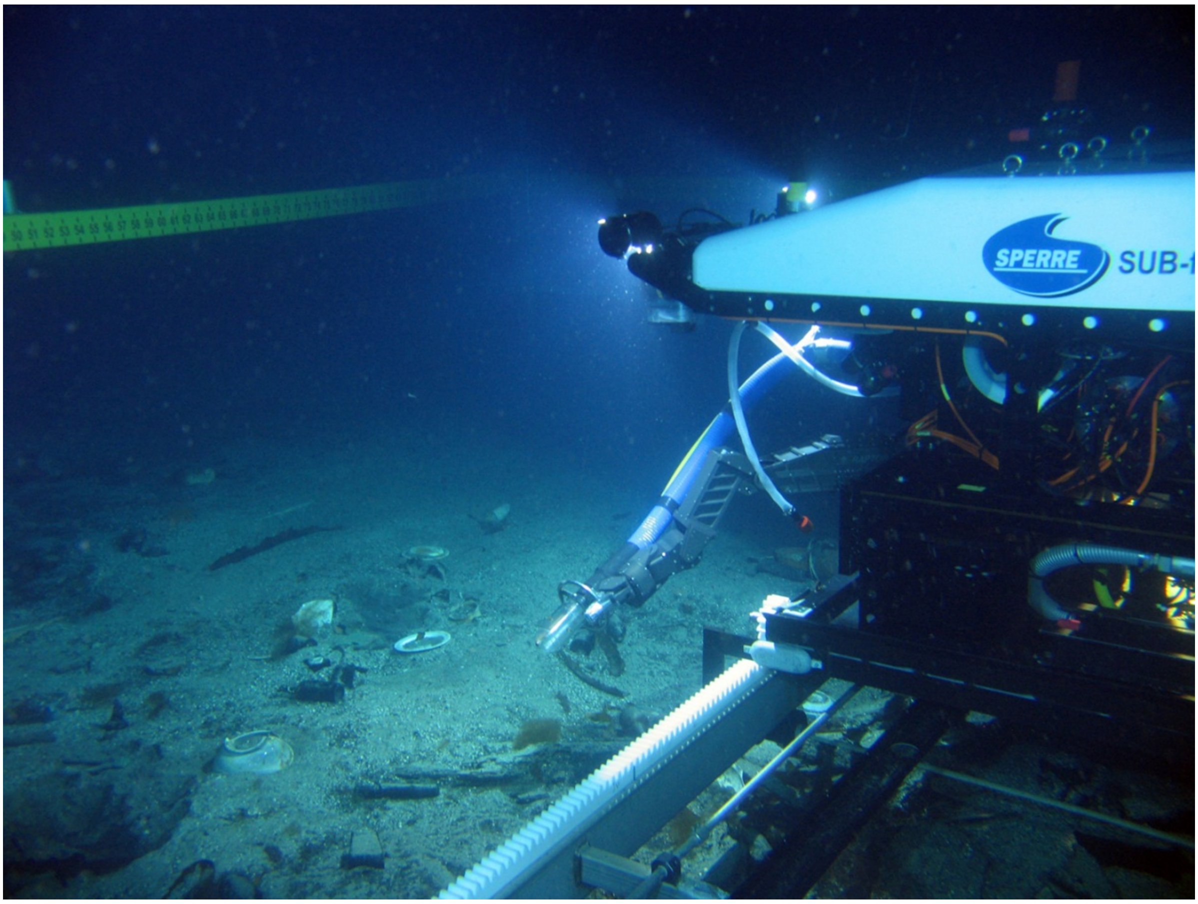

Figure 6 – The ROV at work during the archaeological investigation in 2005, docked on the excavation frame. Photo: NTNU Vitenskapsmuseet

During the marine archaeological surveys in 2003, an 18th century shipwreck of approximately 90ft length was discovered close to the proposed route for the Ormen Lange pipeline at a depth of 170 meters (Askeladden ID: 91448). As the wreck was confirmed to be more than 100 years old, it is protected under §14 in the Act concerning the cultural heritage (Cultural Heritage Act) No.50 of 1978.

In accordance with the Directorate for Cultural Heritage's letter of exemption from the Cultural Heritage Act (see Appendix 1), the NTNU University Museum conducted marine archaeological investigations of the wreck site in 2004 and 2005. Furthermore, non-intrusive fieldwork was conducted in 2003, but in 2004 and 2005 the investigations included intrusive methods of excavation. The investigations revealed that the ship was wrecked during the first quarter of the 19th century, and that it was built in the late 18th century. The site consists of the bottom part of a carvel built sailing vessel, as well as a plethora of inorganic artefacts, primarily pottery and glass bottles of varying European provenance and dating (Bryn, Jasinski and Søreide 2007).

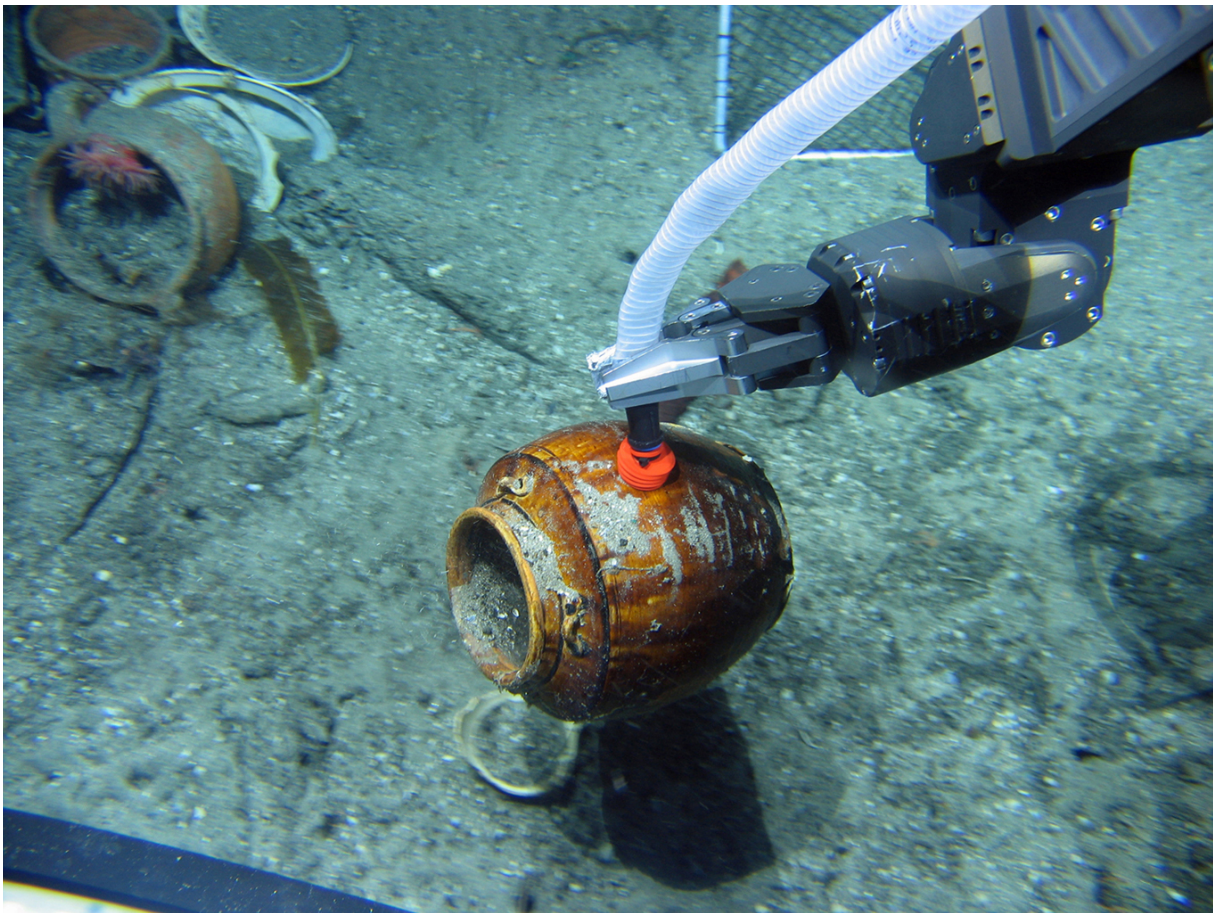

Figure 7 – ROV picking up artefacts from the site during the 2005 investigation using the manipulator and a gentle suction device. Here a Martabani stoneware jar is being recovered. Photo: NTNU Vitenskapsmuseet

The site must be described as a closed find where the ship sank to the seabed in one, more or less intact, piece. After settling on the seabed, the wreck has primarily been exposed to biological degradation, the prime effect being that the parts of the hull not covered in the sediments have been extensively degraded, much due to wood borers such as the *teredo navalis*. There are no indications of damage being caused by human activity such as trawling or other intrusive underwater actions (Bryn, Jasinski and Søreide 2007).

"*The bow section was recognisable by the presence of four lead hawse-pipes through which anchor lines would have passed and which would have been at the very bow of the ship, to the starboard and port of the bowsprit and pulpit. Clearly visible in the bow was the massive cant-frames and stem-timber and possibly the remnants of major timbers such as the apron and keelson in good state of preservation"* (Bryn, Jasinski and Søreide 2007:106).

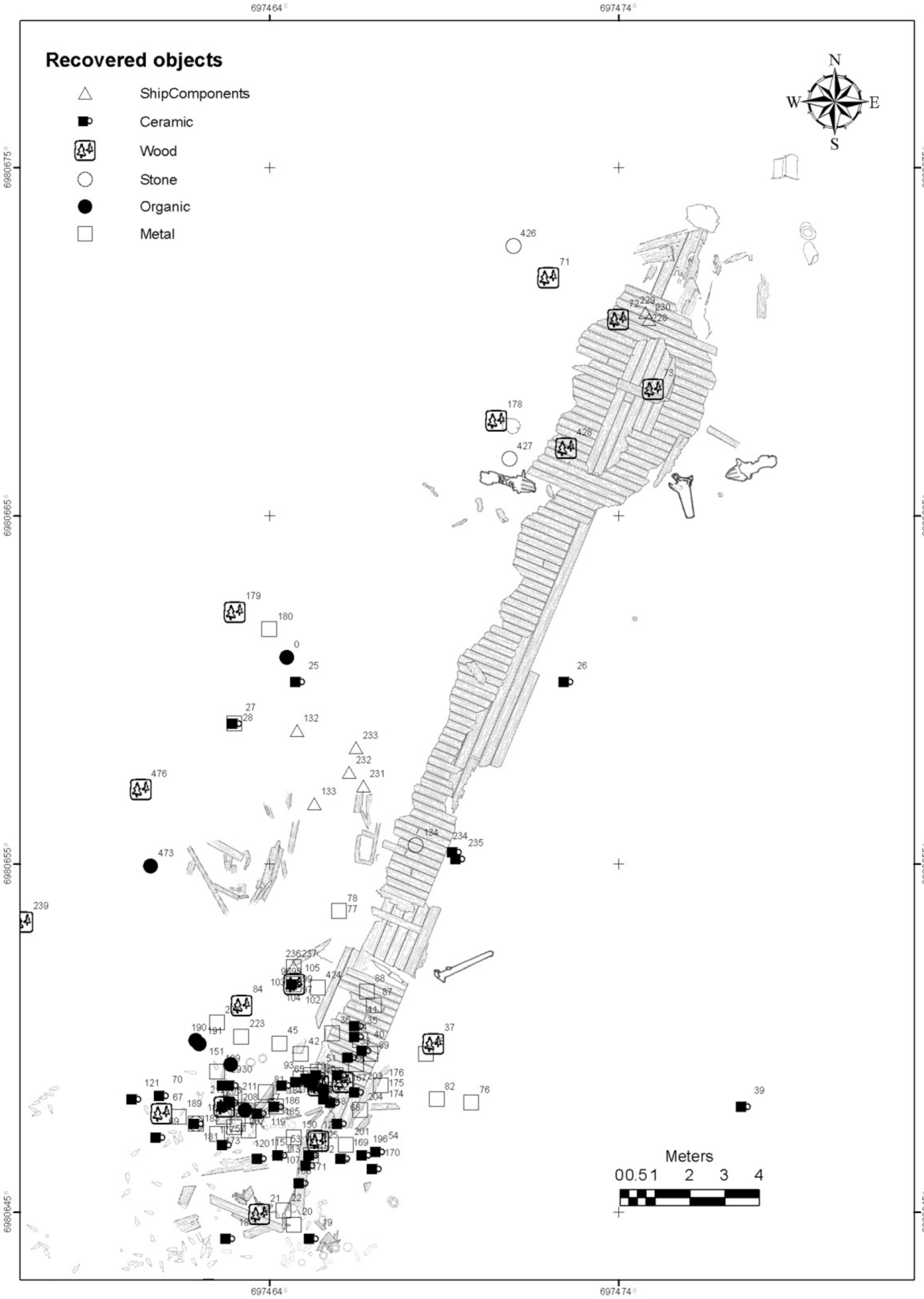

Figure 8 – Preliminary overview of the hull construction and artefact distribution made during the 2005 investigations. Illustration: NTNU Vitenskapsmuseet

One of the terms of exemption put forth by the Directorate for Cultural Heritage in their letter of June 2005, was environmental monitoring of the site. The shipwreck site being in fact a non-renewable resource, the Directorate for Cultural Heritage was of the opinion that environmental monitoring was necessary in order to acquire data relating to the further development of the site, as the long-term effects of such projects in such settings have not previously been documented (see Appendix 1:4-5). The Directorate for Cultural Heritage saw the need for environmental monitoring, but did not specify how the monitoring should be realised; that was for NTNU University Museum to decide in collaboration with Hydro. This was specified with Hydro and later with Shell (Contract of 2007). The project was to focus on changes in erosion and rates of sedimentation, obtained by a combination of visual observation and data acquisition. The excavations and the environmental monitoring should collectively provide valuable and much needed insight into the wrecking process and the various processes of disintegration and stabilisation relating to this specific enclosed find in deep waters.

The monitoring project was established in 2005, and the first survey conducted in 2006. Further surveys were carried out in 2007, 2008, 2009, 2011, 2012 (spring) and 2012 (autumn). The 2012 autumn survey was the last in the project, as the NTNU University Museum and the Directorate for Cultural Heritage were of the opinion that the acquired data were sufficient to document the level of risk between the installed pipelines and the wreck site. Moreover, they concluded that Shell had fulfilled its obligation as the developer towards the Cultural Heritage Act and the Directorate for Cultural Heritage's letter of exemption. Here must also be noted the rock dumping described in Chapter 3.3.

5. Project management and details

5.1. Clients

Norsk Hydro was in charge of the planning and building of the Ormen Lange Pipeline. When the installation was completed, the pipeline and its entire infrastructure were taken over by AS Norske Shell, being the operator for the production phase.

This transfer of ownership also implied that from 2008 AS Norske Shell became responsible for the environmental monitoring of the Ormen Lange shipwreck site, and a contract was signed in 2007 between AS Norske Shell and NTNU Vitenskapsmuseet (Contract nr: 4610014567).

5.2. Project management and participants

NTNU Vitenskapsmuseet has been in charge of the environmental monitoring project, being the regional governmental body in charge of the management of the underwater cultural heritage in central Norway.

Professor Marek E. Jasinski (NTNU IAR) was the principal instigator of this monitoring project. He was in charge of the excavation of this shipwreck from 2003-2005, and naturally continued as project director of the succeeding environmental monitoring from 2006 - 2012. Jasinski worked closely with Fredrik Søreide from NTNU (NTNU IAR), first on the excavations and later on the monitoring aspect. Fredrik Søreide acted as principal investigator from 2006 - 2012. Another important person on this project was Martin Ludvigsen (NTNU DMT) , who on all cruises from 2006 – 2012 was in charge of the day-to-day running of the project, as well as in charge of most of the preparations.

In 2012 there was a change of management. The Museum appointed Fredrik Skoglund as new project manager, and Øyvind Ødegård also became part of the project management team.

Although the project has been led by the NTNU Vitenskapsmuseet, there has been a most fruitful operation involving many parts of the NTNU organization. Especially Martin Ludvigsen and other people from the Department of Marine Technology have been key to facilitate and participating in accomplishing the surveys. Since the start of the AUR-lab, a marine technology hub at NTNU started in 2010, this group of specialists has taken charge of the marine operations of the project. Prior to this, personnel from Sperre AS were in charge of the ROV operations, as they were during the 2003-2005 archaeological investigations.

The excellent crew of the R/V Gunnerus must also be mentioned, especially Captain Arve Knudsen and Svenn Ove Linde. Their hands-on involvement has greatly facilitated the project, and indeed been necessary for the accomplishment of each cruise.

5.3. Timeline

The environmental monitoring project spanned from 2006 to 2012, with fieldwork conducted once every year, with the exemption of 2010. Initially the project was planned to last from 2006 until the end of 2015, as agreed in the 2007-contract between AS Norske Shell and the NTNU University Museum; however, based on the information contained within the data collected the project ended its fieldwork and data acquisition in 2012.

A final confirmation on the conclusion of the project was given in a letter from the Directorate for Cultural Heritage to AS Norske Shell dated 17.01.2014 (see Appendix 3). In this letter the Directorate for Cultural Heritage verified that the environmental shipwreck monitoring, founded on the Directorates earlier decisions had been completed, and that the conditions for exemptions from the Cultural Heritage Act were fulfilled by the client.

5.4. Vessels and equipment

5.4.1. Vessels

Several vessels have been used throughout the course of the project.
During the first phase (2005 – 2006) Fugro used three different vessels: in September 2005 - *MV "Urter"*, in January 2006 – *MV" Ocean Flower"* and in June and October 2006 - *MV "Elisabeth".*

Figure 9 – R/V Gunnerus. Photo: Skoglund/ NTNU Vitenskapsmuseet

In 2009 the survey was carried out using Subsea7's multi-purpose offshore vessel "*Normand Commander".* Apart from the 2009 cruise, all surveys carried out by NTNU from 2006 to 2012 used NTNU's own research vessel R/V "*Gunnerus*". The ship was inspected by representatives of the client in advance of every cruise, either as a general audit or more thoroughly, as was the case in January 2008 when an IMCA M149 inspection was conducted by SEAMR on behalf of AS Norske Shell. Using the same vessel for every cruise proved highly beneficial as all operations on board could be adapted better than had different vessels been hired for each cruise. Especially working with the same crew and captain was quite invaluable. The ship is fitted with a Kongsberg DP system and a HiPAP 500 unit, and is optimal for ROV operations and the positioning of any deployed equipment. It has an LOA of 31.25m, extreme breadth of 9.90m and a draught of 2.70m. Within NTNU it is used for a variety of research activities within biology, technology, geology, archaeology, oceanography, fisheries research as well as for educational purposes.

5.4.2. ROVs

Fugro accomplished their deployments and recovering of the current meter without the use of ROVs; however, when NTNU took over, ROVs had to be utilised due to the more multi-facetted tasks planned. Essential was the use of video recordings for documenting the annual conditions on the site, visual inspections of the sediment indicators as well as making sure that the instrument rigs were securely installed outside the boundaries of the hull of the wreck. In 2009, the ROV on board the "Normand Commander" was used. Apart from that cruise, NTNU used their own ROVs when on board the R/V Gunnerus. R/V Gunnerus is not fitted with an ROV, but is adapted for the use of such. Consequently, the ROV had to be mobilised for each cruise. There were two ROV systems that were used during this project, both owned by NTNU and both produced in Norway by Sperre AS.

The SUB-fighter 30K was custom made for the excavations of the Ormen Lange shipwreck in 2004 and 2005 (see Figure 6 and Figure 7 of the ROV in work). It is a heavy-duty electric work-class ROV, rated to 1200m. Importantly, the ROV is equipped with a 7-function manipulator with force feedback that renders the challenging tasks regarding the installing and retrieval of the instrument rigs possible. The weight of 1880 kg made it less manoeuvrable on deck using the standard deck crane on board R/V Gunnerus; consequently AS Norske Shell with regards to HSE, organised for a LARS to be built (see Chapter 6.2). The other system was a SUB-fighter 7500, named "*Minerva*". This ROV was especially designed by Sperre AS in 2003 to fulfil the needs of scientists at NTNU. The vehicle is rated to 700 m depth, and is operated from a standard 15 feet cargo container. Real time video from the ROV video cameras was screened in the mess room aboard R/V Gunnerus during field operations.

5.4.3. Equipment

The main monitoring instruments used in this project have been the current meter and the sediment trap. For a description of the Aquadopp Open water 3D current meter from Nortek, see Chapter 7.5. For a description of the Parflux Mark 8 sediment trap from McLane Research Laboratories, see Chapter 7.3. Initially one set of both instruments were thought sufficient. But later in the project this was re-evaluated and one extra set of each were bought. This was done in order to save time in the field as a new and already programmed instrument could be deployed soon after the active one had been recovered. Prior to this the active units had to be recovered, the data unloaded, the battery changed and the new cycle programmed into the unit, then to be deployed. The cost of an extra unit was far outweighed by the time saved in the field, and these were an extra reassurance should one of the units in any way become inoperable. The latter was unfortunately the case and probably more than any other factor, prompted the purchase of the second set of units.

6. Regulations and policies

6.1. Cultural Heritage Act

The Act Concerning the Cultural Heritage (Cultural Heritage Act) of 9 June 1978 No.50 is the law that defines what constitutes a cultural heritage monument in Norway, as well as obligations of finders and restrictions of the use of sites with such monuments.

In regards of ship finds, this is described in its own section; § 14 Ship finds. This section states that: "*The State shall have the right of ownership of boats more than 100 years old, ships' hulls, gear, cargo and anything else that has been on board, or parts of such objects, when it seems clear under the circumstances that there is no longer any reasonable possibility of finding out whether there is an owner or who the owner is.*
The authority appointed under the Act may dig up, move, examine or raise objects as described in the first paragraph, regardless of who is the owner, and take other steps to preserve the object or take it into safekeeping. Such measures, or any other measures that may damage the object, may not be implemented either by the owner or by others without the permission of the competent authority, or if so, then subject to certain conditions. As far as possible, the owner or user of the land shall be notified before measures in accordance with this paragraph are effectuated. The provisions in Section 9, Section 10 and the second paragraph of Section 11 similarly apply.
The finder of an object as described in the first paragraph has a duty to report the find to the local police or the authority appointed under the Act. If a find is State property, the competent authority may, after the object has been examined, hand it over wholly or in part to the finder or the landowner.
The Ministry may decide on the amount of a reward by valuation. The third paragraph of Section 13 similarly applies. The finder is defined as the person who discovers and reports a previously unknown find, cf. the third paragraph".

As the Ormen Lange wreck was more than 100 years old (determined from date of construction) it, as well as the associated objects on the seabed, came under the protection of §14. Thus the developer had to obtain permission from the Directorate for Cultural Heritage to undertake their project, and this was given on specified conditions (see Chapter 4 and Appendix 1). The Directorate's conditions also included environmental monitoring in order to map whether the installed pipelines would affect the continued stability and preservation of the shipwreck site.

6.2. Health, Safety and Environment

HSE is an important and integrated part of all NTNU projects. The HSE guidelines and Manual are implemented as part of NTNU's commitment to the safety of all persons involved in the various work tasks when operating from a vessel. The HSE philosophy shall be in accordance with Norwegian laws and regulations, and is to be the overall guideline for the safety work within this project. Compliance with NTNU HSE policies forms an integral part of all management objectives and is an essential part of the individual goals of each employee. The Project HSE Manual describes the overall requirements and systems for ensuring safe work practices; and the aspects of HSE also comprised important parts of the projects Operations Procedures (see Chapter 6.3), and formed the foundation for the Mobilisation/Demobilisation Procedures (see Chapter 6.4).

Contractors, suppliers and third party personnel working on board NTNU vessels are required to conduct themselves in a manner that is in compliance with NTNU's HSE policy, as well as the policies of their respective employers. Ensuring efficient collaboration between

NTNU and Hydro/Shell regarding the HSE aspects of this project was of great importance, and the results were satisfactory.

Focus on HSE was implemented throughout the project and directed much of the day-to-day operations when at sea. There was a huge benefit in using the same vessel, for all the cruises, apart from in 2009. This meant that the safety aspects were easier to carry out having previously done the same operations. There was an audit of the vessel almost every year, and the work permit was not issued until the audit was satisfactorily completed. There was also a bridging document issued in order to bridge the contingency organisation of A/S Norske Shell Operations with the contingency organisation of the vessel in the event that an emergency situation should occur in connection with the vessels operations at the installation. Moreover, the document bridges the contingency organisation of the vessel to the contingency organisation of the installation during the operation.

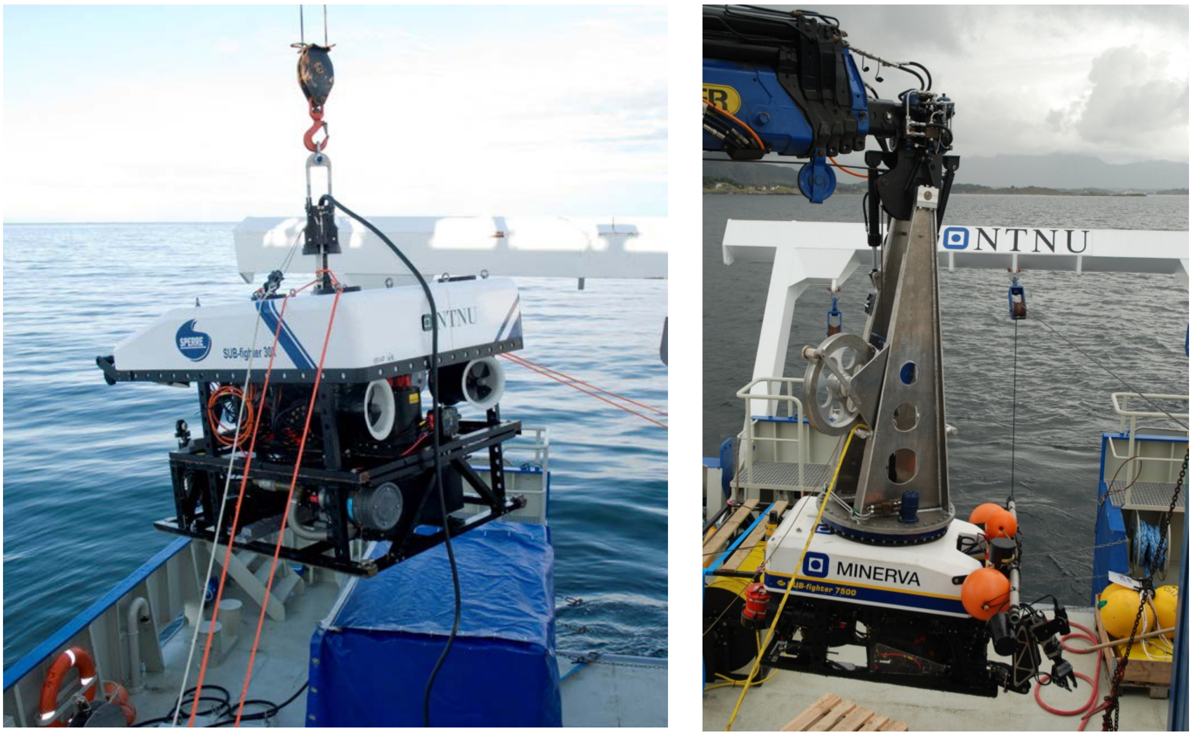

Figure 10 - Until 2011 the lifting operations were carried out with a latch attached to the deck crane and the need of ropes to control the horizontal movements of the ROV whilst in the air, here lifting the 30k ROV (left). The Palfinger deck crane fitted with LARS in 2011 lifting the Minerva ROV (right). Photos: NTNU Vitenskapsmuseet

Familiarisation and safety briefings were held for all personnel upon their first arrival on board the vessel. One focus was related to personal protective equipment (PPE) to be worn on work-deck during operations; it included hard hat, safety boots and life vests when at sea. Safety meetings were held when necessary, and also toolbox talks as part of safety monitoring in advance of vital operations such as recovery of the sediment traps.

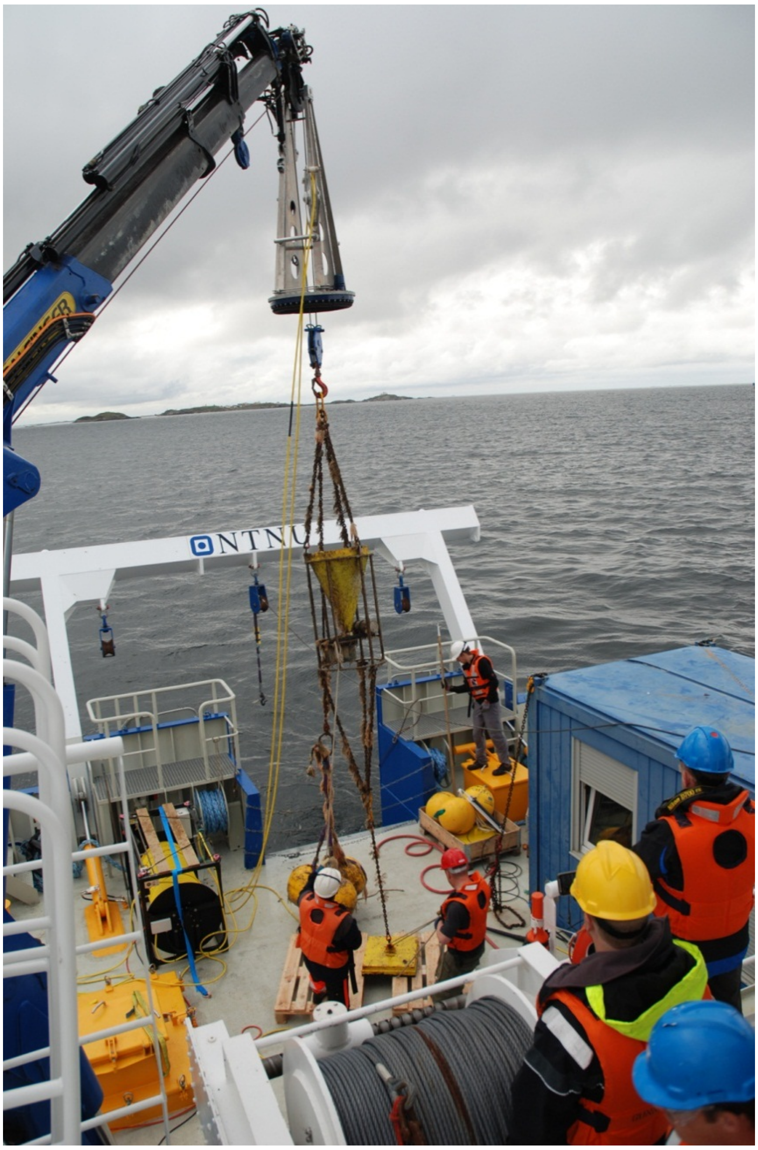

Figure 11 – The fitted LARS in some ways restricted the use of the deck crane for lifting operations other than for the ROV, here seen recovering the sediment trap. This led to the use of the port side crane for such operations. Photo: NTNU Vitenskapsmuseet

HSE was a dynamic element throughout the project and many operations were altered for the better. The project especially had to deal with the lifting of heavy objects, as one of the ROVs employed weighs 1800 kg, and lifting it in and out of the water using the deck crane was a crucial operation. Initially the ROV launch was done just using the deck crane and a latch (see Figure 10, left), but for the 2011 season a LARS had been custom built for the R/V Gunnerus (see Figure 10, right). The LARS was implemented in order to be able to carry out the launch and recovery operations with a deck cleared of personnel thus minimizing the risk of personnel-related injuries. The LARS system is basically a frame mounted on the crane in order to minimize and stabilize horizontal and vertical movements when lifting the ROV.

The launch and recovery of both sediment trap and current meter were thoroughly discussed with Hydro and Shell HSE personnel. Initially the instruments were deployed and recovered over the stern part of the vessel using the Palfinger deck crane. This was later changed, and the instruments were launched on the port side of the vessel using the smaller hydrographic crane, where there was also a diver's platform that could be lowered into the water to avoid unnecessary the risks of having the equipment suspended in the air. Later, the recovery of the instruments was done using the port crane, resulting from the fact that the LARS when fitted to the deck crane restricted the cranes usage for such operations (see Figure 11 and Figure 12).

When the instruments were deployed a transponder was attached to the wire so that the people on the bridge as well as the ROV pilots could monitor the position of the instruments being lowered into the sea. The hook was fitted with a release triggered from deck, and this was executed after the ROV had confirmed its position on the seabed. When recovering the instruments from the seabed, the wire was similarly fitted with a transponder, but this time the ROV on the seabed used its manipulator to attach the hook to the lifting arrangement on the instrument rig.

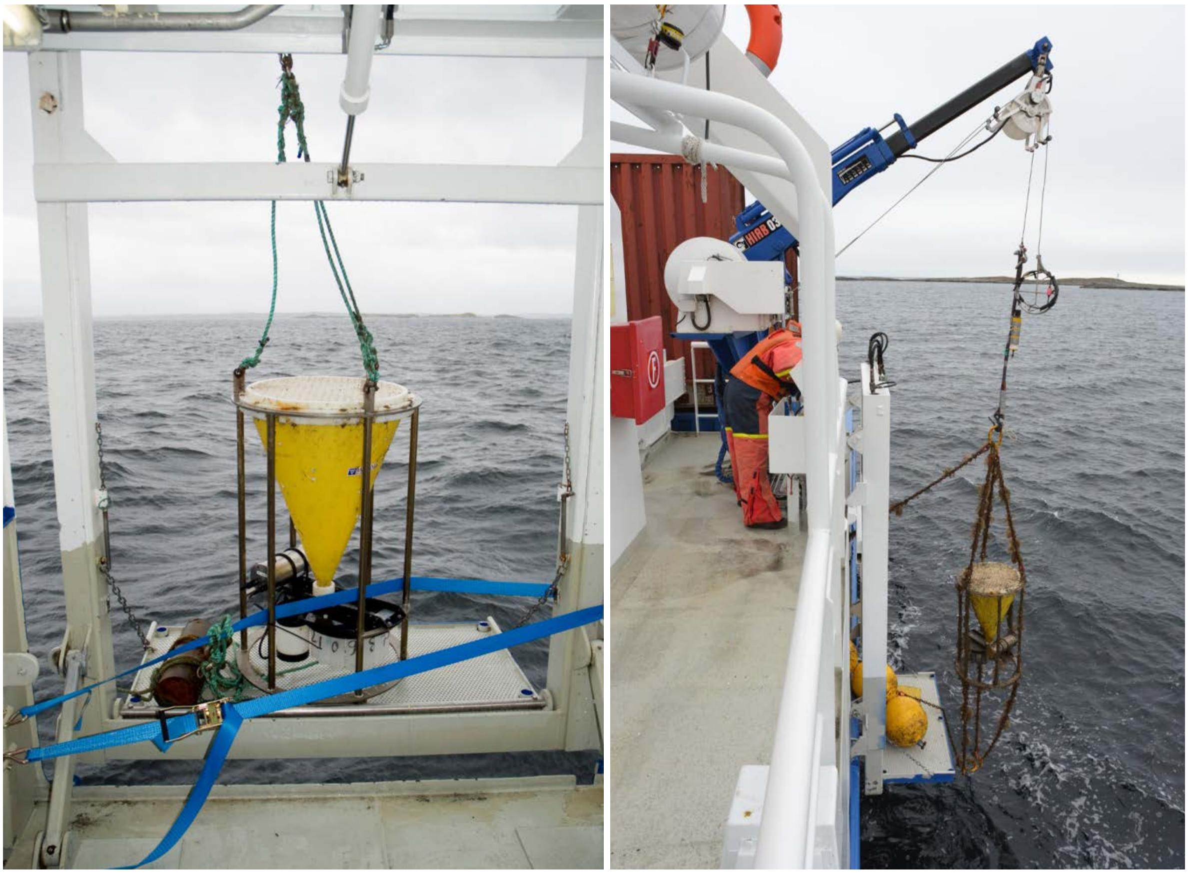

Figure 12 - Sediment trap resting on diver's platform ready to be launched in 2008 (left), and being recovered in 2012 (right). Photos: NTNU Vitenskapsmuseet

6.3. Operations Procedures

For every cruise Operations Procedures (OP) were issued by the project management. The document provided an overall brief description of operation procedures to be used during that year's Ormen Lange Marine Archaeological project fieldwork. The OP was approved by the client prior to start of operations.

The OP contained an overview of the activities planned during the fieldwork as well as detailed information on the work scope with tasks prioritized should there be time delays. Overview of the organisations taking part with job descriptions and contact information was also included. Moreover, a chapter on quality management formed part of the OP. Further, there was a chapter relating to the project HSE in a less detailed manner compared to the project HSE main manual. Additionally, administrative requirements such as daily reporting, non-conformances, and communication were described.

6.4. Mobilisation/ Demobilisation Procedures

For every cruise Mobilisation/ Demobilisation Procedures (MDP) were issued by the project management. The document describes activities and requirements to be performed in order to mobilise and demobilise for the Ormen Lange Marine Archaeology Project fieldwork. The MDP were approved by the client prior to start of operations.

Having detailed sets of procedures for these events was imperative, as both heavy and expensive equipment would be brought on board for the surveys. This was especially true for the ROV system and, in particular, the SUB-fighter 30K ROV (1880 kg) and the accompanying 18ft operation container (4400 kg) and cable winch. In that respect, sea fastening was important, and demanded good collaboration with the vessel crew. The project coordinator was one of the crew, and took charge of the mobilisation and demobilisation according to the MDP.

The MDP described how lift planning and job site review were to be undertaken, in what order operations were to be carried out, who were in charge, and who were to take part. The importance of toolbox talks was also addressed and appropriate forms included. Risk assessment and HSE were crucial elements to be considered for every operation in connection with the MDP.

7. Methodology

7.1. General

The aim of the project was to acquire valid data sets comparable with data acquisition of the following surveys. Some years, however, the contents of the fieldwork had to be altered, either due to bad weather or malfunctions with instruments or instrument rigging. As a consequence of this, there is no complete series of measurements from 2006 to 2012 either from the sediment trap or the current meter.

The methodological aspects can be found described (not detailed) in the 2007 contract between AS Norske Shell and NTNU Vitenskapsmuseet (page 16) where it is specified that "*the environmental monitoring project will form the basis of the evaluation of any long-term effects on the cultural heritage site induced as a result of the construction* [i.e. of the pipelines]*. Valid data on erosion are difficult to provide, and thus one wishes to measure the difference between net and gross rate of sedimentation in the area, as an indicator to how extensive the actual erosion is. NTNU Vitenskapsmuseet is also of the opinion that visual observation of level of sedimentation on the sediment indicators on each survey in addition to the measured rate of sedimentation in between the surveys will provide a sound impression regarding the sedimentation situation on the site. This combined with measurements of currents and visual observations can address the development of the level of preservation on the site over time. The measurements will be sought related to the construction* [i.e. of the pipelines] *as much as possible*"

The planned schedule for the monitoring project as it was described in the 2007 contract with AS Norske Shell (page 16), was as follows:
1. At every survey ROV-based visual inspections are to be carried out, and these are to be compared to previously conducted surveys in order to establish the existence of changes on the site.
2. A current meter is to be installed on the site to document the on-site current situation.
3. Three sediment indicators with centimetre indicators are to be installed on the site in order to document the level of sedimentation (net sedimentation) at every inspection.
4. A sediment trap is to be installed to document the actual rate of sedimentation (gross sedimentation) between the inspections.

The above-mentioned approaches to the monitoring study to a large extent stems from the Directorate of Cultural Heritage's letter of exemption dated June 8th 2005 (see Appendix 1). In this letter Hydro is given permission to install the pipelines in Bjørnsund on several conditions, one of which is that "*the developer shall include video recordings of the site, acquisition of data from current meter and visual control of sedimentation, as part of the developers program of inspection of the pipeline route in the operational phase. Marine archaeologists from NTNU Vitenskapsmuseet shall advice, and participate in this environmental monitoring of the cultural heritage site, as well as receive the collected data*". Later in the same letter the Directorate states that "*the specified condition regarding environmental monitoring is necessary in order to collect data regarding the development on the site, as the long-term effects of this type of project previously have not been documented under such conditions* [i.e. the depth]".

The environmental monitoring project as set out here was basic in its idea and implementation. It was the first of its kind in deep waters in Norway the Directorate for Cultural Heritage had to assess, and both the Directorate and NTNU in many ways saw this as a pilot project within deep water archaeological monitoring, to be assessed for future projects of similar kind. The challenges were mainly related to the depth, which prompted the use of ROVs and many adjustments of instrument rigging and gear. Being a deep water project has also meant that there were a much more detailed and strict sets of rules to be adhered to as well as an increasing set of logistics to be able to carry out the tasks properly, compared to a near shore operation with divers.

The methodological approaches chosen at the onset of the project was kept more or less without change throughout the duration of the project. The various instruments and approaches are further explained in Chapters 7.3 – 7.9. A short discussion of the methodological approaches can be found in Chapter 10.

7.2. Project timeline

In the initial contract with Hydro, a proposed time-line for the project's duration was proposed with the start of NTNU University Museum's involvement in 2006. In the subsequent contract with AS Norske Shell from 2007, this initial time-line was continued (page 16):

- 2008: Change battery in current meter and sediment trap. Data acquisition.
- 2009: Change battery in current meter and sediment trap. Data acquisition.
- 2010: Change battery in current meter and sediment trap. Data acquisition.
- 2011: Change battery in current meter and sediment trap. Data acquisition.
- 2012: Change battery in current meter and sediment trap. Data acquisition.
- 2013: Change battery in current meter and sediment trap. Data acquisition.
- 2014: Change battery in current meter and sediment trap. Data acquisition.
- 2015: Change battery in current meter and sediment trap. Data acquisition.

Prior to 2008, NTNU had performed surveys in 2006 and 2007; additional current meter measurements had been carried out by Fugro prior to 2006 (see Chapter 8.1). From 2008 and until 2012, the project followed this initial time plan to a large extent. No survey was conducted in 2010 owing to bad weather in the available time slots. According to the contract cruises were scheduled to be undertaken in 2013, 2014 and 2015, but for reason stated earlier, the last survey was conducted in 2012.

There was a planned cruise every year during the project period; this was mostly due to the battery capacity of some of the sensors. This meant that e.g. the current meter would be able to perform active logging on the seabed for approximately one year before the battery had to be changed. Initially surveys every second year, which was proposed, but due to battery capacity one had to settle for more frequent yearly surveys.

With the change in project management in 2012, it was realised that there had to be either substantial changes made to the project methodology, or that that the data collected was sufficient. Changes would be necessary as the project, apart from an attempt on wood-sampling in 2011, had not updated is methodology since the start in 2006. The current methodology only gave insight into processes within the water column, and was not directed at studying the actual preservation and stability of the shipwreck itself. Thus updating the toolbox to include more thorough insight into the actual remains on the seabed would be necessary were the project to continue and be scientifically valid. After thorough discussions, amongst other with the Directorate for Cultural Heritage, it was concluded that the collected data in many ways would be sufficient to make the necessary predictions regarding the state of preservation of the site, and more precisely; to conclude whether the pipelines were coming into conflict with the wreck site. As the answer to the latter was negative, it was decided that the survey in autumn 2012 was conclusive.

7.3. Sediment trap

Figure 13 – The sediment trap and mooring recovered during the 2012 survey. Photo: NTNU Vitenskapsmuseet

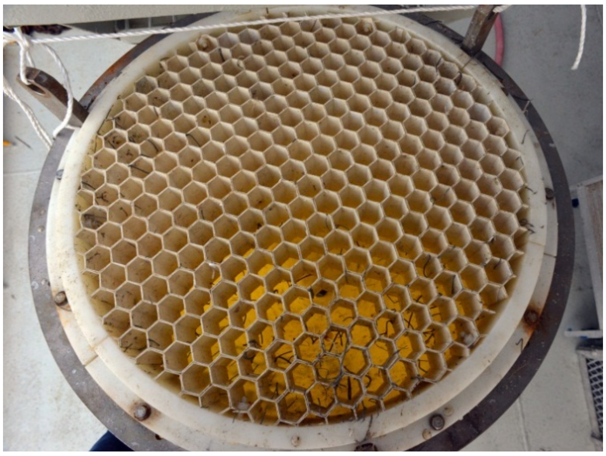

Figure 14 – Topside view of the funnel's honeycomb baffle. Photo: NTNU Vitenskapsmuseet

During the archaeological investigations/ excavations in 2004 and 2005 the wreck was uncovered by removing the protective sediments in order to undertake the necessary onsite documentation. An ROV with fitted pump removed the sediments, and at the end of the investigations, the pump was reversed and used to redeposit the sediments back over the wreck to loosely cover it (Jasinski and Søreide 2006:2).

It was supposed that the sediments were protecting the organic materials from degradation. Therefore, one of the intentions of the environmental monitoring was to see whether the sediments covering the wreck stayed in place. If the sediments stayed in place, it was assumed that the wreck was being protected. Consequently, measuring changes in rate of sedimentation on the site was deemed necessary the first years after the installation of the pipelines in order to assess the site's protective parameters and level of scouring.

In order to measure the net rate of sedimentation on the wreck site, a sedimentation trap was installed in 2006 (Jasinski and Søreide 2006:6). The device was a Parflux Mark 8 from McLane Research Laboratories. The Mark 8 sediment trap is a time-series instrument that autonomously collects the flux of settling particles on an operator-defined schedule. The wide top funnel (53.7 cm) collects particulate specimens into 13 individual 250 ml sampling bottles. The sample interval for each bottle was set to 30 days. The results provide information of the net rate of sedimentation in the water column (see Chapter 9.1.3), as the opening on the trap was positioned approximately 3-4 meters above the seabed, same as the current meter (see Chapter 7.5). The buoyancy was approximately 7 meters above the seabed.

When deploying the instrument setup, much care was taken to assure that the rigging was put in a position on the seabed not directly in contact with the shipwreck itself. The ROV would always be positioned on the seabed to ensure a safe position.

During the 2008 survey, after successfully changing the sample bottles and offloading the data, a shackle broke as the rigging was lifted over the side during redeployment "*and the unit sank to the seafloor*" (Jasinski, Ludvigsen and Søreide 2008:2). It was not until the following year it was ascertained that it had actually landed on the seabed properly and had indeed gathered sediment samples the whole year. This incident led to the whole instrument rigging being assessed as part of HSE work. The weights were changed as well as some materials that proved to lead to the corrosive actions where they were connected. AS Norske Shell were responsible for the changes to the rigging set up.

Figure 15 – The lower part of the sediment trap with the sample bottles, controller housing and stepper motoring housing. Photo: NTNU Vitenskapsmuseet

All sediment samples collected by the sediment trap have been analysed by NGU in Trondheim (see Appendix 4) and their reports have been included in the annual reports in 2007, 2008, 2009 and 2012. The same method has been applied throughout the course of the project in order to get as consistent results as possible.

NGU has conducted grain size distribution with laser diffraction. The instrument is based on principles of how (angles) particles at different size diffract monochromatic laser light. At NGU a Coulter LS 200 instrument is used. The instrument can measure in the range from 0.4 µm to 2000 µm. Particles larger than 2000 µm have to be determined with other techniques such as sieving. The grain size distribution is determined with respect to volume %, and with the assumptions of uniform density of the sample, this should correspond to mass based distributions. The instrument cannot detect particles smaller than 0.4 µm and the grain size distribution is calculated based on an assumption of 100 % in the measuring range. For samples containing a relative large amount of fine fraction (especially < 0.4µm) the grain size distribution obtained with this technique could deviate from other techniques (such as the pipette method). If the samples contain organic material or salts these has to be removed prior to analysis. Wet samples are dried usually with freeze-drying.

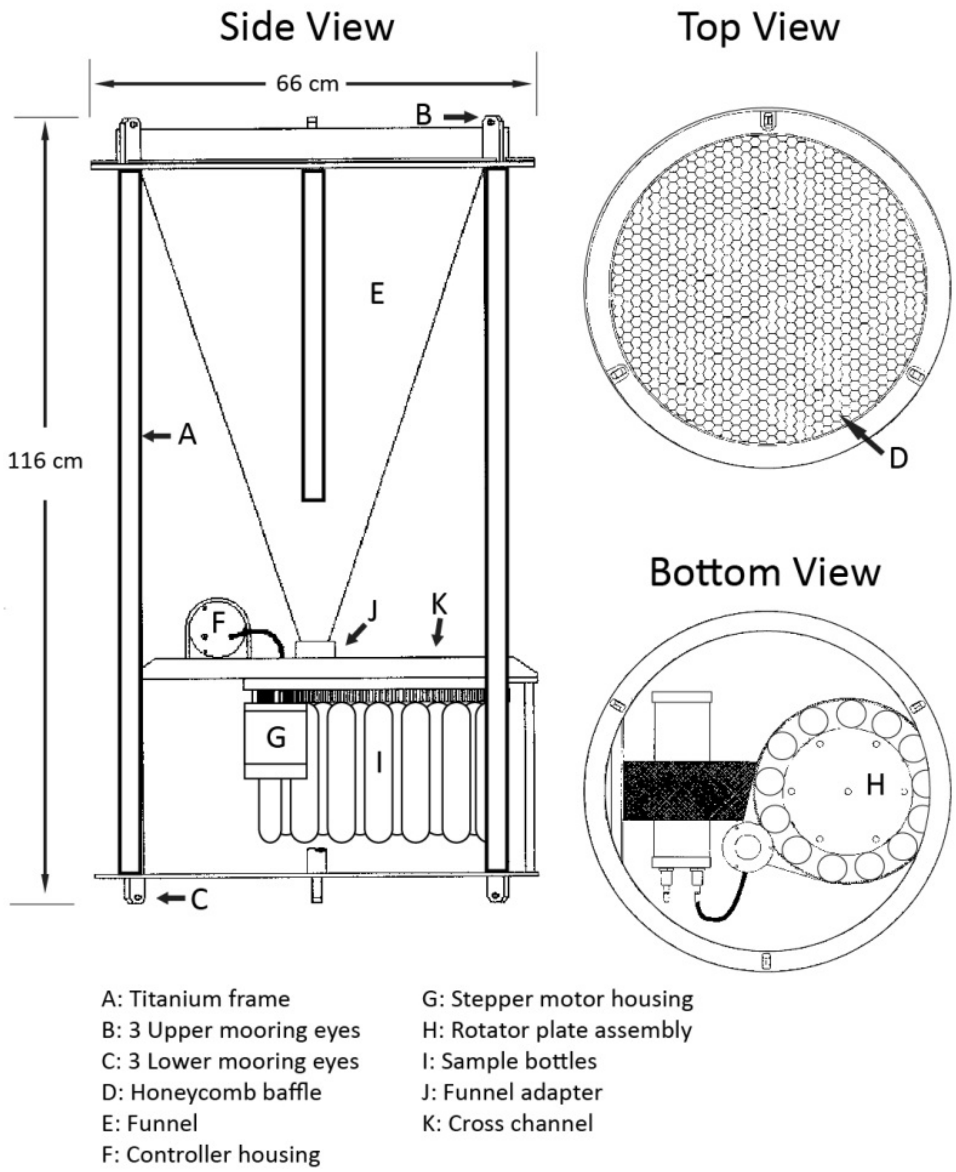

Figure 16 - Line drawing of Parflux Mark 8 sediment trap with 13 sample bottles. Illustration based on sediment trap user manual page 1-2.

7.4. Sediment indicators

The above described sediment trap collects sediment in the water column, not directly on the seabed. It was then suggested to have sediment indicators fixed on the seabed to measure gross rate of sedimentation.

The sediment indicators were custom-made and positioned on the seabed under direction of Norsk Hydro, prior to the 2006 survey. They are metal poles 70 cm high, with a rectangular ring on top for hoisting it. The poles are mounted on rectangular bases and are painted in bright yellow and black as 10 cm indicators. There are three sediment indicators placed on the wreck site: in the bow- (#3), mid- (#13) and stern (#1) section of the wreck. The purpose was to have an easy way to visually measure the level of sedimentation and scouring on various parts of the site, thus gaining insight into the gross rate of sedimentation at the time of visit. The sediment indicators were filmed on each of the annual cruises.

As they are fixed on the seabed and geographically positioned (see Chapter 9.2.1), they were left on site after the 2012 survey, so that future visits to the sites can use them for future data acquisition, as well as for orientation on the wreck site.

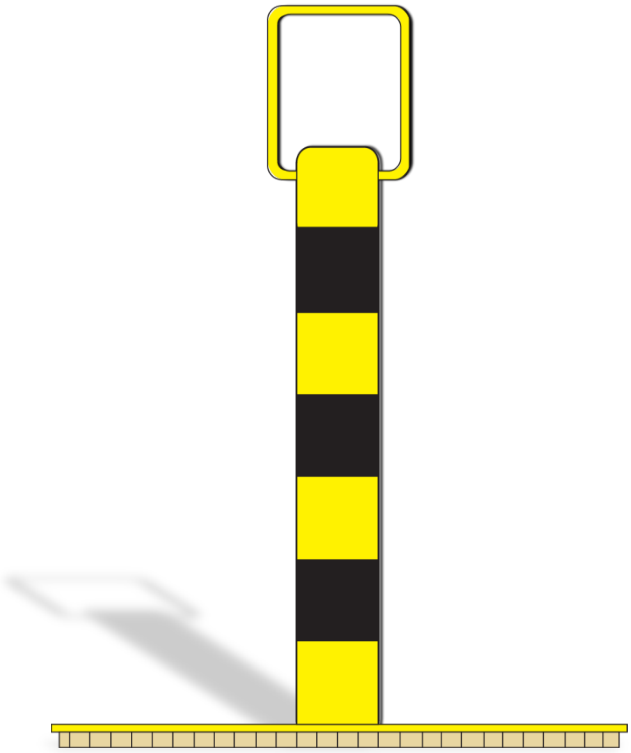

Figure 17 – Illustration of the design of the sediment indicators. Illustration: Skoglund/NTNU Vitenskapsmuseet

7.5. Current meter

A feared change in local currents on the shipwreck sites caused by the pipeline trenches was one of the main concerns when evaluating the proposed pipeline routes from a cultural heritage perspective. Such a change was undesired as it might result in erosion accelerating degradation of the organic material on the site. Monitoring the onsite currents was thus considered an important task, as it would give insight into general patterns, seasonal fluctuations and distinct changes. The use of a current meter was also directly mentioned by the Directorate for Cultural Heritage intheir letter of exemption.

In 2005 a current meter was positioned on the site. The instrument is an Aquadopp Open water 3D from Nortek. It was fitted with a standard sensor head with three beams. The Aquadopp measures the Doppler-shift occurring when transmitting and receiving sound along two or more narrow acoustic beams (the Doppler-shift is proportional to the velocity component along the beam). The battery capacity is maximum 18 months. The acoustic centre frequency of the unit is 2 MHz. The instrument contained sensors for: roll, pitch, heading, pressure and temperature in addition to the acoustic sensors. All measurements were logged to an internal memory. The unit was battery-powered during the deployment period (Ludvigsen, Jasinski and Søreide 2009:5). From 2005 until 2007 the acquisition of the current data was conducted by Fugro GEOS. From 2007 and until the end of the project, it was carried out by NTNU Vitenskapsmuseet.

In 2011 the instrument rig with the current meter was lost, and later retrieved by local fishermen. Evidently, a shackle fastening the mooring to the weight broke off due to corrosion. The rig was not replaced on site.

Figure 18 - Nortek Aquadopp fitted with Aquafin. On the left is a transponder fitted to the wire to monitor the position of the rigging during deployment and re-deployment of the instrument rig. Photo: NTNU Vitenskapsmuseet

The initial mooring was designed with a weight connected to a Sonardyne acoustic release (see Figure 19). The current sensor was attached to the acoustic release with a chain. A flotation unit kept the current meter in an up-right position (Ludvigsen, Jasinski and Søreide 2009:5). This setup was however changed during the course of the project. The acoustic release was removed after the Fugro period of involvement, as it would be recovered using a ROV, and the sensor was later also fitted with Aquafin, which allowed the Aquadopp to swivel freely so that its beams always looked into undisturbed flow. In all setups the current meter itself was positioned 3 meters above the seabed.

When deploying the instrument setup, much care was taken to assure that the rigging was put in a position on the seabed not directly in contact with the shipwreck itself. The ROV would always be positioned on the seabed to ensure a safe position.

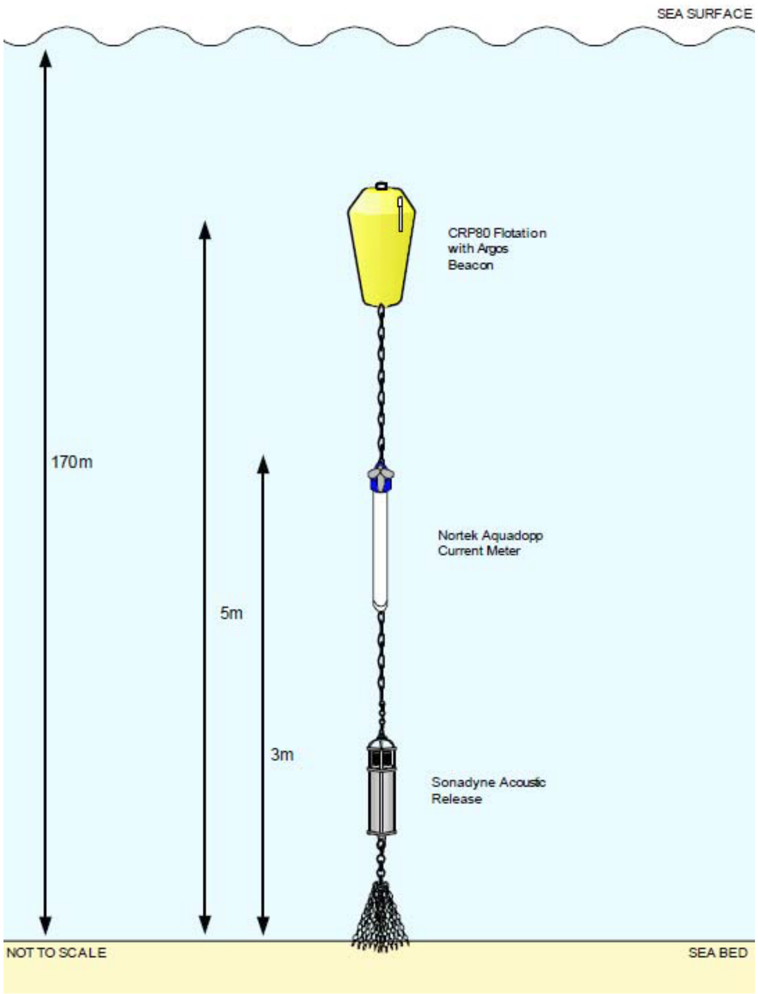

Figure 19 - The original mooring rigging of the current meter, as described by Fugro. Changes to the setup were however made during the project. Image: Ludvigsen *et.al.* 2009:5.

7.6. Video and still photography

In the 2007 contract between AS Norske Shell and NTNU Vitenskapsmuseet (page 16) it is stated that "*[…] one wishes to measure the difference between net and gross rate of sedimentation in the area, as an indicator to how extensive the actual erosion is. NTNU Vitenskapsmuseet is also of the opinion that visual observation of level of sedimentation on the sediment indicators on each survey in addition to the measured rate of sedimentation in between the surveys will provide a sound impression regarding the sedimentation situation* *on the site. This combined with measurements of currents and visual observations can address the development of the level of preservation on the site over time".* This clearly dictates the need for visual documentation of sediment indicators as well as general observations on the state of sedimentation on the site as a whole. This clearly correlates with the terms specified by the Directorate for Cultural Heritage in 2005 (Appendix 1:2); "*the developer shall include video recordings of the site, acquisition of data from current meter and visual control of sedimentation*".

Visual observations have been key in order to see the bigger picture apart from what is documented through sediment trap and current meter measurements. This was further emphasised in the 2007 contract with Shell in the description of the project's planned schedule, in the first point: "*1. At every survey ROV-based visual inspections are to be carried out*". This can be found implemented as one of the main goals for each survey in Chapter 8.

In order to document the visual observations, ROV-mounted cameras have been utilised. In some surveys one has used still cameras in addition to video cameras, but not regularly. The basic set-up has been with the use of digital video cameras, sending the live feed to the vessel to record and monitor. Single video cameras have been used, not recording in 3-view mode. When a still camera has not been mounted on the ROV, still photos of the site and sediment indicators have been grabbed from the digital video. In order to facilitate for comparative analysis of the video data from one year to the next, a specified track on the site has been followed.

7.7. Wood sampling

The main monitoring instruments applied in the project were the sediment trap and the current meter logged data in the water column. The only methodology aimed to some degree at the wreck itself, was the video documentation conducted during every cruise. The nature of the video documentation is that it had to be manually compared to the other video runs of previous surveys, and that the result was to be made by subjective interpretation and not scientifically comparable datasets. More important; the visual documentation only provided insight into the seabed surface, there was no penetration into the seabed. Nor did it provide any comparable datasets into the actual physical condition of what makes up the item of interest; namely the wood structures that constitute the wreck itself.

In light of this, a new methodological approach focusing on wood sampling was proposed by Elizabeth E. Peacock and Fredrik Skoglund for the 2011 survey after discussions within the project group, much based on their ideas from the Deepwater Preservation and Management of Archaeological Sites (DePMAS) project (Skoglund and Peacock 2012). The new methodological approach was initially thought to be a project within the project with Skoglund and Peacock in charge and it was entitled "*Monitoring the taphonomic degradation of marine archaeological wood in the deepwater Ormen Lange shipwreck*". Below is presented much of what was proposed in the project proposal (Peacock and Skoglund 2011). The wood sampling approach was approved by the Directorate for Cultural Heritage for the 2011 survey, but was initially only supposed to retrieve pieces of wood that were not in situ as part of the wreck, i.e. dismantled pieces on the seabed so as not to make unnecessary intrusions into the wreck.

7.7.1. Project Proposal

The environmental monitoring of submerged maritime vessels is a well-established and much practiced method of underwater cultural heritage management. Programmes normally consist of: 1) providing site protection; 2) continually gathering environmental information on current activity and physico-chemical parameters; and, 3) investigating the material condition of the wreck itself. The Ormen Lange monitoring project lacks this third component, i.e., investigating the material condition of the wreck itself. The proposed "*Monitoring the taphonomic degradation of marine archaeological wood in the deepwater Ormen Lange shipwreck*" project will directly complement the current monitoring project in linking the environmental information (i.e., current activity and sedimentation) already being gathered to the actual condition of the wreck and, hence, the success of the site protection.

Throughout history, wood has been the material most used for shipbuilding, and a large number of shipwrecks has been deposited in the marine environment worldwide. Once wrecked, they are exposed to mechanical and biological degradation. The state of preservation varies as the result of local conditions. Factors such as oxygen content, salinity, sediments and currents are key factors that control the rate of biological decay. The main wood-degraders in seawater are the marine borers, fungi and bacteria; microbial degradation is also present in timbers protected by sediment.

Because wood is so prominent in wrecks the world over, it is the material of choice for being able to draw comparisons over geographical regions, climates and depths. Extensive research and studies have been carried out to map the type and degree of degradation of marine archaeological wood. Not only is this of importance for taphonomic studies and underwater cultural heritage management programmes, but it informs about trade, raw material sourcing, provenance and seafaring.

The Ormen Lange wreck is wood-based (oak with pinewood repairs). The wood sampling project proposed to undertake a study of the condition of wood comprising its hull, and to follow up the study by monitoring, at regular intervals, the condition of the same timbers over time. Furthermore, analysis of (still wet) wood recovered during the site excavation of the wreck in 2005 has the potential to provide baseline information regarding the condition of the wreck's wood at the time of site disturbance.

7.7.2. Background

During the archaeological excavation of the Ormen Lange wreck site in 2004 and 2005, all sediment was removed from the surface of the wreck. Although, this exposed the wreck to enable further scientific investigation and documentation, it also disrupted the protective environment of the sediment and exposed the wreck to degrading elements such as scouring, marine scavengers, etc. Following the excavation, the wreck received a protective covering of seabed sediment. Sediment that had been removed from the wreck during the excavation was reused. The covering process consisted of blowing the sediment over the surface of the exposed wreck using the ROV. Although the returned sediment covered the surface completely, it was neither compressed nor affixed to the three-dimensional nature of the wreck surface topography in any manner, nor was the loose sediment covered with any protective material (e.g. geotextile sheets or polymeric matting).

In addition to the visual overall site mosaic mentioned above, the current Ormen Lange monitoring project gathers information on both current and sedimentation activity at one position each at the wreck site. Furthermore, the physico-chemical nature of the sediment is determined. This provides insight into the general environment and its flux at the site.

The current monitoring project does not address the actual state of preservation/degradation of the material components that make up the wreck. Monitoring the sediment and currents does not inform about the state of preservation/degradation of the wreck's materials (e.g. wood, ceramic and glass).

7.7.3. Experimental

Examination of wood decay will be coordinated and carried out by the DePMAS consortium employing an examination protocol that has been shown to make it possible to quantify decay over time. The samples will be visually examined and studied to localise any surface evidence and interior attack by marine biological communities. The micromorphology of the wood and evidence of microbial activity will be mapped.

Temperature, salinity and pH measurements as well as sediment samples taken at the site as part of the current Ormen Lange monitoring programme will complement the microbial information and aid evaluation and implications of the wood decay results.

Data obtained from the examination of wood samples will provide detailed information on the initial and further microbial decay of marine archaeological wood at the Ormen Lange site; and important insight into the type and degree of wood decay at this deepwater shipwreck site.

7.8. Multi Beam Echo Sounder (*By: Øyvind Ødegård*)

Multi Beam Echo Sounder (MBES) data were acquired during the 2009 survey. Visualising the data in a shaded relief the wreck stands out as an oblong feature on the seabed. Overlaying the MBES data with the wreck site drawing eases the interpretation. MBES acquisition was not part of the scope for the OLM project; therefore there are no other datasets for comparison.

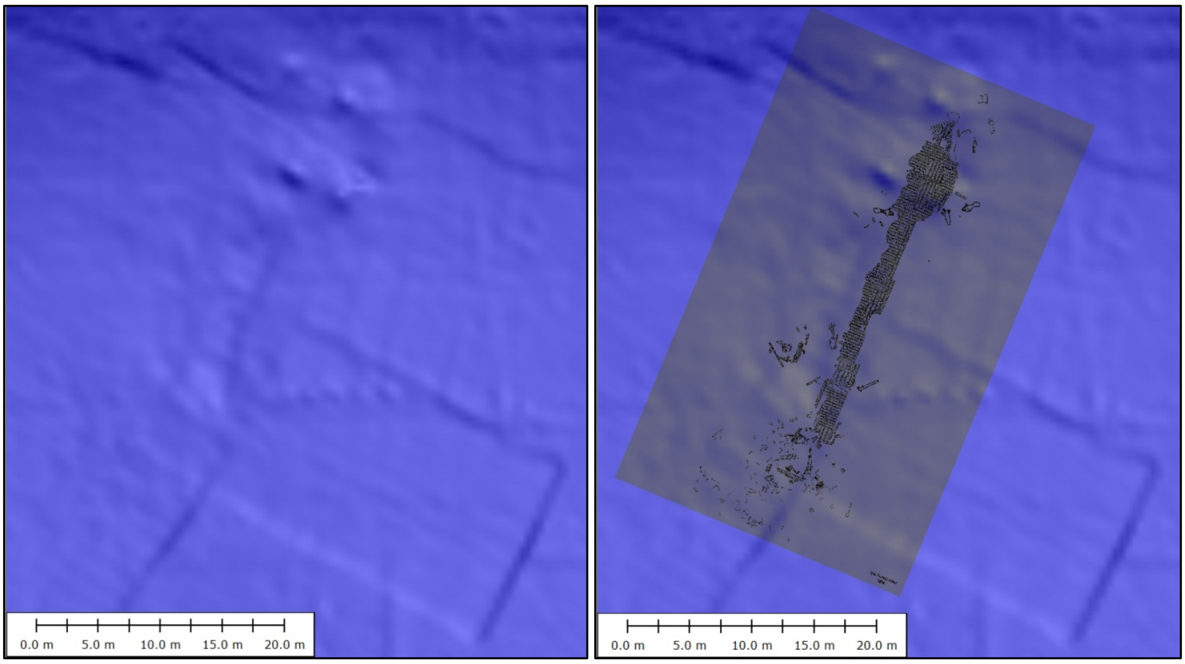

Figure 20 - Figures showing shaded relief visualization of MBES data with (left) and without wreck site drawing overlay (right). Illustration: NTNU Vitenskapsmuseet

7.9. Photomosaic (*By: Øyvind Ødegård*)

Photo mosaics of the site were made during the investigations in 2004 and 2005. Photo mosaics were not specified as part of the methodological work package in the 2007 contract with Shell. During the course of the monitoring project it became evident that new photo mosaics of the site would be beneficial to the understanding of development of the site. The Directorate for Cultural Heritage did not however accept this in 2011, but agreed that it was to be done during the last survey in 2012.

In 2004, 2005 and 2012 photo mosaics of the wreck were compiled from images gathered with the ROV. The method used was based on automated image acquisition with a camera pointing vertically down towards the seabed while the ROV followed a pre-planned pattern of lines ensuring full coverage with a certain overlap. Special software was used to post-process the images, and create mosaics based on feature recognition. In 2012 a DP system installed on the ROV was used for navigation. For some reason imagery was not acquired for parts of the wreck site during this survey, rendering an incomplete mosaic of the wreck site for 2012.

8. Annual surveys

8.1. 2005-2006 Fugro surveys

In 2006 NTNU began the series of fieldwork with data acquisition from the seabed. Prior to this Fugro carried out four deployments and recoveries of the current meter. Apart from the current meter, no other instruments were utilised on the seabed for data acquisition in the period before NTNU started conducting their own surveys. The Fugro involvement is further described in the 2009 summary of current measurements (Ludvigsen, Jasinski and Søreide 2009), but a brief overview of the actions undertaken is cited here.

"*The first deployment in this program was completed by Fugro on September 19th 2005 using the vessel MV Urter. The instrument was recovered. Before redeployment the instrument was serviced and all data was downloaded. The unit was positioned using an HPR system when it was lowered to the seabed and placed on the wreck site*" (Ludvigsen, Jasinski and Søreide 2009:4).

"*The second deployment was completed by Fugro on January 7th 2006 using the vessel MV Ocean Flower. The instrument was recovered on January 5th. Before the redeployment the instrument was serviced and all data was downloaded. The unit was positioned using an HPR system when it was lowered to the seabed and placed on the wreck site*" (Ludvigsen, Jasinski and Søreide 2009:4).

"*The third deployment was completed by Fugro on June 3rd 2006 using the vessel MV Elisabeth. The instrument was recovered June 2nd. Before redeployment the instrument was serviced and all data was downloaded. The unit was positioned using an HPR system when it was lowered to the seabed and placed on the wreck site*" (Ludvigsen, Jasinski and Søreide 2009:4).

"*The forth deployment was completed by Fugro on October 12th 2006 using the vessel MV Elisabeth. The instrumented was recovered 10th of October. Before redeployment the instrument was serviced and all data was downloaded. The unit was positioned using an HPR system when it was lowered to the seabed and placed on the wreck site*" (Ludvigsen, Jasinski and Søreide 2009:4).

Series	Date		Operator
1	19.09.2005	Deployment of ADCM	Fugro
	05.01.2006	Recovery of ADCM	Fugro
2	07.01.2006	Deployment of ADCM	Fugro
	02.06.2006	Recovery of ADCM	Fugro
3	03.06.2006	Deployment of ADCM	Fugro
	10.10.2006	Recovery of ADCM	Fugro
4	12.10.2006	Deployment of ADCM	Fugro
	17.10.2007	Recovery of ADCM	NTNU

Figure 21 – Dates of deployment and recovery of current meter during Fugro period.

8.2. 2006 - Survey

Time	Vessel	Sediment trap	Current meter	Other
04.10.2006	R/V Gunnerus	Installed	Handled by Fugro	

Figure 22 - Key information regarding the 2006-survey

Project participants	Status	Affiliation
Marek E. Jasinski	Project Director	NTNU
Fredrik Søreide	Principal Investigator	NTNU
Martin Ludvigsen		NTNU
Thor Olav Sperre	ROV supervisor	Sperre AS
Karl Ingar Asland	ROV operator	Sperre AS
Crew of R/V Gunnerus		NTNU

Figure 23 – Main project participants in 2006-survey

The first survey in the project was carried out in October 2006. Prior to this Fugro had completed several cruises acquiring current data, but this was the first cruise NTNU conducted and the first of what was defined as a monitoring project.

"*The marine archaeology project in October 2006 had the following goals:*
1. Survey the wreck-area with ROV to establish the current conditions of the site.
2. Inspect existing sediment indicators on the site
3. Install sediment trap on the site" (Jasinski and Søreide 2006:2)

"*The shipwreck was completely covered with sediments following the archaeological investigation in 2005. The shipwreck area was surveyed with the ROV to determine the current situation on the shipwreck site. This revealed that the sediment cover on the stern and mid sections is very acceptable, while the bow section is not sufficiently covered by sediments. Structural items in the bow section that were originally covered by sediments are now visible on the seafloor. It is recommended that the bow section should be covered with additional sediments during the next inspection scheduled for 2007*" (Jasinski and Søreide 2006:2).

8.3. 2007 - Survey

Time	Vessel	Sediment trap	Current meter	Other
16-19.10.2007	R/V Gunnerus	Retrieved and deployed	Retrieved and deployed	

Figure 24 - Key information regarding the 2007-survey

Project participants	Status	Affiliation
Marek E. Jasinski	Project Director	NTNU
Fredrik Søreide	Principal Investigator	NTNU
Thor Olav Sperre	ROV supervisor	Sperre AS
Svenn Ove Linde		NTNU
Fredrik Skoglund		NTNU
Crew of R/V Gunnerus		NTNU

Figure 25 - Main project participants in 2007-survey

"*The marine archaeology project in 2007 had the following goals:*
1. Survey the wreck-area with ROV to establish the current conditions of the site.
2. Recover and redeploy current meter on the site
3. Recover and redeploy sediment trap on the site" (Jasinski, Søreide and Ludvigsen 2007:5).

"*The shipwreck area was surveyed with ROV to determine the current situation on the shipwreck site. The shipwreck was completely covered with sediments following the archaeological investigation in 2004-2005. The 2006 inspection revealed that the sediment cover on the stern and mid sections was acceptable, while the bow section was not sufficiently covered by sediments. Large structural items in the bow section that were originally covered by sediments are now visible on the seafloor. In section "B Frame grab" snap shots from the video is printed. The sediment situation must be closely monitored and a decision made if the bow section is to be covered with additional sediments*" (Jasinski, Søreide and Ludvigsen 2007:5).

In the 2006-report, it was suggested "*that the bow section should be covered with additional sediments during the next inspection scheduled for 2007*" (Jasinski and Søreide 2006:2). After discussions regarding methodology and the purpose of the project, this idea was however withdrawn. Neither in 2007 nor later in the project, were parts of the wreck covered with sediments.

Both the sediment trap and the current meter were successfully recovered, the data unloaded, and redeployed on the seabed.

8.4. 2008 - Survey

Time	Vessel	Sediment trap	Current meter	Other
01-03.09.2008	R/V Gunnerus	Recovered and deployed	Recovered NOT deployed	Current meter malfunction. Sediment trap lost during deployment

Figure 26 - Key information regarding the 2008-survey

Project participants	Status	Affiliation
Marek E. Jasinski	Project Director	NTNU
Fredrik Søreide	Principal Investigator	NTNU
Martin Ludvigsen		NTNU
Svenn Ove Linde		NTNU
Fredrik Skoglund		NTNU
Thor Olav Sperre	ROV supervisor	Sperre AS
Jesper Nordgård	ROV operator	Sperre AS
Crew of R/V Gunnerus		NTNU

Figure 27 - Main project participants in 2008-survey

"*The marine archaeology project in 2008 had the following goals:*
Survey the wreck-area with ROV to establish the prevailing conditions of the site.
1. Recover and redeploy current meter on the site
2. Deploy current meter on the site
3. Recover and redeploy sediment trap on the site
4. Deploy sediment trap on the site" (Jasinski, Ludvigsen and Søreide 2008:1).

"*The shipwreck area was surveyed with ROV to determine the prevailing situation on the shipwreck site. The shipwreck was completely covered with sediments following the archaeological investigation in 2004-2005. The investigation revealed that structural items in the bow section are still uncovered. This may result in a deterioration of the wreck site.* ***This situation must be closely monitored and a decision made if the bow section is to be covered with additional sediments"***(Jasinski, Ludvigsen and Søreide 2008:1).

The sediment trap was recovered, the sediment samples collected, and data retrieved, but as the instrument was being lifted over the side for redeployment, a shackle broke and the unit sank to the seafloor. It was not until the following year that it was ascertained that it had actually landed on the seabed properly and had, indeed, gathered sediment samples the whole year.

The current meter was recovered, but when trying to unload the data, the data were not recoverable. The instrument was returned to the manufacturer, who actually managed to download it. As there was no spare current meter on board, a new replacement could not be deployed on the site during the time frame of the operations. Thus no current meter data was collected between 2008 and 2009.

 

Figure 28 – Broken shackle from sediment trap rig, 2008. Photo: NTNU Vitenskapsmuseet

8.5. 2009 – Survey

Time	Vessel	Sediment trap	Current meter	Other
08-09.12.2009	MS Normand Subsea	Recovered and deployed	Deployed	MBE survey

Figure 29 – Key information regarding the 2009-survey

Project participants	Status	Affiliation
Marek E. Jasinski	Project Director	NTNU
Fredrik Søreide	Principal Investigator	NTNU
Martin Ludvigsen		NTNU
Crew of Normand Subsea		Subsea 7

Figure 30 - Main project participants in 2009-survey

"*The marine archaeology project in 2009 had the following goals:*
1. Recover sediment trap lost on site in 2008
2. Install new sediment trap
3. Install new current meter
4. Survey the wreck-area with ROV to establish the current conditions of the site.

The project was carried out in cooperation with Shell from the Subsea 7 operated vessel Normand Subsea and using the on-board ROV equipment" (Jasinski, Ludvigsen and Søreide 2009:1).

"*The shipwreck area was surveyed with ROV to determine the current situation on the shipwreck site. This investigation showed that the sediment situation on the shipwreck* *appears to be stable relative to the previous investigations in 2006 – 2008. Visual data must also be compared later with data from the current meter and the sediment trap. Visual inspection indicates that there is a shallow sediment layer covering the complete wreck-site, with better cover in the south (stern) section and less sediment cover in the north (bow) section*" (Jasinski, Ludvigsen and Søreide 2009:1).

The sediment trap was lost in 2008 when a shackle broke during redeployment. The unit was however fully rigged when this accident occurred, and the unit sank to the seabed where it was recovered in 2009. The sediment trap had completed its data acquisition so the data could be successfully collected in 2009. Due to the uncertainty of the state of the sediment trap when it was lost in 2008, a new one was purchased, and this was deployed when the old one was recovered in 2009.

The current meter recovered during the 2008 survey proved to be malfunctioning. It was not redeployed in 2008,with no collected between 2008 and 2009. A new current meter was purchased for the 2009 survey and this was successfully deployed.

A seabed visual/ MBES survey was conducted over the wreck site, as the on-board ROV was equipped with these instruments. The grid was 50m in length by 18m wide and was made of ten parallel lines, spaced 2m apart. Each of the 10 grid lines was surveyed. The seabed was flat and consisted of fine silt/mud sediment with isolated areas of seaweed present. Clumps of seaweed growing on the seabed obscured some of the surface detail. An additional close-up seabed survey was conducted in the bow section of the wreck (Jasinski, Ludvigsen and Søreide 2009:18).

8.6. 2011 - Survey

Time	Vessel	Sediment trap	Current meter	Other
13-16.09.2011	R/V Gunnerus	Recovered and deployed	Old lost, new not deployed	

Figure 31 - Key information regarding the 2011-survey

Project participants	Status	Affiliation
Marek E. Jasinski	Project Director	NTNU
Martin Ludvigsen		NTNU
Robert Staven		NTNU
Øyvind Ødegård		NTNU
Fredrik Skoglund	Wood sampling	NTNU
Crew of R/V Gunnerus		NTNU

Figure 32 - Main project participants in 2011-survey

The following activities were planned in 2011 (Ludvigsen 2011:5):

- Video survey of site
- Recovery of rig with sediment trap
- Recovery of rig with current meter
- Launch of new rig with sediment trap

- Launch of new rig with current meter
- Wood sampling in the area surrounding shipwreck

The site was successfully surveyed visually with ROV-mounted video systems. The sediment trap rig was successfully recovered and deployed.

The current meter was lost. Evidently, the shackle connecting the rig to the weight had broken due to corrosion. The current meter was later found by local fishermen who handed it over to NTNU and the data was downloaded. The mooring was recovered during the 2012-2 survey (see Figure 64). The plan was to replace the current meter on site with a new one to e.g. save time in downloading data. As the new current meter was rigged the same way as the previous, and it was unclear what the fault with the rigging was, the new current meter was not deployed.

There was initially planned a photomosaic of the wreck site, but this was not approved by the Directorate for Cultural Heritage. They did however partially accept the proposed plan for the extraction of wood samples for further analysis of state of preservation. Four pieces of wood were identified as possible targets during the video survey. After recovering the first successfully, the ROV's manipulator locked and the ROV had to surface, preventing more time to collect further samples of wood.

Figure 33 – The sediment trap on deck after recovery in 2011. Photo: NTNU Vitenskapsmuseet

8.7. 2012 - Survey February

Time	Vessel	Sediment trap	Current meter	Other
13-16.02.2012	R/V Gunnerus			

Figure 34 - Key information regarding the 2012 spring survey

Project participants	Status	Affiliation
Marek E. Jasinski	Project Director	NTNU
Robert Staven		NTNU
Martin Ludvigsen		NTNU
Crew of R/V Gunnerus		NTNU

Figure 35 - Main project participants in 2012 spring - survey

The following activities were planned in February 2012 (Marek Jasinski pers.comm):

- Recovery of sediment trap
- Launch of new rig with sediment trap
- Launch of new rig with current meter
- Video survey of site

Unfortunately, bad weather disrupted most of the planned tasks. A ROV video survey was the main outcome.

8.8. 2012 – Survey October/ November

Time	Vessel	Sediment-trap	Current meter	Other
29.10– 01.11.2012	R/V Gunnerus	Recovered, not deployed	Old lost, new not deployed	Last survey

Figure 36 - Key information regarding the 2012 autumn - survey

Project participants	Status	Affiliation
Fredrik Skoglund	Project Director	NTNU
Øyvind Ødegård		NTNU
Robert Staven	ROV Supervisor	NTNU
Mauro Candeloro		NTNU
Ulrik Jørgensen		NTNU
Fredrik Dukan		NTNU
Christian Malmquist		Novatek
Crew of R/V Gunnerus		NTNU

Figure 37 - Main project participants in 2012 autumn - survey

The following activities were planned in October/ November 2012:

- Recovery of rig with sediment trap
- Recovery of mooring from lost current meter
- Photo-mosaic and MBE of site of shipwreck
- Video survey of site of shipwreck

The rig with the sediment trap was successfully recovered and the data collected and sediment samples safely retrieved. As this was the last cruise in this project, the sediment trap was not redeployed on site. A video survey was conducted as planned and the sediment indicators were visually checked. The sediment indicators were left in situ for future reference.

The current meter was lost in 2011 but, later retrieved; it was not replaced on site. The mooring from this rig was recovered during this year's operations in order not to contaminate the site.

An integrated survey of the site was carried out, combining photomosaic, MBE and video documentation. The survey was done using DP on the ROV which was run in an automated lawn-mover pattern. Due to problems with pitch and roll, we did not get good MBE data. Halfway through the survey software problems we encountered with the ROV DP, which took time to resolve. This unfortunately led to the result that the photomosaic was not completed.

It must be noted that this survey was combined with a survey of the inshore pipelines near Nyhamna on behalf of Shell, so there were people on board to serve multiple tasks.

9. Results

9.1. Sediment trap

9.1.1. Overview

	2006	2007	2008	2009	2011	2012-I	2012-II
Retrieved	No	Yes	Yes	Yes	Yes	No	Yes
Date retrieved	-	19.10.2007	3.9.2008	09.12.2009	13.9.2011	-	30.10.2012
Deployed	Yes	Yes	Yes	Yes	Yes	-	No
Date deployed	4.10.2006	19.10.2007	3.9.2008	09.12.2009	13.9.2011		-
Deployed: N		6980667.0	6980659.8	6980664.3			-
: E		687480.0	697495.1	697452.2			-

Figure 38 - Table showing coordinates for the position of the sediment trap, as well as dates for retrieval and deployment. Datum: ED50-UTM31

9.1.2. Year by year

Figure 39 - The sediment trap before the first installation on the site in 2006. Photo: NTNU Vitenskapsmuseet

2006: "*A McLane sediment trap was installed on the site to measure actual sedimentation rates. This system will make monthly measurements and will be recovered in the autumn of 2007*" (Jasinski and Søreide 2006:6).

2007: "*A McLane sediment trap was installed on the site to measure actual sedimentation rates in 2006. The trap is shown in Figure 3.1. [i.e. in the 2007 survey report]. This system measures the sedimentation on a monthly basis. The trap was recovered during the fieldwork and the data collected. The trap was reinstalled and will be recovered again in 2007. The results are presented in section "C Sediment report" in the appendix of this report*" (Jasinski, Søreide and Ludvigsen 2007:5). The results of the NGU analysis is presented in Appendix – 4 to this report.

Figure 41 - Sediment trap as installed in 2006. Photo: NTNU Vitenskapsmuseet

2008: "*The McLane sediment trap was successfully recovered and data collected. During the redeployment a shackle broke and the unit sank to the seafloor. It was not possible to determine the extent of the damage. The unit must be recovered later and redeployed*" (Jasinski, Ludvigsen and Søreide 2008:2). The results of the NGU analysis from the collected sediments were published in the 2008 survey report, and are also presented in Appendix – 4 to this report.

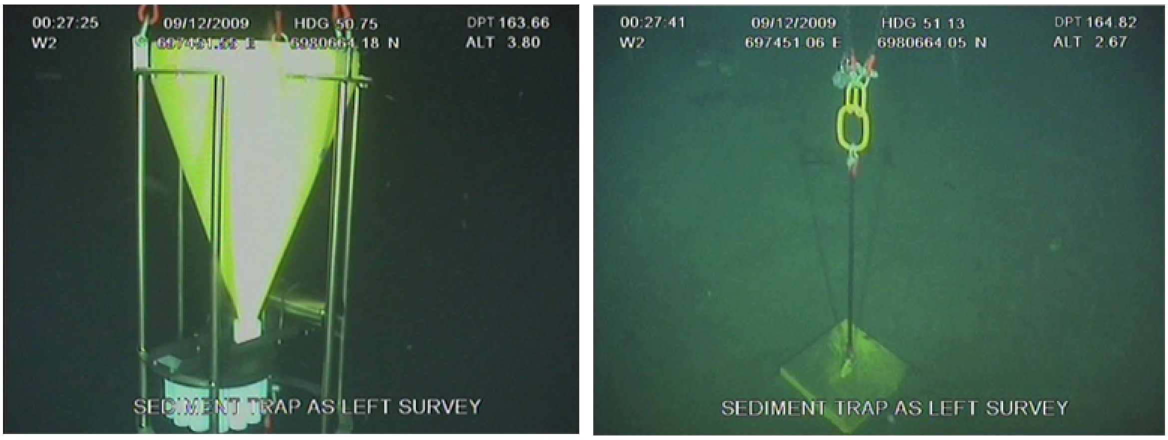

Figure 40 - Sediment trap as left in 2009; instrument on the left picture and mooring on the right. Photo: NTNU Vitenskapsmuseet

Figure 42 – Sediment trap's honeycomb baffle in 2012 after one year on the seabed. Photo: NTNU Vitenskapsmuseet

2009: "*The McLane sediment trap was successfully recovered and data collected. The data has been analysed by NGU* […]. *A new McLane sediment trap was successfully installed on site" (Jasinski, Ludvigsen and Søreide 2009:1). This year's survey was conducted using Subsea7's vessel "Normand Commander*". The results of the NGU analysis of the collected sediments were published in the 2009 survey report, and are also presented in Appendix – 4 to this report

In 2011 the sediment trap was successfully recovered, the data downloaded and the rig was redeployed with new set of sampling bottles. As there was no survey in 2010, the rig had been situated on the seabed since December 2009 when it was recovered in September 2011. Obviously it had not been collecting sediments the whole period, but the rig itself was luckily intact.

In October 2012 the McLane sediment trap was successfully recovered and data collected. As this was the last cruise the sediment trap was not redeployed. The data was analysed by NGU to the same standards as previous analyses.

Figure 43 - Collecting the sediment samples in 2012. Photo: NTNU Vitenskapsmuseet

9.1.3. Results and overall impression

For our studies we have the analyses of the collected sediments from the 2007, 2008, 2009 and 2012 surveys (Appendix 4). The data from these analyses are graphically juxtaposed in various diagrams below, in Figures 45 – 59 in order to make the data more accessible than that which is the case from the raw-data presentations made by NGU.

It must be noted that the wreck was uncovered and its state of equilibrium disturbed during the excavations in 2004 and 2005, the wreck was covered afterwards by only fanning the loose sediments back over the hull structures. There was no attempt to fix the loose sediments in order to maintain their presence on the site. Naturally, it would take some years after it was covered in 2005 for the sediments to reach a new level of equilibrium and, until then, the fine sand sediments would have been shifting on the seabed, and some would have been transported in the water column to be collected by the sediment trap.

With regard to the rock dumping carried out on July 17th 2007 (see Chapter 3.3), this corresponds to sample 10 from the sediment trap in 2007 (see Figure 46). There is no noticeable effect in the measurements in that period. Although there is a slight increase in the following samples, it is uncertain whether this can be directly connected with this particular action. Looking at the annual overview (see Figure 59), one sees that there is generally more sedimentation in August-October, and the sampling from 2007 corresponds with this.

Sieve diameter (µm)	Description
4.000	Gravel
2.000	
1.000	Coarse sand
500	
355	Medium sand
250	
180	Fine sand
125	
90	Very fine sand
63	
< 63	Silt
< 2	Clay

Figure 44 – Grain size distribution specified In sieve diameters. Source: NGU

We see that there are great variations in the data, both with regards to the amount of sediments collected within each year cycle as well as between the registered years. There are also variations in grain size distribution. There is clearly most sediment in the water column in the period 2006-2007, as can be seen in Figure 49 and Figure 50, which is directly after the wreck was covered with sediments after the excavations. Then the rate of sedimentation seems to decline in 2007-2008 and 2008-2009. If we study the general overview presented in Figure 59, there are still sediments collected in the sediment trap in 2012, and with regards to weight (Figure 49 and Figure 50) it is more than in 2008 and 2009. However, looking at the graphs in Figure 59, we see that the graph for 2012 is much more even than the previous years; there are not sudden peaks or changes in the August-October period as was previously the case. This is indicates that the sediments on the site have stabilized to a much larger degree over the years. That there still is significant amounts of sediment in the water column, does not necessarily imply that it is all local, as is further supported by the visual observations from the site that appear to be more or less consistent and less prone to scouring after 2009. There are however no similar measurements carried out at adjacent or nearby sites that could be used for comparative analysis to see whether our results are purely local or fit with the trend in a wider geographical area. We only have the results from this single context, and are thus forced to interpret rather than conclude on the results of the data collected.

2007		
Sample	Weight (g)	Period of sampling
1	42,71	04.10.2006 – 03.11.2006
2	47,52	03.11.2006 – 03.12.2006
3	32,24	03.12.2006 – 02.01.2007
4	31,83	02.01.2007 – 01.02.2007
5	73,25	01.02.2007 – 03.03.3007
6	28,33	03.03.3007 – 02.04.2007
7	33,71	02.04.2007 – 02.05.2007
8	30,32	02.05.2007 – 01.06.2007
9	54,22	01.06.2007 – 01.07.2007
10	42,92	01.07.2007 – 31.07.2007
11	62,54	31.07.2007 – 30.08.2007
12	79,92	30.08.2007 – 29.09.2007
13	16,46	29.09.2007 - 19.10.2007

Figure 45 – Period of sediment sampling 2006-2007. 30 day cycles starting October 4th 2006 and ending October 19th 2007.

2008		
Sample	Weight (g)	Period of sampling
1	45,96	19.10.2007 – 18.11.2007
2	3,20	18.11.2007 – 18.12.2007
3	5,85	18.12.2007 - 17.01.2008
4	53,22	17.01.2008 – 16.02.2008
5	3,47	16.02.2008 – 17.03.2008
6	3,32	17.03.2008 – 16.04.2008
7	3,35	16.04.2008 – 16.05.2008
8	5,30	16.05.2008 – 15.06.2008
9	9,04	15.06.2008 - 15.07.2008
10	15,73	15.07.2008 – 14.08.2008
11	75,62	14.08.2008 – 03.09.2008
12	0,06	

Figure 46 – Period of sediment sampling 2007-2008. 30 day cycles starting 19th of October 20007 and ending September 3rd 2008.

2009		
Sample	**Weight (g)**	**Period of sampling**
1	28,08	05.09.2008 - 05.10.2008
2	9,22	05.10.2008 - 04.11.2008
3	1,44	04.11.2008 - 04.12.2008
4	0,44	04.12.2008 - 03.01.2009
5	1,21	03.01.2009 - 02.02.2009
6	3,17	02.02.2009 - 04.03.2009
7	4,88	04.03.2009 - 03.04.2009
8	9,04	03.04.2009 - 03.05.2009
9	20,05	03.05.2009 - 02.06.2009
10	10,21	02.06.2009 - 02.07.2009
11	10,52	02.07.2009 - 01.08.2009
12	81,82	01.08.2009 -31.08.2009
13	4,99	31.08.2009 - 30.09.2009

Figure 47 – Period of sediment sampling 2008-2009. 30 day cycles starting September 5th 2008 and ending September 30th 2009.

2012		
Sample	**Weight (g)**	**Period of sampling**
1	37,46	14.09.2011 - 13.10.2011
2	14,36	14.10.2011 – 12.11.2011
3	26,13	13.11.2011 – 12.12.2011
4	24,33	13.12.2011 – 11.01.2012
5	36,93	12.01.2012 – 10.02.2012
6	19,89	11.02.2012 – 11.03.2012
7	8,23	12.03.2012 – 10.04.2012
8	14,89	11.04.2012 – 10.05.2012
9	13,99	11.05.2012 – 09.06.2012
10	12,75	10.06.2012 – 09.07.2012
11	21,08	10.07.2012 – 08.082012
12	34,47	09.08.2012 – 07.09.2012
13	52,92	08.09.2012 – 07.10.2012

Figure 48 – Period of sediment sampling 2011-2012. 30 day cycles starting September 14th 2011 and ending October 7th 2012.

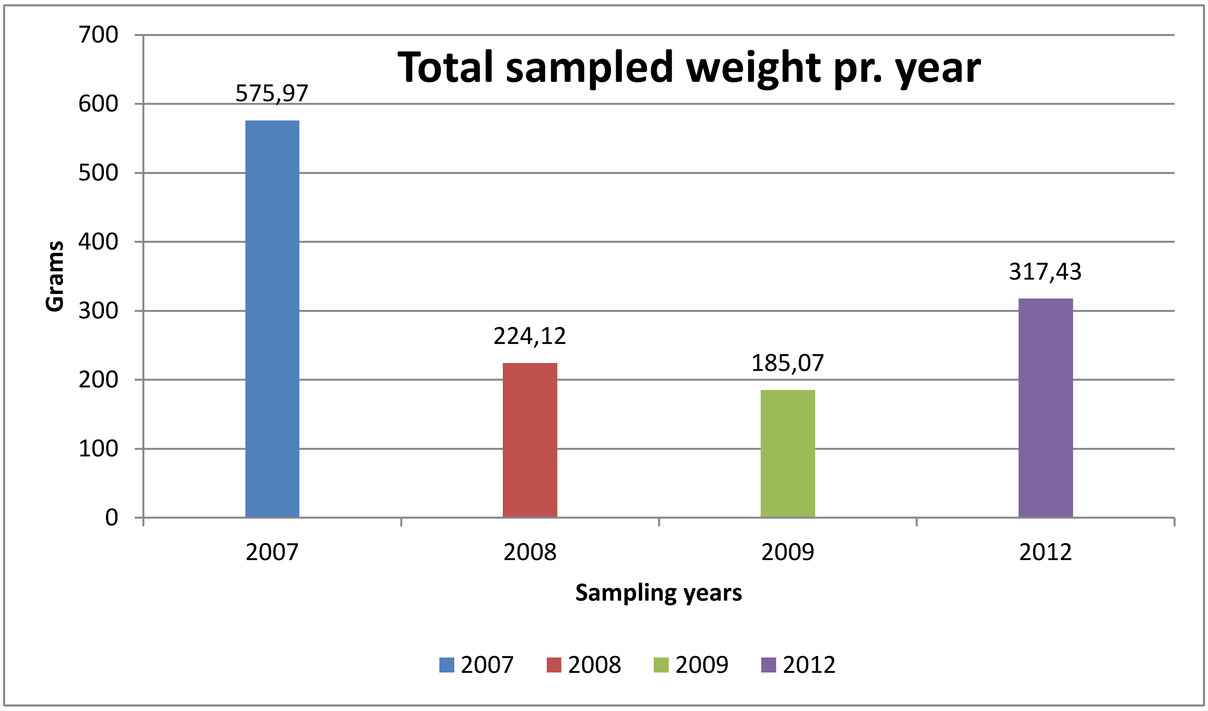

Figure 49 – Diagram showing the total sampled weight (grams) from each of the four sampling years dealt with in this report.

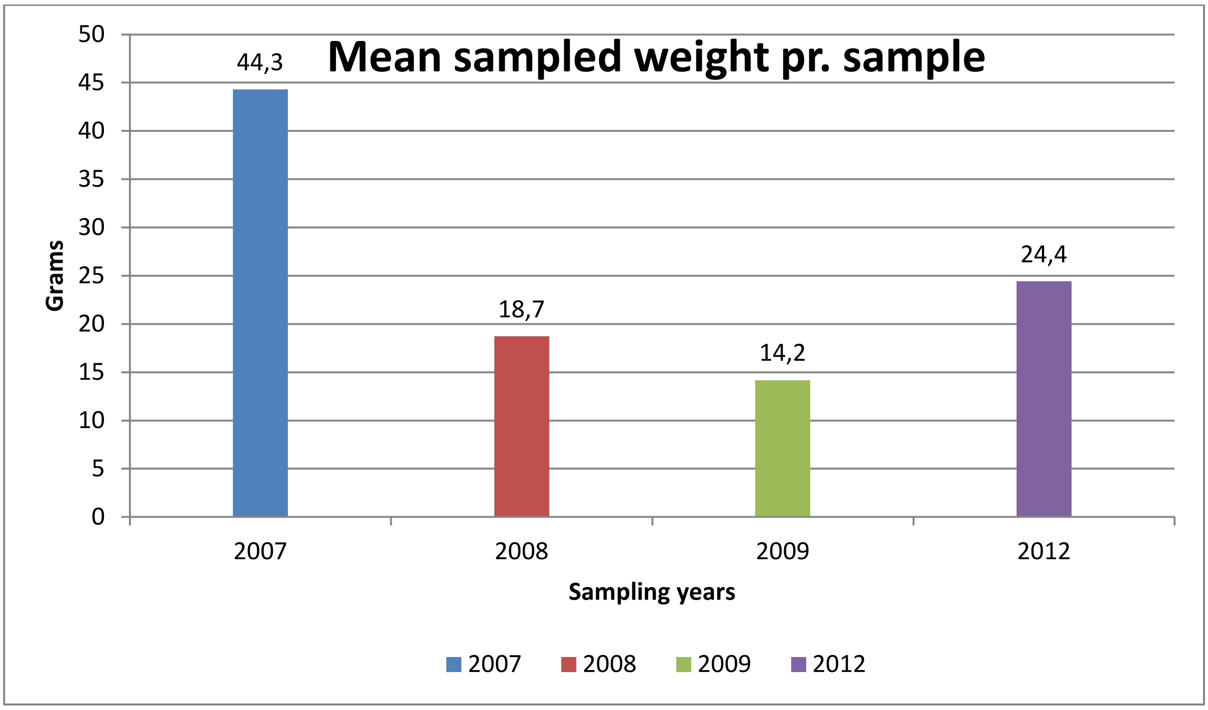

Figure 50 - Diagram showing the mean sampled weight (grams) from each of the four sampling years dealt with in this report.

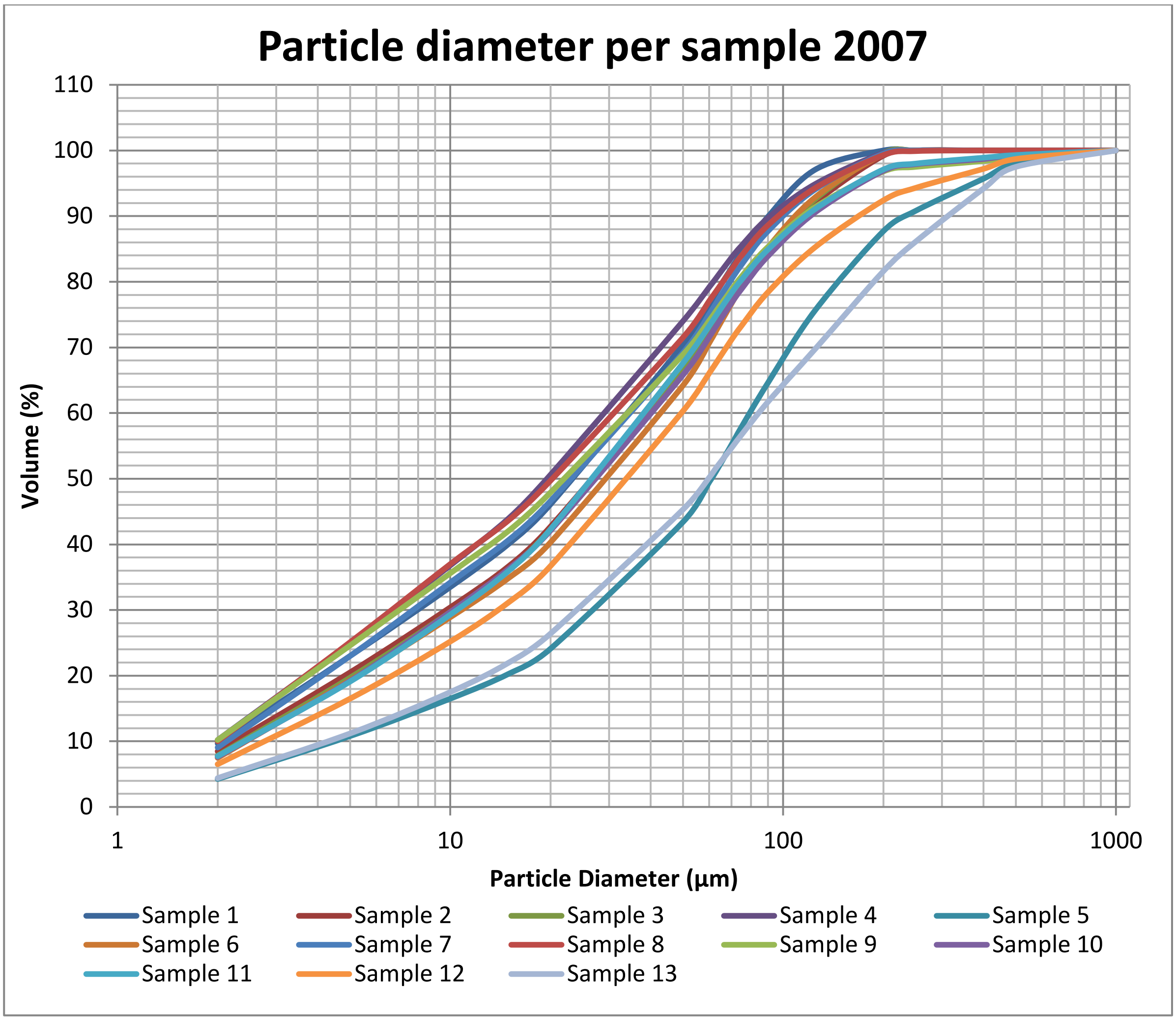

Figure 51 – Particle diameter per sample from the 2007 sampling period, as described in Figure 45. In total 13 samples analysed.

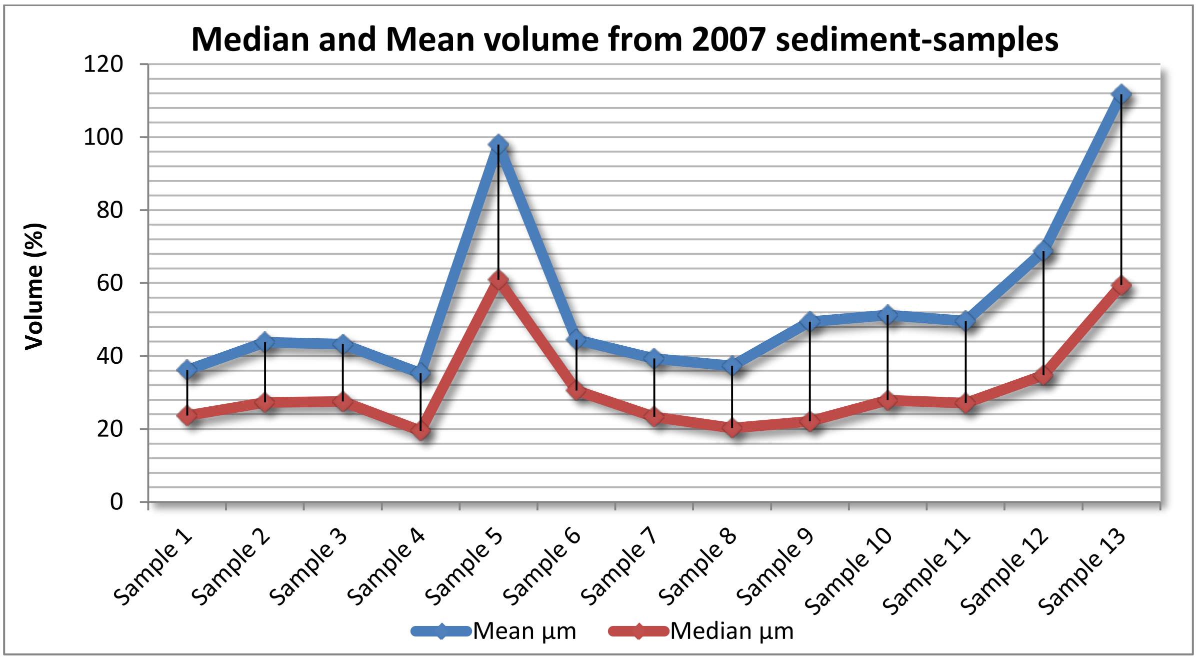

Figure 52 - Diagram displaying the median and mean volumes from the 2007 sampling period, data collected from NGU report-Appendix 4

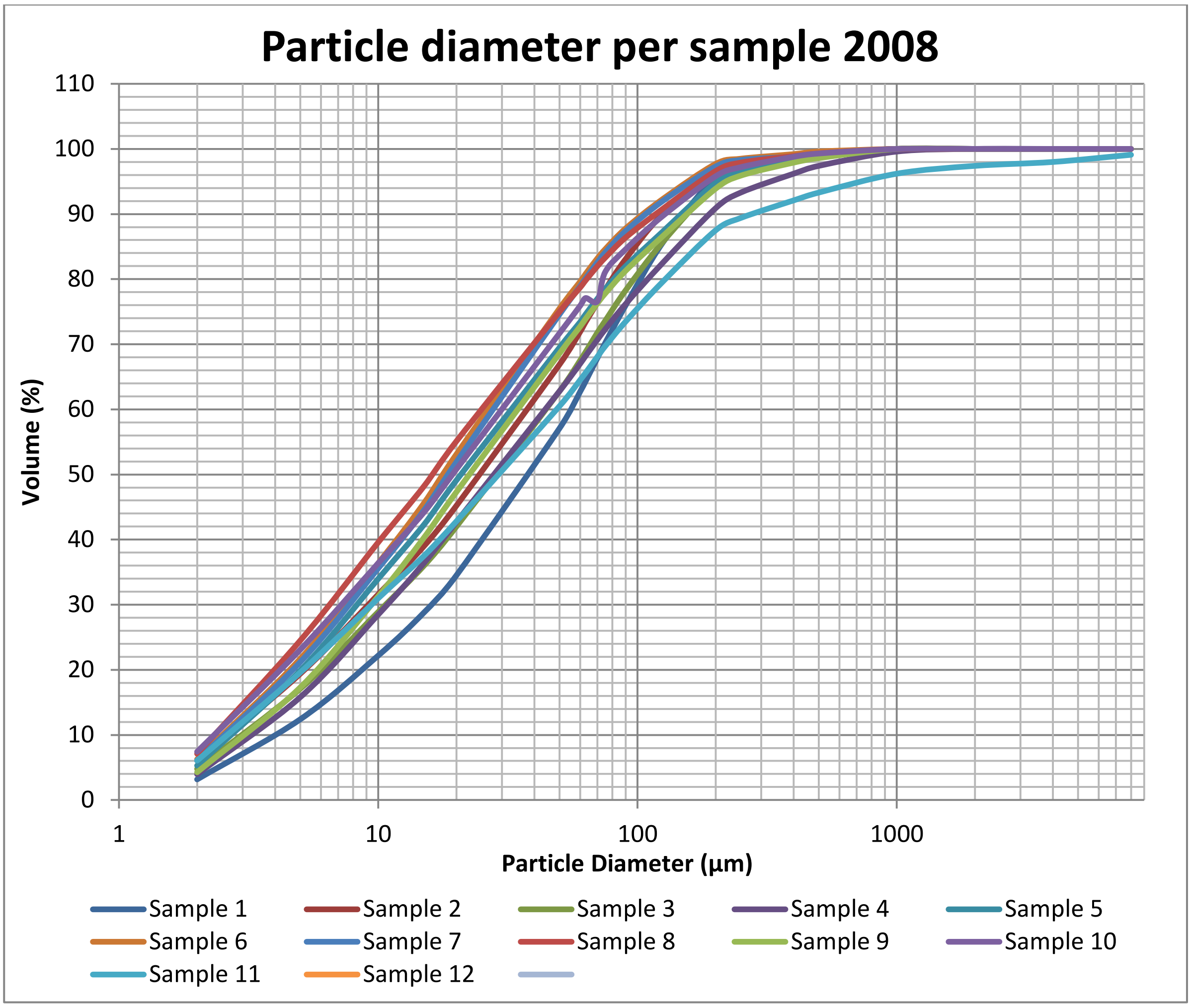

Figure 53 – Particle diameter per sample from the 2008 sampling period, as described in Figure 46. In total 12 samples collected, although sample 12 did not contain enough material to be analysed.

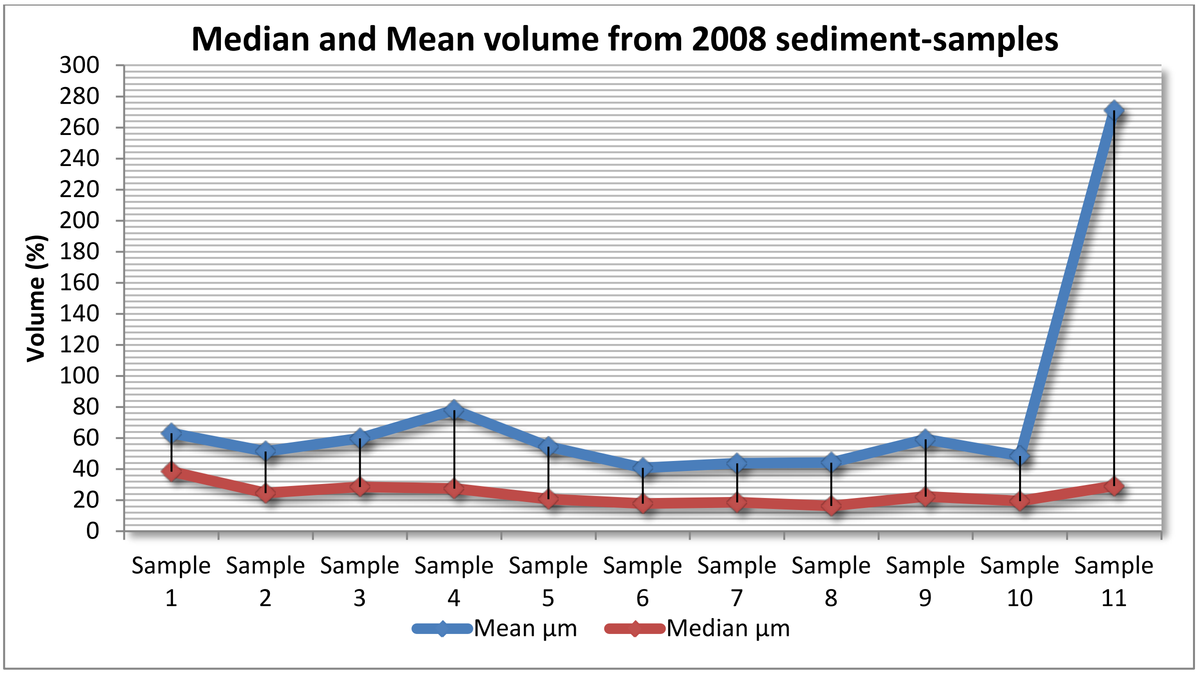

Figure 54 – Diagram displaying the median and mean volumes from the 2008 sampling period, data collected from NGU report-Appendix 4

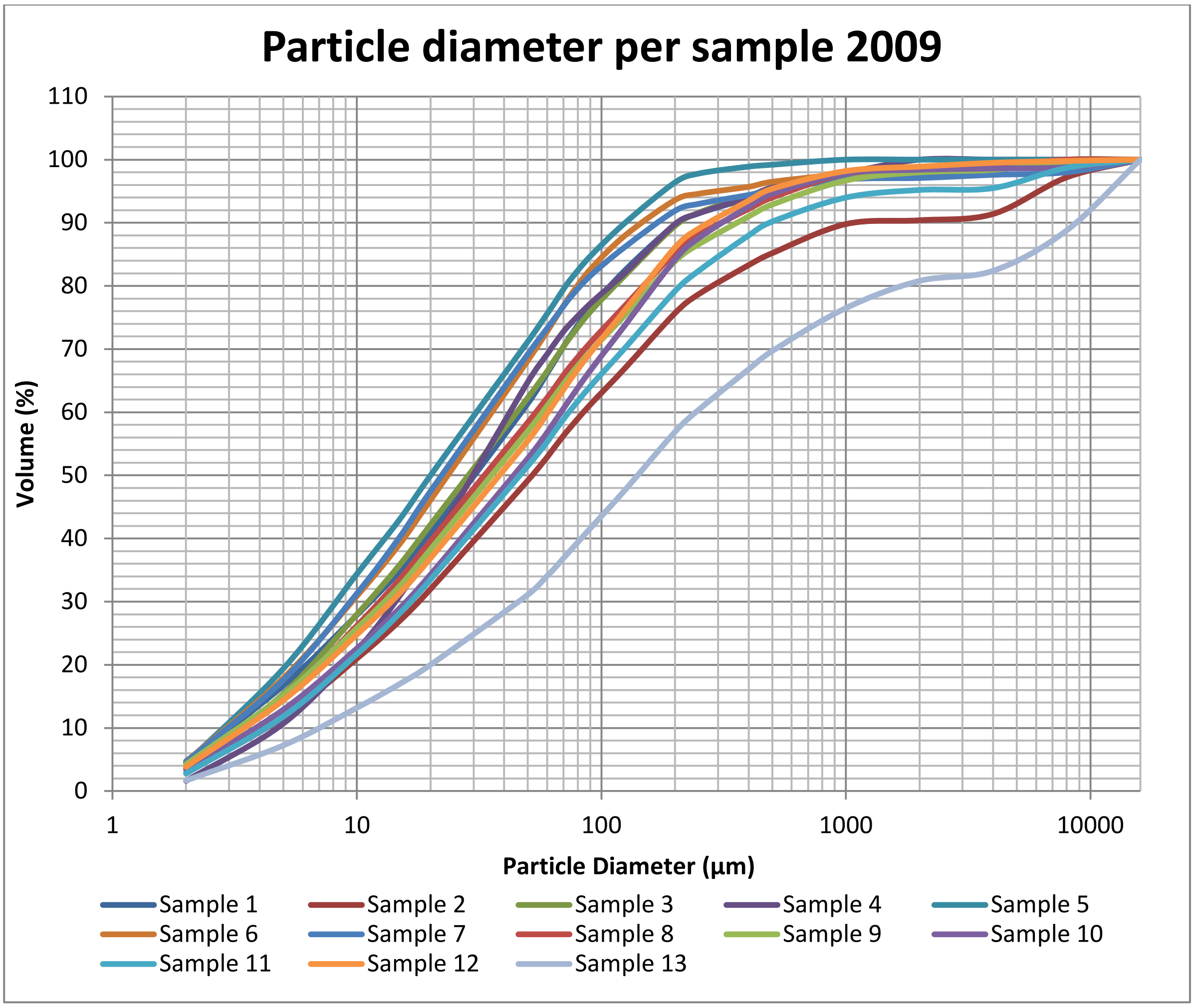

Figure 55 – Particle diameter per sample from the 2009 sampling period, as described in Figure 47. In total 13 samples analysed.

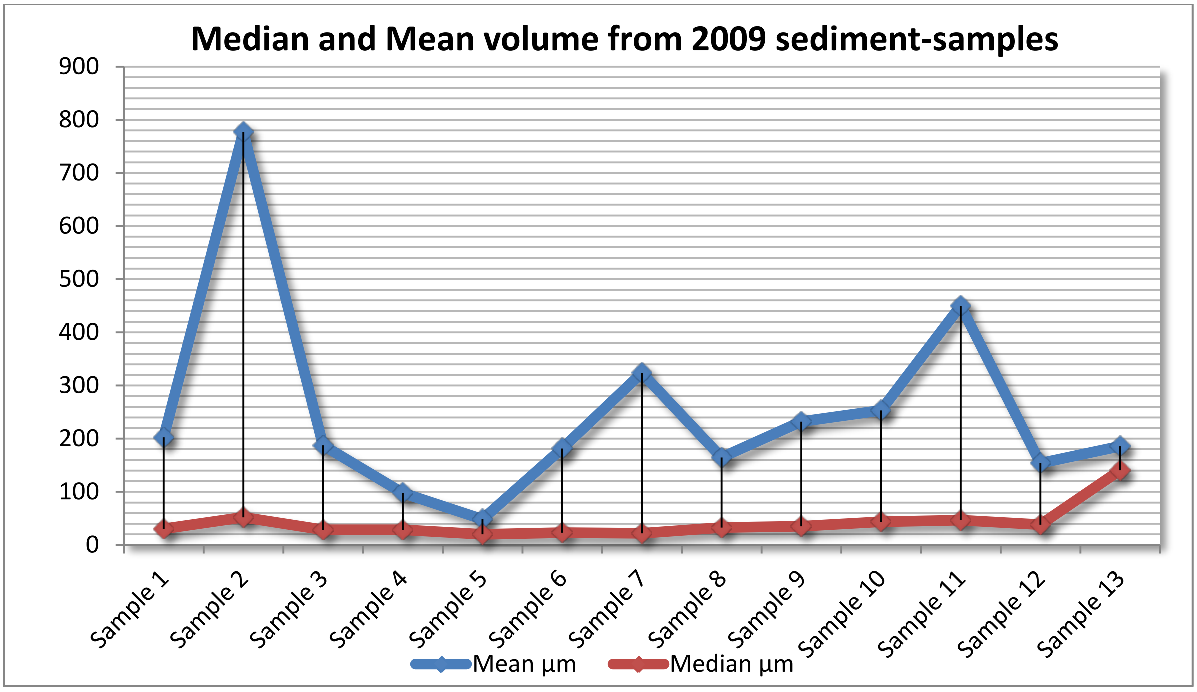

Figure 56 - Diagram displaying the median and mean volumes from the 2009 sampling period, data collected from NGU report-Appendix 4

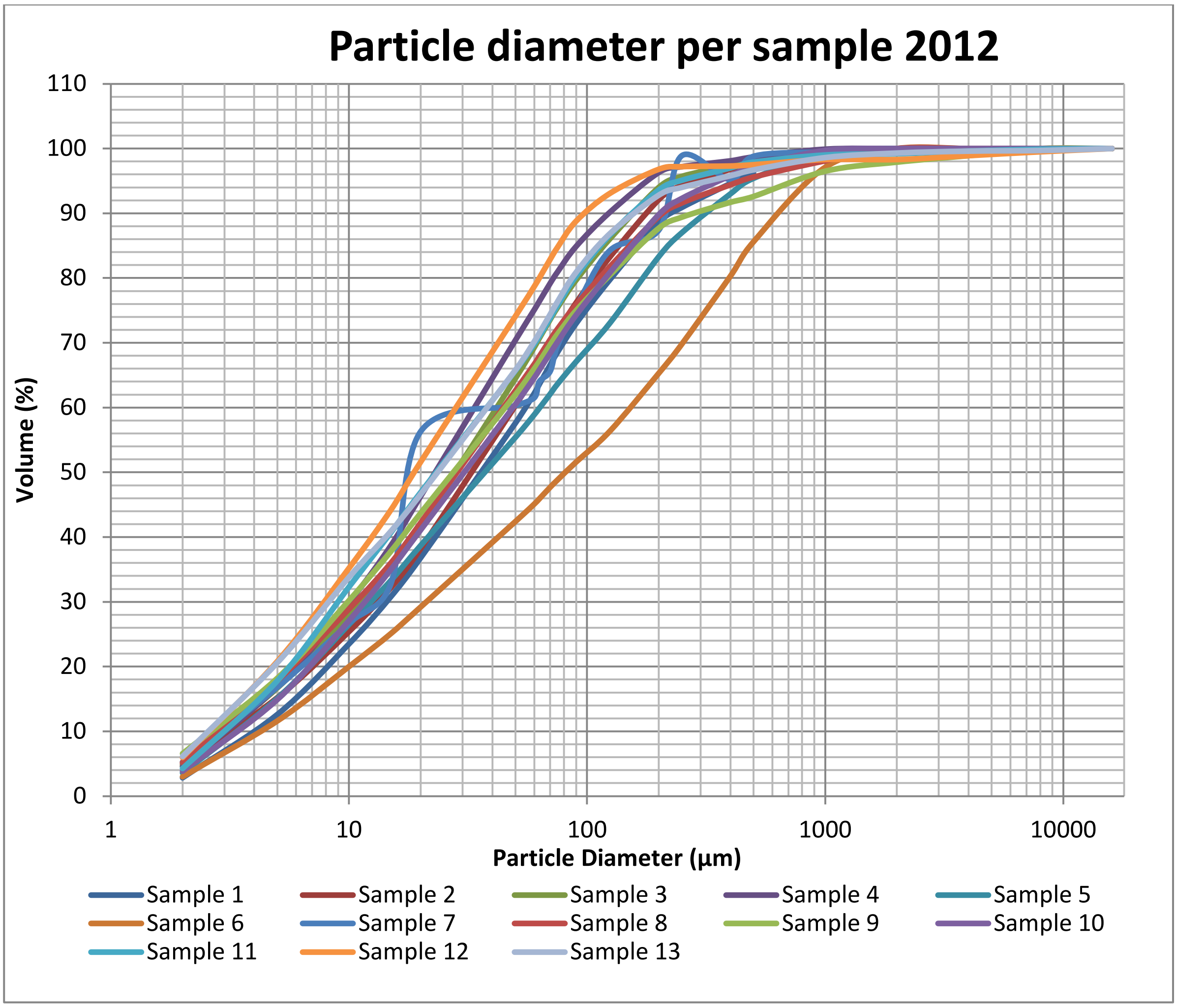

Figure 57 – Particle diameter per sample from the 2012 sampling period, as described in Figure 48. In total 13 samples analysed.

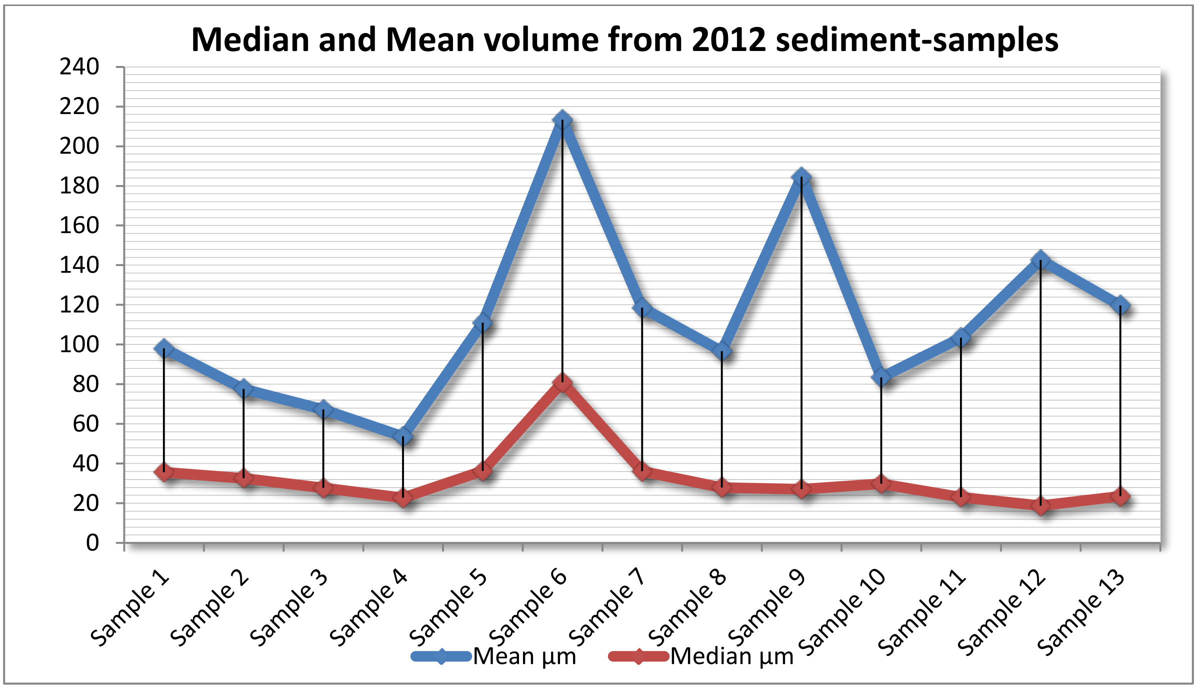

Figure 58 - Diagram displaying the median and mean volumes from the 2012 sampling period, data collected from NGU report-Appendix 4

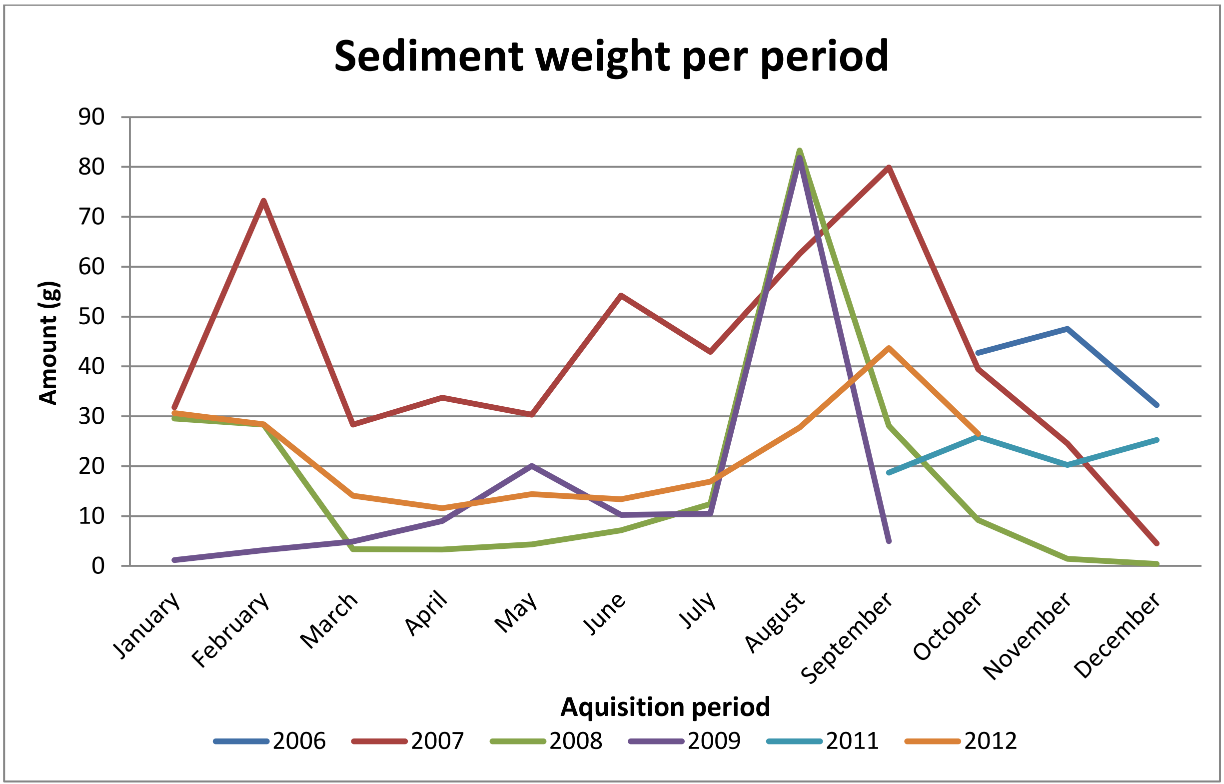

Figure 59 – Diagram showing the amount of sediment collected in the sediment trap for each period, based on the numbers in Figures 45- 48. A calculation has been made to extract the mean value from those months that are divided by two samples.

9.2. Sediment indicators

9.2.1. Overview

	Bow-section (#3)	Mid-section (# 13)	Stern-section (# 1)
N	6980676.7	6980657.2	6980641.2
E	697477.0	697462.0	697457.4

Figure 60 - Table showing coordinates for positioning of the three sediment indicators on the site. Datum: ED50-UTM31.

Prior to the 2006 survey, three sediment indicators were positioned on the wreck site by Hydro. One was placed near the bow of the wreck, in the northern part of the site and was labelled #3. The second was positioned near the mid-section part of the wreck and labelled #13. The third and last was positioned near the stern of the wreck in the southern part of the site and was labelled #1. The sediment indicators were meant to provide visual indications to sedimentation and scouring on the site, and were filmed during each cruise for comparative studies.

9.2.2. Results and overall impression

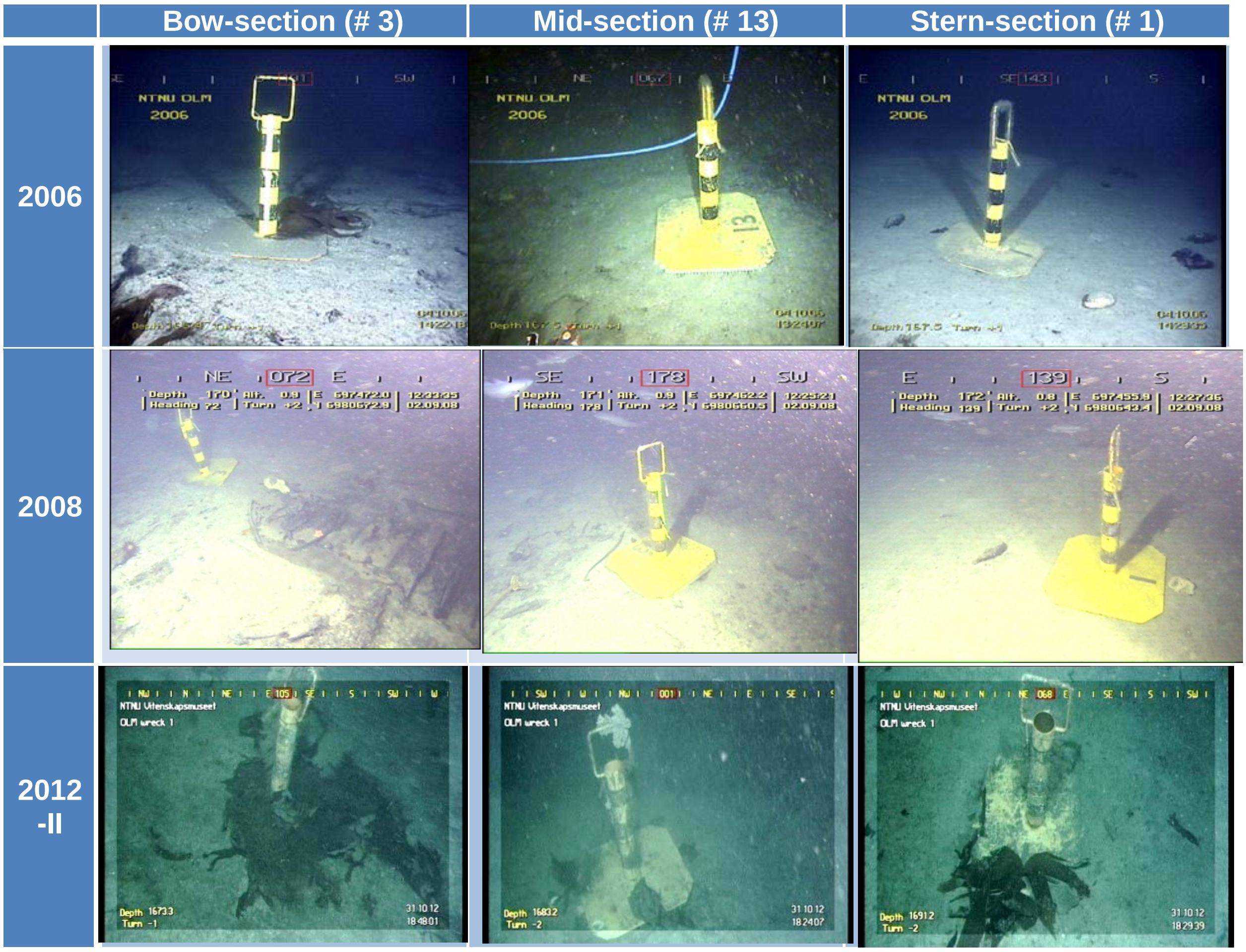

Figure 61 - Images of the three sediment indicators from the 2006, 2008 and 2012-II surveys. Photos: NTNU Vitenskapsmuseet

In Figure 61, images of the sediment indicators from three different surveys are presented. In 2006 the base of sediment indicator #3 near the bow appears to be covered by a very, very fine layer of sediment most likely very fine sand. In the mid-section, indicator #13 is hardly covered by sediment at all, just slightly less than #1 with its see-through layer of sediment. In 2008 there appears to be a slight collection of sediments on the west side of the base of indicator #3; whereas, indicators #13 and #1 show no signs of sedimentation. In 2012 indicator #3 is covered with kelp and sea grass fully blocking the view of the base. There was no point in trying to remove the kelp using the ROV, as the thrusters probably would have blown away any potential sediment from the base. We can see a slight collection of sediment on one of the corners of the base of indicator #13, as well as some kelp. Indicator #1's base is slightly covered in a thin layer of sediment.

Comparing from one year to another, indicator #3 is most covered in 2006 and less in 2008; whereas, it is not possible to compare with the situation in 2012. Indicator #13 appears to be most covered in 2012, and not at all in 2006 and 2008, but the level of coverage in 2012 must be stated as being very slight indeed. Indicator #1 seems to have the same slight coverage in 2006 as in 2012, but shows no sign of sedimentation in 2008.

None of the indicator measurements suggest much sedimentation throughout the project, but of the three, indicator #3 seems to be the one displaying most sedimentation coverage. This is if we by using the amount of entangled kelp in 2012 can assume that there is also some entrapped sediments underneath the plant remains. Interestingly, the presence of kelp is indeed evidence of underwater currents, as kelp does not live at this depth it must have been washed free in shallower waters and transported by the current. Indicator #1 in the stern part of the wreck has a slightly smaller rate of sedimentation during these three years compared to indicator #3; while, indicator #13 in the centre of the site shows little or no sign of sedimentation in either of the three years.

The clearest sign of sedimentation on indicator #3, correlates with a statement regarding the level of sedimentation in the 2006 report, incidentally the only time the sediment indicators are mentioned directly in the reports; "*the sediment level on the northern indicator* [i.e. indicator #3] *is higher than in the mid-section and to the south of the wreck*" (Jasinski and Søreide 2006:6). It was further stated that "*it is impossible to verify if the sediment levels are a result of actual sedimentation or movement of sediments along the seafloor. The results will be compared with the sedimentation rate obtained from the sediment trap that was installed on the site* […] *following the 2007 survey*" (Jasinski and Søreide 2006:6). We thus have to compare the subjective interpretation of the indicators with the documented amount of sediments collected in the sediment trap for the specified periods. In Figure 59 we find the data of interest, corresponding with the time the indicators were filmed. The Figure does not give the exact amount of collected sediment from the specified day of film- documentation, but rather a number for that particular month. We then find that in October 2006 the sediment weight is 39.44g, in September 2008 it is 28.08g and in October 2012 29.46g. These results only partly correlate with the evidence of the pictures. In 2006 there is indeed sediment on indicators #3 and #1, but not #13. In 2012 and 2008 there is a near equal amount of sediment, but the pictures show a significant difference between the indicators these years. The indicators undoubtedly display sediment as a result of scouring, as well as sedimentation, and this is hard to differentiate even after comparing the visual indicators with the results from the sediment trap from the specified periods.

The sediment trap only collected sediment at one location, whilst the indicators were spread out on the site, and this can explain some of the internal differences. It must also be noted that it appears that the design of the indicators is not optimal. The base seems too distinct as it does not appear to integrate with the seabed. The base instead gives the impression of creating some sort of sediment obstacle, as we see in some of the pictures, like in Figure 61 where cavities form around the base of some of the indicators. As a result of this it is questioned whether the indicators manage to portray the actual level of sedimentation in a realistic manner. We have seen from the various surveys that the sediment shifted quite a lot from one year to another in somewhat complex cycles. Parts of the hull were uncovered one year and covered the next, but this was not necessarily portrayed in the observation of the sediment indicators. The indicators give an almost identical portrayal of the situation from one year to the next. As the indicators have a fixed position on the site, they were left in situ when we finished in 2012 for future reference in case of new visits to the site.

9.3. Current meter

9.3.1. Overview

	2006	2007	2008	2009	2011	2012-I	2012-II
Retrieved	Yes	Yes	Yes	No	No	No	No
Date retrieved	10.10.2006	19.10.2007	03.09.2008	-	-	-	-
Deployed	Yes	Yes	No	Yes		No	No
Date deployed	12.10.2006	19.10.2007	-	09.12.2009		-	-
Deployed : N	6980660.6	6980658.77	-	6980634.0		-	-
: E	0697470.8	0697478.14	-	0697458.5		-	-

Figure 62 - Table showing coordinates and dates of retrieval and deployment of the current meter after NTNU took charge of the surveys in 2006. The dates prior to this can be found in Figure 65. Datum: ED50-UTM31

9.3.2. Year by year

"*The first deployment in this program was completed by Fugro on September 19th 2005 using the vessel MV Urter. The instrument was recovered. Before redeployment the instrument was serviced and all data was downloaded. The unit was positioned using an HPR system when it was lowered to the seabed and placed on the wreck site*" (Ludvigsen, Jasinski and Søreide 2009:4).

"*The second deployment was completed by Fugro on January 7th 2006 using the vessel MV Ocean Flower. The instrument was recovered on January 5th. Before the redeployment the instrument was serviced and all data was downloaded. The unit was positioned using an HPR system when it was lowered to the seabed and placed on the wreck site*" (Ludvigsen, Jasinski and Søreide 2009:4).

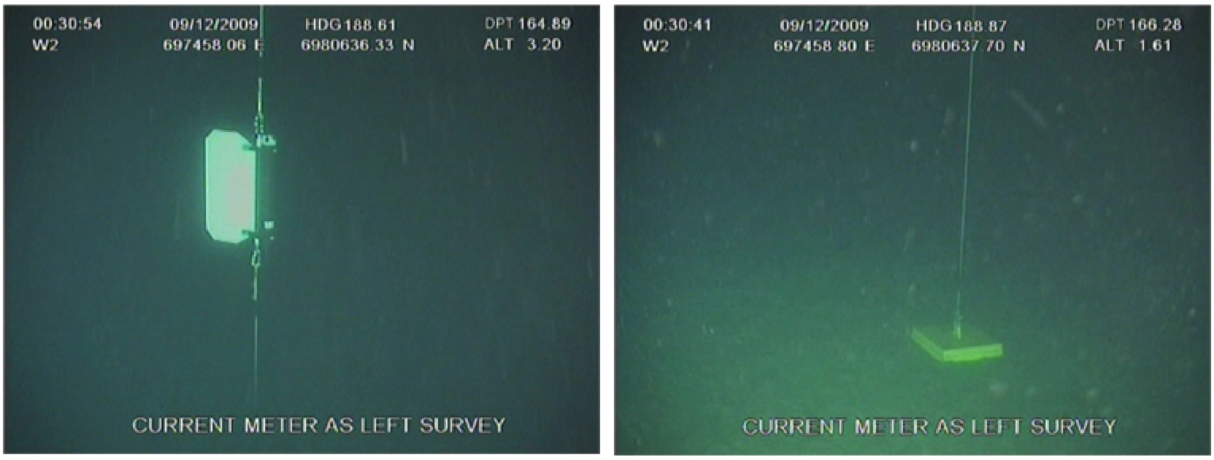

Figure 63 - Current meter as left in 2009; instrument on the left and mooring on the right. Photo: Jasinski et.al. 2009:28.

"*The third deployment was completed by Fugro on June 3rd 2006 using the vessel MV Elisabeth. The instrument was recovered June 2nd. Before redeployment the instrument was serviced and all data was downloaded. The unit was positioned using an HPR system when it was lowered to the seabed and placed on the wreck site*" (Ludvigsen, Jasinski and Søreide 2009:4).

"*The forth deployment was completed by Fugro on October 12th 2006 using the vessel MV Elisabeth. The instrumented was recovered 10th of October. Before redeployment the instrument was serviced and all data was downloaded. The unit was positioned using an HPR system when it was lowered to the seabed and placed on the wreck site*" (Ludvigsen, Jasinski and Søreide 2009:4).

Figure 64 - Mooring from lost current meter in 2011, as found with part of broken shackle in October 2012. Photo: NTNU Vitenskapsmuseet

"*The fifth deployment was completed by NTNU on October 19th 2007 using the vessel RV Gunnerus. The instrumented was recovered on October 17th and all data was downloaded before it was redeployed. The unit was positioned using a HiPAP system when it was lowered to the seabed and placed on the wreck site. The fifth deployment was recovered on September 2nd 2008. A fault was found on the instrument and it was not redeployed*" (Ludvigsen, Jasinski and Søreide 2009:4).

"*In 2007 the current sensor was recovered on October 17th by NTNU and RV Gunnerus. The unit was redeployed on October 19th. The data was collected and will be presented in "Ludvigsen, Martin; Jasinski, Marek E.; Søreide, Fredrik. Ormen Lange Marine Archaeology Project - Summary of current measurements on Wreck Site - Report 2005 - 2008*" (Jasinski, Søreide and Ludvigsen 2007:6).

In 2008, "o*n recovery of the current sensor the dataset was not recoverable. The instrument was returned to the manufacturer for data download. The manufacturer successfully downloaded the data. The data set covered the complete deployment period and will be presented in separate report. A new unit must be installed on the site later"* (Jasinski, Ludvigsen and Søreide 2008:2).

In 2009, *"The current meter previously installed on the site was recovered in 2008 and found to be malfunctioning. No current data has therefore been collected between 2008 and 2009 cruise dates. A new Aquadopp current meter was purchased and was installed on the site. Information about location can be found in the survey report in Appendix E*" (Jasinski, Ludvigsen and Søreide 2009:2).

There was no survey in 2010, and the current meter was left as deployed in December 2009. During 2011 the rig set-up was lost as the shackle connecting the rig to the mooring broke (see Fig. 63). Due to its buoyancy, the rig subsequently surfaced and was later found by local fishermen who reported it to the NTNU University Museum. The data was however successfully retrieved. The shackle probably broke due to corrosion. As there was uncertainty to what caused the corrosion, a new rig was not deployed during the survey in 2011. As it was decided that the 2012 survey would be that last in the project, there were no measurements after 2010/2011.

9.3.3. Results and overall impression

As the reports from the current meter measurements after 2008 (i.e. 2009) have not been made available for this report, we must use the material already at hand. In 2009 a comprehensive report was made which summarized the measurements of currents on the wreck site from September 19th 2005 through to September 2nd 2008 (Ludvigsen, Jasinski and Søreide 2009) - thus a span of three whole years of continuous measurements. This period spans the time just following the end of the excavations when the wreck was covered in loose sediments, through to the time after July 2007 when parts of the nearby pipeline trench were covered with a stone filling (see Chapter 3.3). September 2008 is nearly three years after the end of the excavations and physical intrusion on the site that disrupted the once stable sediments. After three years, it must be assumed that the situation to some degree stabilized. One more year of measurements would thus not necessarily have given a much different picture than what is presented in the 2009 report. Had there been measurements right up until the end of the project or, as was the case with the sediment trap, a single year's measurements at the very end of the project period, that would be more valuable than an extra year to the already summarized period. Based on this fact, we use the results from the 2009 report assuming that the conclusions made are valid and can be used to form the general basis of the situation of currents on the shipwreck site.

In the following, the main results from the 2009 *Summary of current measurements on Wreck Site* report are represented. There are five series of measurements that are used in the presentation and discussion, and the period of these time series are given in Figure 65. The standard deviation for the sensor measurements is according to the Nortek manual 1% of measured value ± 0.5 cm/s. The Doppler noise typically induces 1 c/m uncertainty to the data also according to the manual (Ludvigsen, Jasinski and Søreide 2009:6). The max current for the five data sets vary from 0.28 m/s to 0.35 m/s. The current directions associated with the maximum current readings vary from 65° to 265°. The mean current varies from 0.06 m/s to 0.08 m/s (Ludvigsen, Jasinski and Søreide 2009:7), see Figure 66.

Series	Date		Operator
1	19.09.2005	Deployment of ADCM	Fugro
	05.01.2006	Recovery of ADCM	Fugro
2	07.01.2006	Deployment of ADCM	Fugro
	02.06.2006	Recovery of ADCM	Fugro
3	03.06.2006	Deployment of ADCM	Fugro
	10.10.2006	Recovery of ADCM	Fugro
4	12.10.2006	Deployment of ADCM	Fugro
	17.10.2007	Recovery of ADCM	NTNU
5	19.10.2007	Deployment of ADCM	NTNU
	02.09.2008	Recovery of ADCM	NTNU

Figure 65 – Overview over the time periods for the series used in the summary of the measurements of currents from 2005-2008. Table from: *Ludvigsen et.al. 2009:4*

In the report the conclusion was: "*The data sets show fairly stable and similar results during the three year period*" (Ludvigsen, Jasinski and Søreide 2009:7). As can be seen when studying the datasets from this report represented below the changes and differences seems to occur within each year and do not constitute a visible difference between years, especially when it comes to mean and maximum measured underwater current. There seem to be cyclic fluctuations that appear to be inherent. What is lacking here is datasets that span the period prior to the excavations and the construction of the pipeline trenches. But using the datasets at hand, they do not provide any solid proof or even an indication that the construction of the pipelines has brought about noticeable changes to the underwater currents in this specific area that directly disrupts the protected shipwreck.

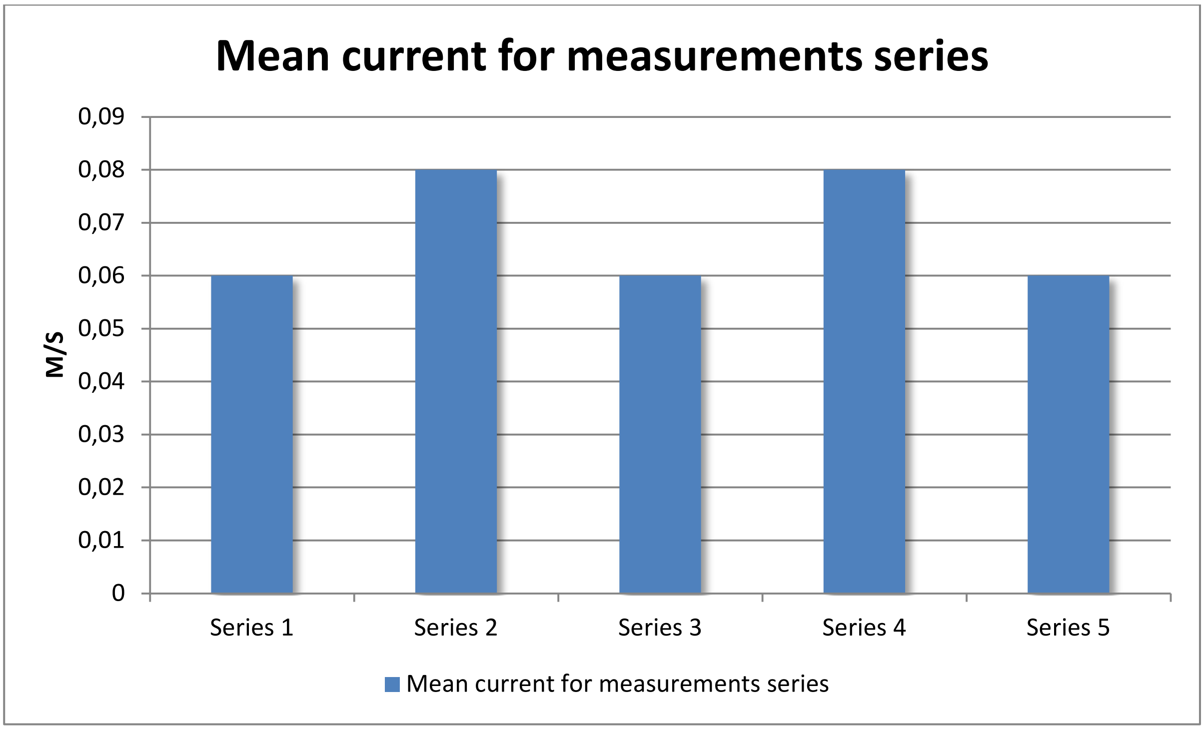

Figure 66 - Histogram showing mean current m/s for the five described data sets. Illustration from: *Ludvigsen et.al. 2009: Figure 4.1*

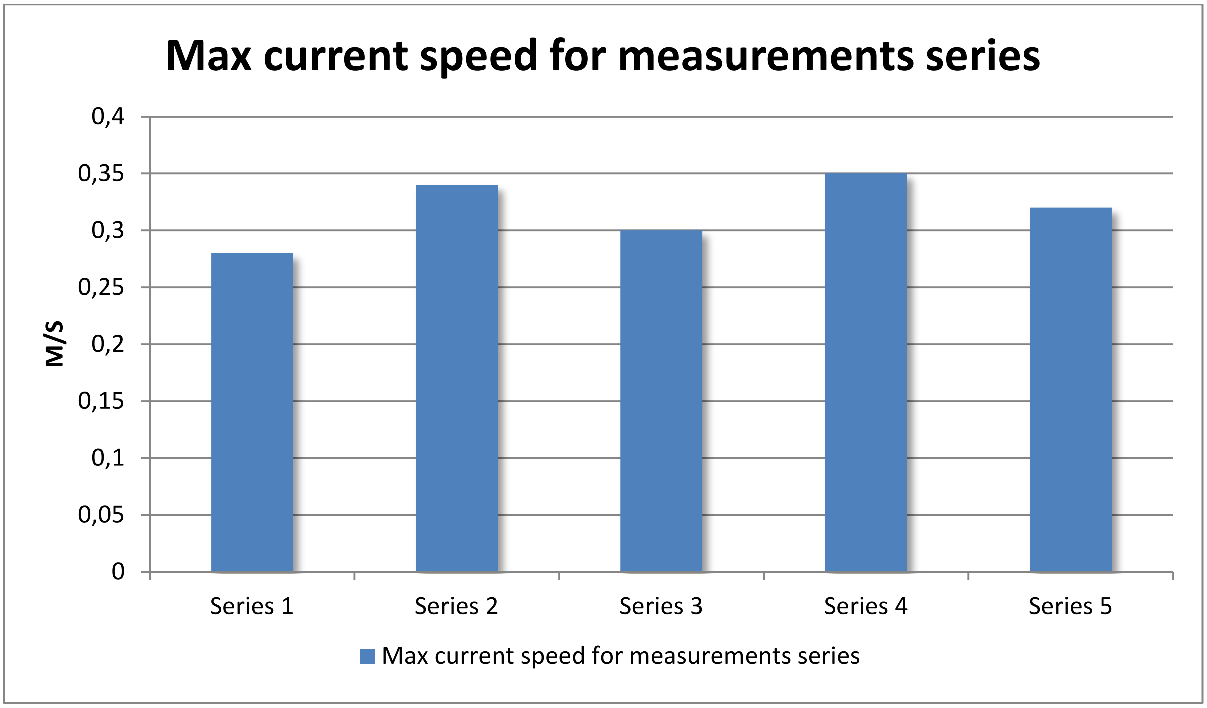

Figure 67 - Histogram showing the max current m/s for the five described datasets. Illustration from: Ludvigsen et.al. 2009: Figure 4.2.

Series	1	2	3	4	5
Start of period	19.09.2005	07.01.2006	03.06.2006	12.10.2006	19.10.2007
End of period	05.01.2006	02.06.2006	10.10.2006	17.10.2007	02.09.2008
Max current speed	0.28 m/s	0.34 m/s	0.30 m/s	0.35 m/s	0.32 m/s
Max current direction	74°	247°	262°	65°	265°
Mean current speed	0.06 m/s	0.08 m/s	0.06 m/s	0.08 m/s	0.06 m/s
Mean current direction	278° (E-W)	284° (E-W)	289°	254° (E-W)	247° (E-W)
Max. temperature	10.8°C	10.2°C	9.3°C	10.2°C	10.1°C
Mean temperature	10.0°C	9.0°C	9.0°C	9.1°C	9.0°C
Minimum temperature	8.9°C	7.8°C	8.7°C	8.1°C	8.4°C
Sampling interval	10 min	10 min	10 min	30 min	30 min
Datum	ED50/UTM31	ED50/UTM31	ED50/UTM31	ED50/UTM31	ED50/UTM31

Figure 68 – Summary of deployment details of current meter from September 2005 – September 2008. From: *Ludvigsen et.al. 2009:8*

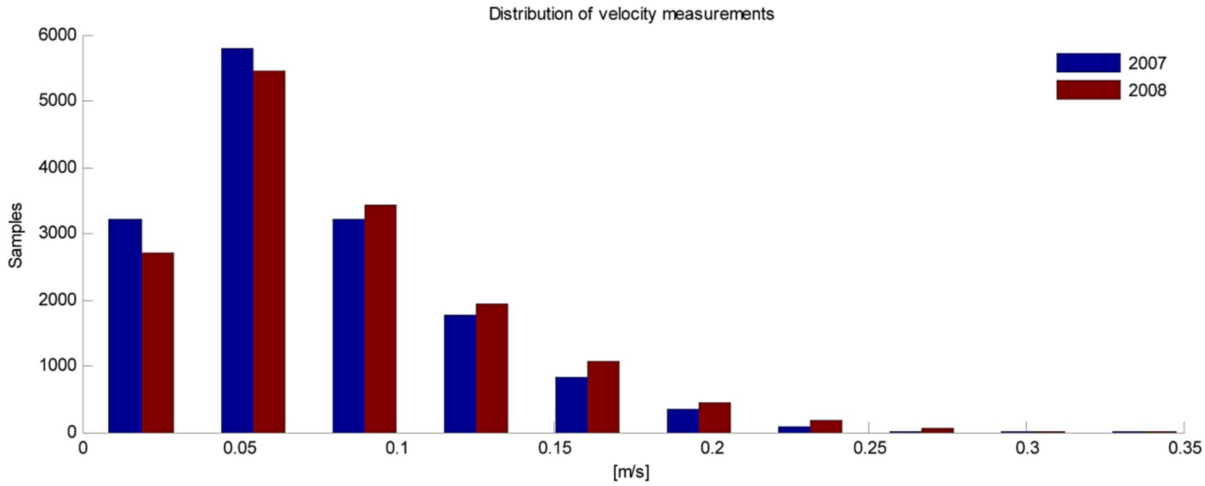

Figure 69 - Histogram of distribution of current intensity. From: *Ludvigsen et.al. 2009:9*

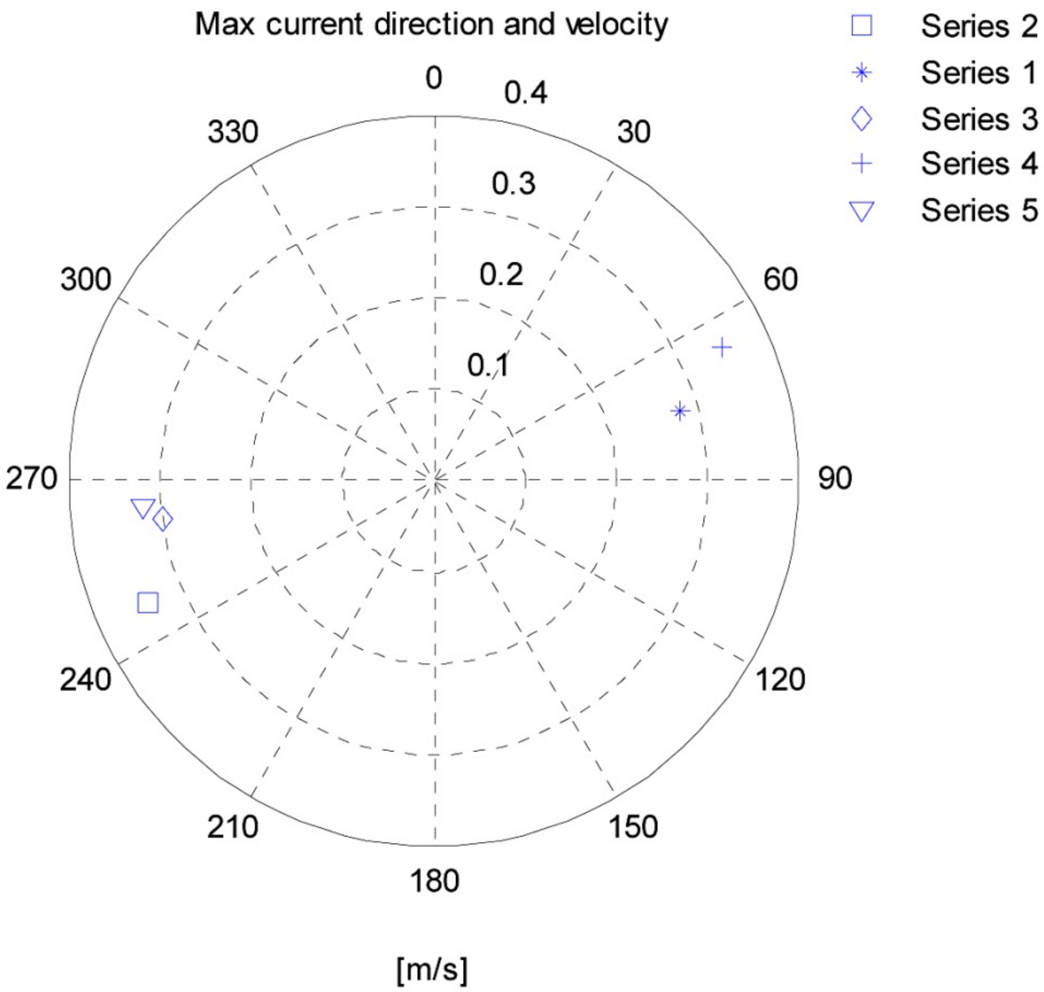

Figure 70 - Direction and intensity of maximum current measurement for all five measurement series. From: *Ludvigsen et.al. 2009:11*

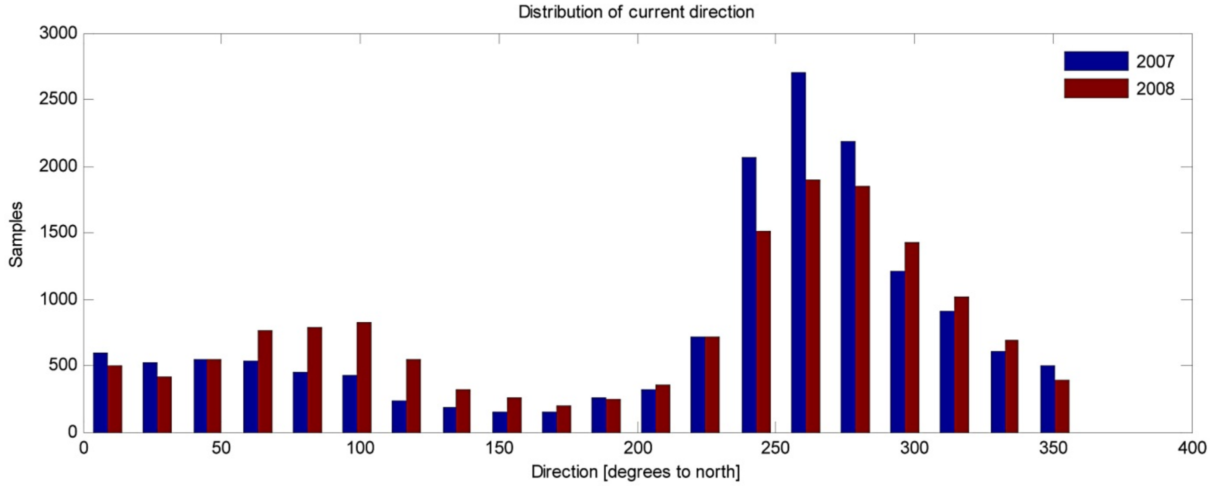

Figure 71 – Histogram of distribution of current directions. From: *Ludvigsen et.al. 2009:10*

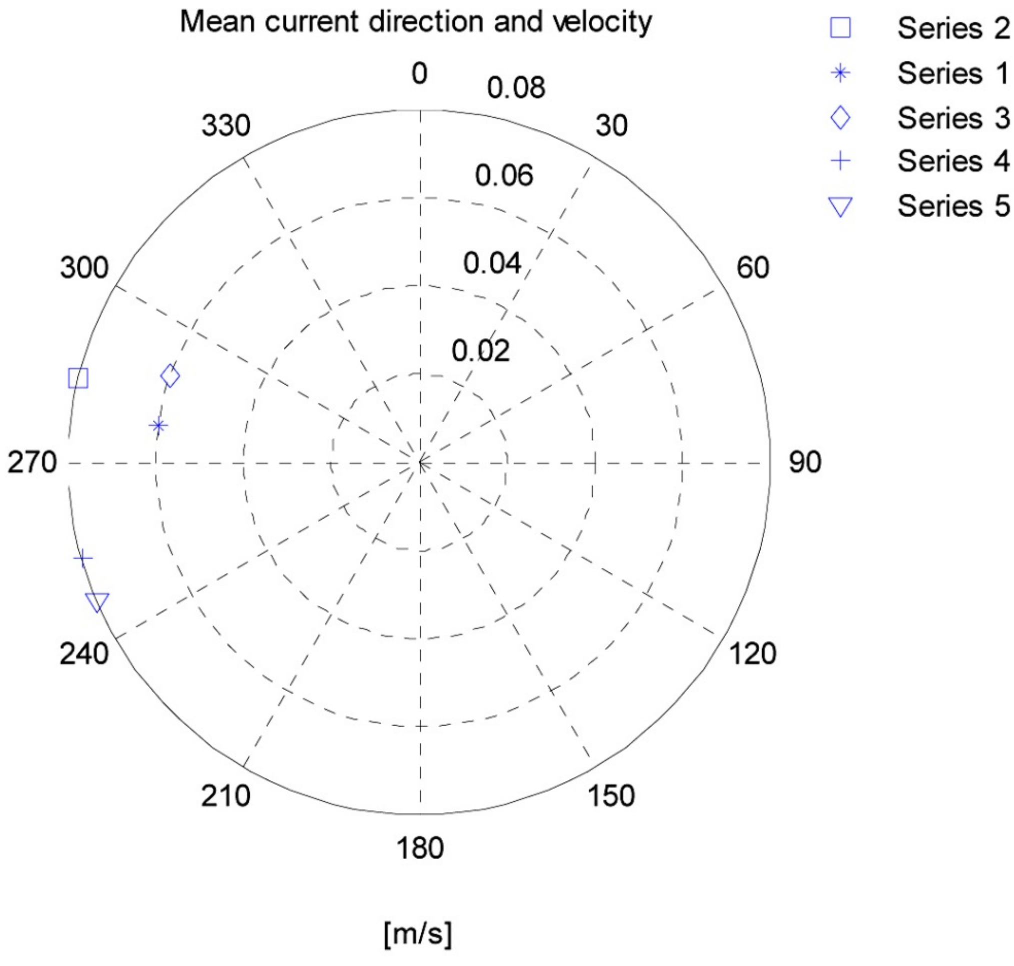

Figure 72 - Direction and intensity of mean current measurement for all five measurement series. From: *Ludvigsen et.al. 2009:12*

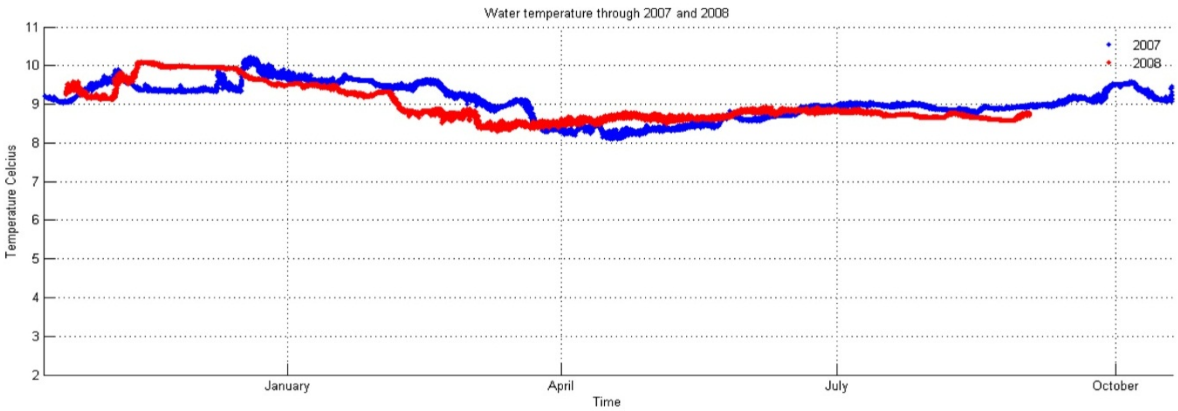

Figure 73 - Temperature plotted for the entire year for the measurement series 4 and 5. From: *Ludvigsen et.al. 2009:13*

9.4. Video and still photography

To facilitate for comparative analysis of the video data from one year to the next, a specified track was followed. The ROVs were not fitted with DP, so the ROV operators have followed the predetermined track manually. The visibility on the site has differed from one year to another resulting in different heights above the seabed in order to get valid data. Furthermore, currents and other parameters might have caused the ROV to behave differently from one survey to the next. There has also been used different ROVs, and although their cameras are basically the same, the size of the ROVs and the angle of the video camera would have caused differences between the surveys. All this of course means that there are variations in the video footage from one year to the next, making it more challenging to directly compare or make overlays than was planned for at the onset of the project.

In addition to the general video survey of the site, visual documentation of the sediment indicators has been carried out in order to measure the net level of sedimentation. This is further described in Chapters 7.4 and 9.2. Apart from these, no systematic documentation of specified artefacts or parts of the hull were conducted for comparative analysis.

Below, various pictures from the surveys from the bow-, the mid-, and the stern section are presented. Unfortunately, they do not display the exact same view as would have been optimal, but they still provide the useful information to be able to understand the general level of sedimentation at various parts of the site. As can be seen there are large hull structures exposed in the bow section in the first years. In the mid-section we also see exposed timbers in the years between 2006 and 2008, and the same is the case in the stern part of the wreck. There seems to be a shift around 2009, when the sediment appears to start stabilizing covering the wreck yet again. We do not have images from the 2010 as no survey was conducted that year, neither from 2011 nor 2012-I (see Chapter 3.2). But from the 2011 survey, when trying to find wood pieces for analysis, most of the site was fully covered making it difficult to find the suitable materials. As can be seen from the October 2012 images, the situation was the same as in 2011, with hull timbers covered in sediment, though the artefacts (mainly glass bottles) in the stern section are still very much exposed. Although the sediment now seem to have stabilized to some degree covering the hull, we do not know the exact thickness of the sediment cover; thus, we do not know to which degree the organic materials are actually protected. It is not the nature of the visual inspection to provide data on sediment thickness; but, it is worth noting that although the wreck at present is covered, the cover itself may not provide any protection from biological or chemical threats.

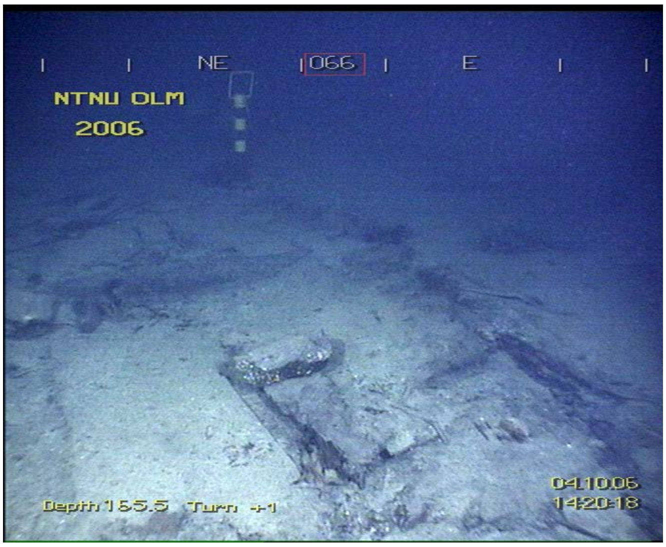

Figure 74 - Sedimentation level in the bow-section, October 2006. Photo: NTNU Vitenskapsmuseet

Figure 75 - Sedimentation level in the bow-section, September 2007. Photo: NTNU Vitenskapsmuseet

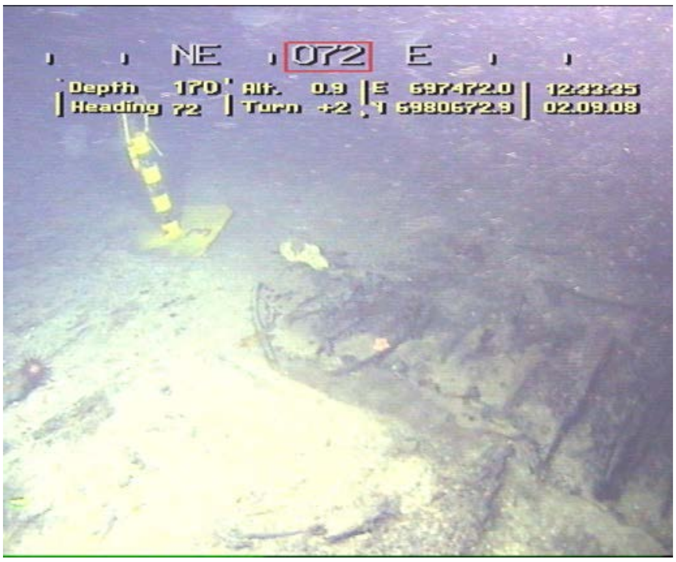

Figure 76 - Sedimentation level in the bow-section, September 2008. Photo: NTNU Vitenskapsmuseet

Figure 77 - Sedimentation level in the bow-section, December 2009. Photo: NTNU Vitenskapsmuseet

Figure 78 - Sedimentation level in the bow-section, October 2012. Photo: NTNU Vitenskapsmuseet

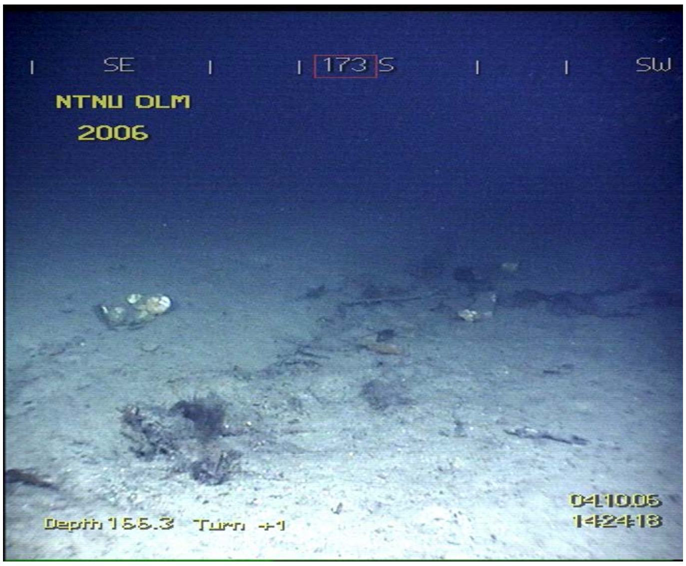

Figure 79 - Sedimentation level in the mid-section, October 2006. Photo: NTNU Vitenskapsmuseet

Figure 80 - Sedimentation level in the mid-section, September 2007. Photo: NTNU Vitenskapsmuseet

Figure 81 - Sedimentation level in the mid-section, September 2008. Photo: NTNU Vitenskapsmuseet

Figure 82 - Sedimentation level in the mid-section, December 2009. Photo: NTNU Vitenskapsmuseet

Figure 83 - Sedimentation level in the mid-section, October 2012. Photo: NTNU Vitenskapsmuseet

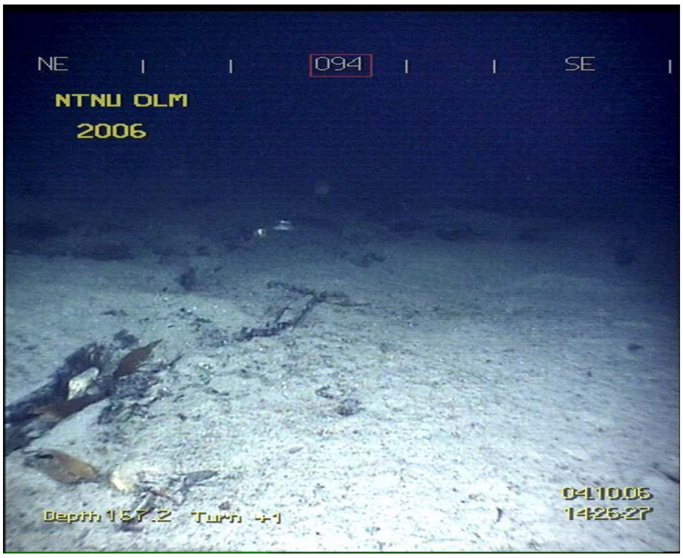

Figure 84 - Sedimentation level in the stern-section, October 2006. Photo: NTNU Vitenskapsmuseet

Figure 85 - Sedimentation level in the stern-section, September 2007. Photo: NTNU Vitenskapsmuseet

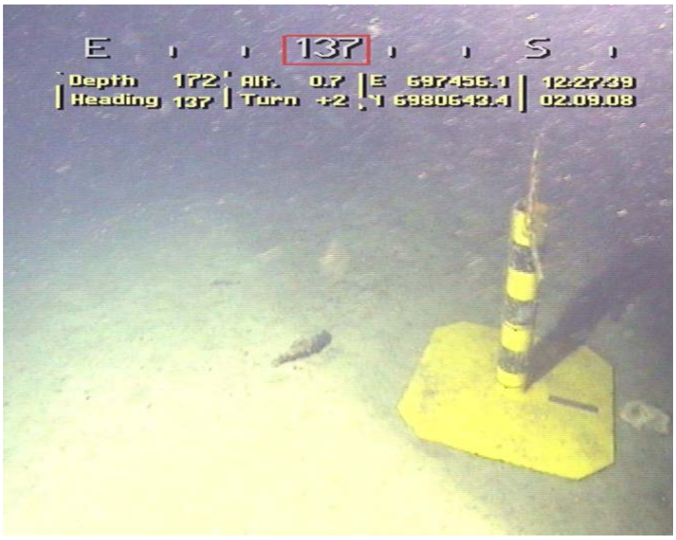

Figure 86 - Sedimentation level in the stern-section, September 2008. Photo: NTNU Vitenskapsmuseet

Figure 87 - Sedimentation level in the stern-section, December 2009. Photo: NTNU Vitenskapsmuseet

Figure 88 - Sedimentation level in the stern-section, October 2012. Photo: NTNU Vitenskapsmuseet

9.5. Wood sampling

The first wood sampling was scheduled to be conducted during the 2011 survey. The initial plan was to retrieve pieces of in situ oak ship timbers, as these would be directly comparable to the oak timbers retrieved during the excavations in 2004-2005. The plans were altered as the Directorate for Cultural Heritage only partially accepted the proposed plan for wood samples extractions for further studies of the state of preservation. The Directorate gave permission to retrieve loose pieces of wood from the site, but not in situ pieces nor did they give permission to excavate to find suitable timbers. The reason was that they feared that such “harmful intervention” could disrupt the site fuelling unwanted degradation. This was a setback as the general scientific value of stray timbers was questioned. But this was seen as the start for a new aspect of the monitoring project.

The plan in the field was to use the existing site plans and measurements in advance of the expedition, combined with on-site video documentation to choose four suitable planks of wood for extraction. The planks must be assured to be from the wreck but not currently physically part of the remaining major hull structure. When the planks were chosen, they would get individual target numbers and their position recorded. A sand-filled bag, labelled with the planks target number, would be placed next to the plank on the seabed. The ROV was then to lift the plank and place it in a specially adapted container and bring it to the surface. On the surface the plank would be accurately documented using photography and 1:1 drawing. Then a test sample would be taken from the plank. The plank would then be labelled for future reference and the plank re-deposited on the same position from which is was taken. A sandbag would then be placed on top of the plank to ensure that it stayed in the same position until next year’s fieldwork for further comparative studies.

Figure 89 – Both sides of the piece of wood retrieved in 2011, picture taken on board R/V Gunnerus directly after retrieval. Photos: Skoglund/ NTNU Vitenskapsmuseet

In 2011 the sedimentation situation was such that most of the wreck was covered with sediments, so were also the most promising timbers that had been identified for sampling prior to the fieldwork from earlier survey documentation. Four pieces of wood were however identified as possible targets during the video survey, although not of the quality that was hoped for, many being fragmented and less representative samples. After recovering the first successfully, the ROV's manipulator locked and the ROV had to surface. Unfortunately this was at the end of the cruise, and there was no time to repair the manipulator and collect additional samples. As the piece was small and already fragmented, it was decided that is was not to be redeposited, a task which nevertheless would be difficult without the manipulator.

Figure 90 - Close up of part of the piece of wood retrieved in 2011, revealing wood borer attack on its side facing the camera. The picture was taken on board R/V Gunnerus directly after retrieval. Photo: Skoglund/ NTNU Vitenskapsmuseet

The one piece of wood we managed to collect was small and it was difficult to ascertain its original function or original position within the ship. It was found in position E: 392523.02, N: 6976228.16 (Datum: ED50-UTM31). The total length was 48.3 cm; it was 12.8 cm wide and 6.7 cm thick. It was sawn in two lengthwise, with the one side having the saw marks and the other being oval shaped (see Figure 89). The reverse side of the saw marks might have been displayed somewhere within the ship, and thus might have formed part of the interior decorations or structure. The wood species was identified as *Betula*. Key identification features included scalariform perforation plates and numerous, small ray-vessel pits (see Figure 91). The wood is most severely degraded on the surface with iron corrosion staining visible both on the surface and through the wood structure (see Figure 89 and Figure 90). Deterioration is severe in some areas with just the middle lamella remaining. Degradation appears to be mainly due to soft rot and erosion bacteria.

Figure 91 – Close up of wood borer attack on piece of wood retrieved in 2011, picture taken on board R/V Gunnerus directly after retrieval. Photo: Skoglund/ NTNU Vitenskapsmuseet

As the project ended in 2012 we did not retrieve wood material in 2012, and thus the wood project ended with only one piece of wood retrieved. This is judged to be a too small and unrepresentative sample for analysis of the state of preservation.

9.6. Multi Beam Echo Sounder (*By: Øyvind Ødegård*)

As MBES data was only gathered during the 2009 survey the data can only give an indication of the wreck site situation that particular year. A small MBES was mounted on the ROV for the 2012 survey, but the data gathered was of poor quality and unsuitable for meaningful analysis.

9.7. Photomosaic (*By: Øyvind Ødegård*)

A comparison of the 2005 and 2012 photo mosaics can give an impression of changes in sedimentation. The mosaics were not co-registered, and the data sets were manually geo-referenced against the wreck site drawing in ED 50 UTM 31N. Many features clearly visible in the 2005 mosaic are not visible in the 2012 mosaic, indicating a considerable increase in sedimentation. Although of no scientific bearing for the OLM project, juxtaposing the 2004 and 2012 mosaics could suggest that at least parts of the wreck are less exposed after excavation and construction of the pipeline.

Figure 92 - Photomosaic showing the situation in 2004. Photomosaic: Martin Ludvigsen/NTNU

Figure 93 - Photomosaic showing the situation in 2004 with wreck site drawing overlay. Illustration: NTNU Vitenskapsmuseet based on photomosaic by Martin Ludvigsen/NTNU

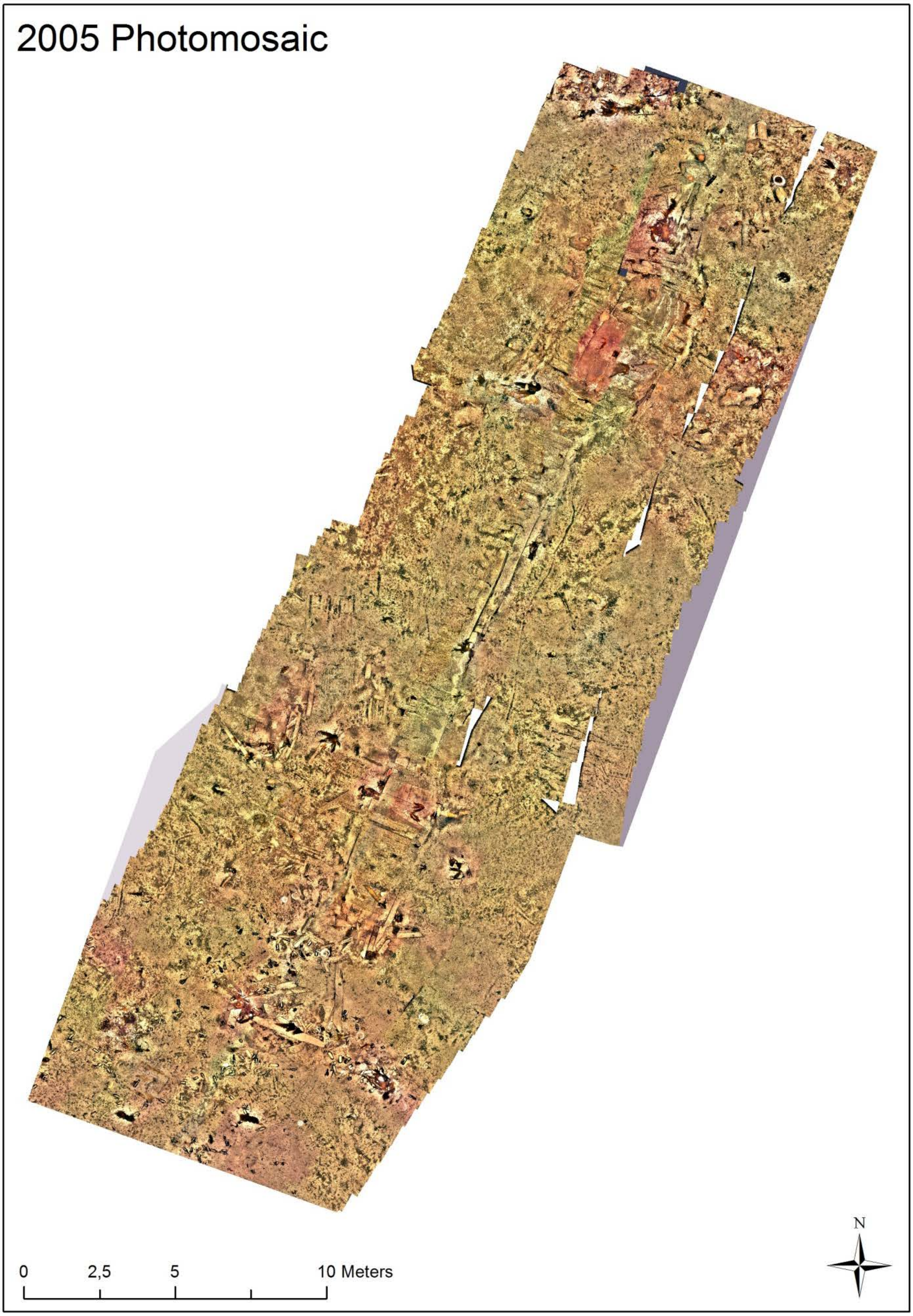

Figure 94 - Photomosaic showing the situation in 2005. Photomosaic: Martin Ludvigsen/NTNU

Figure 95 - Photomosaic showing the situation in 2005 with wreck site drawing overlay. Illustration: NTNU Vitenskapsmuseet based on photomosaic by Martin Ludvigsen/NTNU

Figure 96 - Photomosaic showing the situation in 2012. Photomosaic: Mauro Candeloro/NTNU

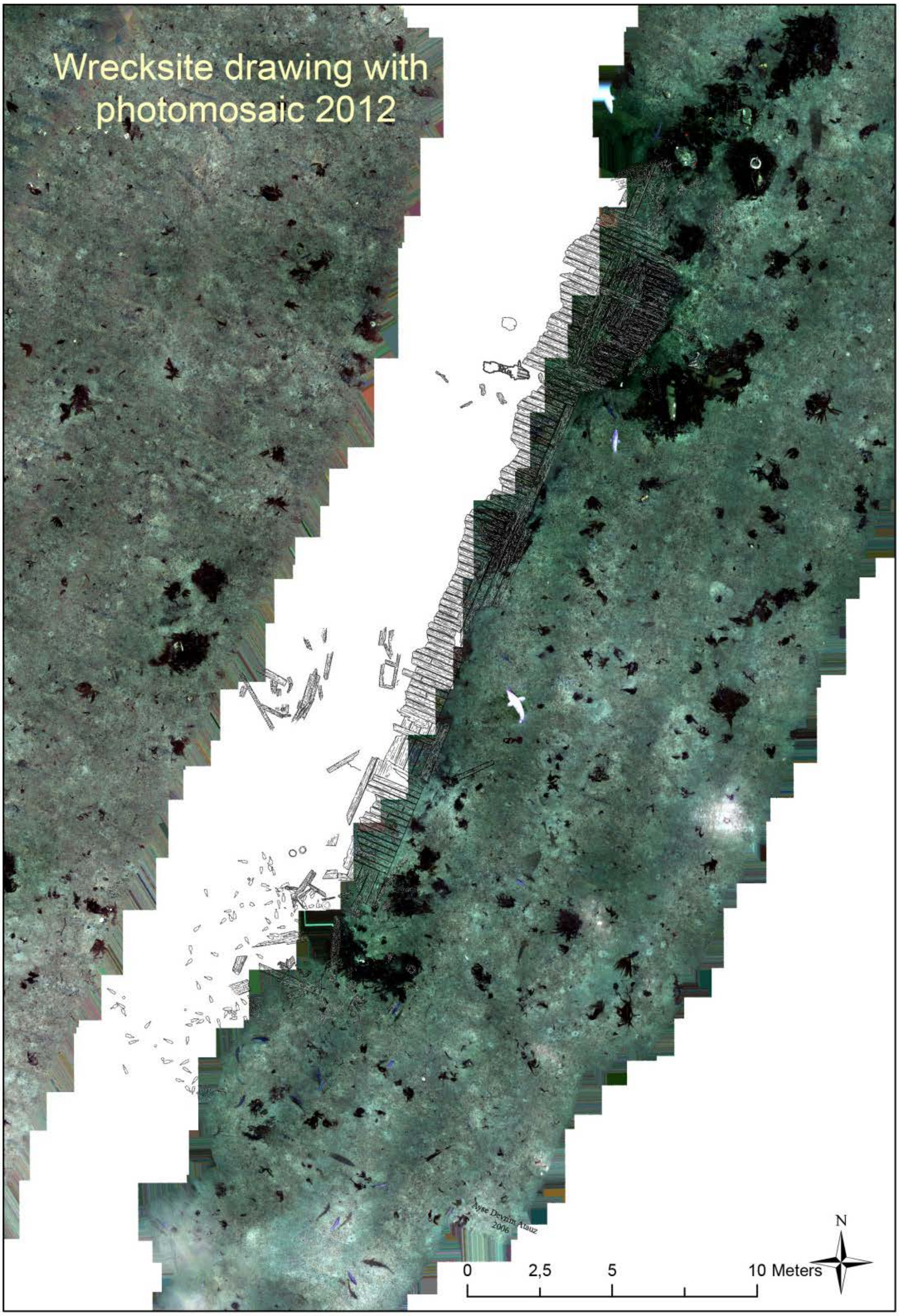

Figure 97 - Photomosaic showing the situation in 2012 with wreck site drawing overlay. Illustration: NTNU Vitenskapsmuseet based on photomosaic by Mauro Candeloro/NTNU

9.8. General

From the results presented above, there are clearly some methods that have provided valid results applicable for further understanding of the site, some methods have provided ambiguous results hard to conclude from, whereas some methodological approaches have not provided any usable results at all.

The visual studies, although not presenting solid data, to some extent provide the best impression of the sediment situation on the site, as to whether the hull structures are covered in sediment or exposed. Although the sediment trap and the current meter have provided valid and comparable datasets, the results are not conclusive as we have no other comparable measurements from nearby sites that can point to whether the data are very local or more regional.

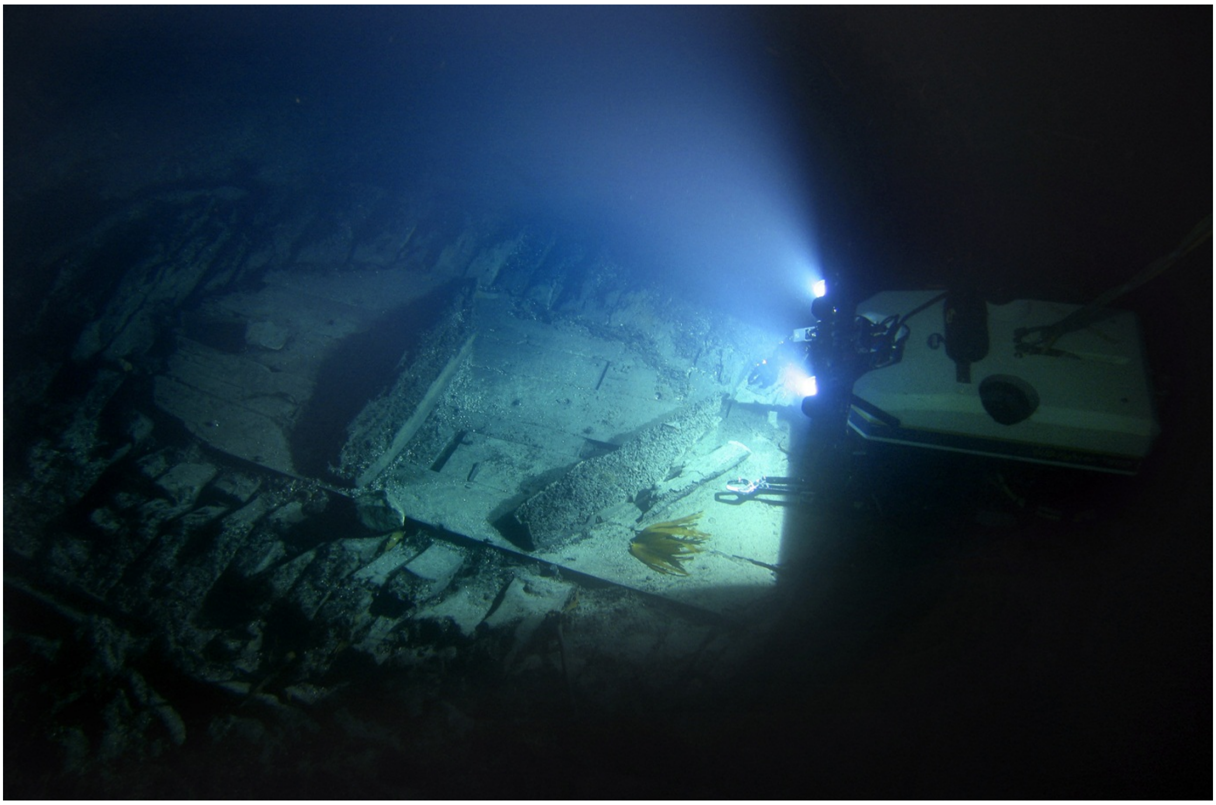

Figure 98 - Picture showing bow part of the hull with all the sediments removed, exposing the organic materials. Photo: NTNU Vitenskapsmuseet

In 2006, 2007 and 2008 the survey reports conclude that the mid- and stern sections seem to be covered in sediment. The bow section, however, which was the part of the hull that was most exposed during the 2004-2005 investigations (see Figure 98), is reported to be exposed during all of these years. In 2009, four years after the wreck was covered, there is sediment covering the whole wreck, although the sediment must be relative scantly distributed in the bow, as the report states that "*that there is a shallow sediment layer covering the complete wreck-site, with better cover in the south (stern) section and less sediment cover in the north (bow) section*" (Jasinski, Ludvigsen and Søreide 2009:1). As there were no direct measurements of the thickness of the sediment, this statement must imply that some structural elements are to some degree still visible. During both the 2011 and the 2012-II survey, the whole wreck seems to be covered, as we cannot make out the parts of the bow that previously had been exposed to various degrees. This indicates what has been noted in the summary to several of the monitoring methods applied in the project; that the sediment appears to have settled over the whole site from 2009 and that the wreck was still covered, although by a unknown amount, at the end of the project in 2012. This denotes that the sediment situation on the site is positively moving towards a new level of equilibrium. The increase in sediment volume from 2011-2012 (Figure 49 and Figure 50), as compared to 2008 and 2009, must imply a general increase in water-column sediment, as the observations made visually of the seabed does not reveal such differences in scouring to explain this increase.

10. Evaluation of methodological approach

At the end of this monitoring project, it is vital to evaluate the various facets regarding the methodology in relation to the scientific outcome. This will be done in the following chapter.

The environmental monitoring project was in many ways pioneer work, both nationally and internationally, as the Directorate for Cultural Heritage pointed out in 2005 when stating that data from such conditions not previously have been documented. Many such projects have been undertaken on shipwreck sites worldwide, but few if any in deep waters, so although there was knowledge of methodological aspects, the site demanded new approaches and adapted methodology to be remotely managed. The project management in instigating the project also created a methodological work-package consisting of sediment trap (net sedimentation rate), current meter, sediment indicators (gross sedimentation rate) and video survey. This remained the investigational focal points throughout the project, as the work package was not formally updated. The addition of the wood-project in 2011 was a late addition not making an impact. The reason for adhering to the methodology must imply that the set-up is the best suited for the project in order to get the results demanded. Unfortunately, neither of the survey reports deals with methodological aspects. In order to understand whether the instruments chosen gave the needed results, we must consider the purpose of the monitoring project, and what it aimed to achieve. The goal was to document the influence of the pipelines on the nearby site, but what was to be monitored?

Was the purpose to monitor the shipwreck site? Then the methodological approach can be said to have worked according to plan. Annual MBES surveys to get more robust data on sedimentation coverage of the whole site, as compared to assumptions gained from the visual surveys, would have been highly beneficial but not imperative. The results presented in this report give enough information to conclude that there are not data from the instruments that support a theory that the pipelines are disturbing the shipwreck site. One problem, however, is that there is not a set baseline condition prior to the monitoring to which the various later datasets can be measured against. And as the final report from the excavation has not been finalised, we know neither the level of scouring or sedimentation prior to the excavations. Comparable datasets from other nearby sites would also have been very helpful in order to better understand whether the data are local or regional.

Was the purpose to monitor the shipwreck as a vulnerable cultural heritage monument? Then the methodological approach cannot be said to have worked according to plan. The results presented in this report do not give any information regarding the condition of the organic materials deposited on this site constituting the actual heritage monument discovered in 2003. There has been no documentation or methods directed towards the monitoring of the organic materials to see their level of preservation and whether the situation has been altered and to which degree. The two main methodological approaches, i.e. the sediment trap and the current meter have only been targeted towards the water-column and not the wreck. The sediment indicators also appear not to have an optimal design, as they do not integrate with the sediments and do not seem to portray the actual level of sedimentation in a realistic manner (see Chapter 9.2.2). Thus we do not really know what happened to the wreck itself. The only methodology focusing solely on the shipwreck itself was the wood sampling, which was only part of the 2011 survey, and with scant results (see Chapter 9.5). But why was not such an approach initiated earlier in order to evaluate the condition of the hull timbers. The piece that was extracted was marked by severe deterioration in some areas, but was this new and increasing damage or had this deteriorating situation declined and levelled? This was not investigated. The focus seems to have been on a more overall environmental issues regarding coverage of the wreck; whether it was covered or not. This is documented in the given survey reports, although a more precise type of measurement as well as knowledge regarding composition would have been desirable.

Neither was there any biological monitoring, only monitoring of the physical situation. Wood borers such as the shipworms only constitute a threat to exposed wooden shipwrecks as they require dissolved oxygen for their respiration. In oxygen deficient environments, microbial decay (fungi and bacteria, such as the erosion bacteria) is still active, but at a very slow rate compared to exposed timbers. Thus measurements of chemical parameters such as dissolved oxygen and redox would have provided factual data concerning the actual state of preservation of the shipwreck, rather than relating to visual observations.

Therefore, what is interesting is not whether the wreck is covered by sediments, it is how. Unless the sediment cover is significant, it will in this setting not constitute a protection, as it will not create an anaerobic environment, but provide for oxygen as well as bacteria and organisms destroying the organic materials, i.e. the timers of the hull and structure.

It appears that the assumption was that the sediments re-deposited on the site were enough to protect the wreck. It must be remembered that the wreck was just loosely covered with sediments after the end of excavation, when intrusive methods were applied which disturbed the state of equilibrium, sediments being re-deposited using the ROV thrusters to fan it into position. The sediments were not fixed in position using sandbagging, debris netting, scour mats or other mitigation measures; neither was geo-textiles used underneath the sand to further protect the vessel. It must however be noted that whilst such measures increasingly have been used successfully on numerous shipwreck sites, none of these have been at such depths, and the logistically implications would have been substantial, although feasible, all the inventive and extensive work with the pipelines and the excavation taken into account (see Bryn, Jasinski and Søreide 2007). And it will be interesting to learn from the final report of the excavations, which discussions took place relating to the covering of the shipwreck and the aimed purpose. When one chose to cover the wreck by just fanning the loose and untangled sediments back over the wreck, one also directed the course of preservation. As the sediment cover was not fixed, one must anticipate scouring until sediments have settled and reached a new level of equilibrium. It is indicative that the years following the excavation saw the bow section to a large degree exposed, until the sediments seemed to settle around 2009, a situation that remains until 2012.

11. CONCLUSION

The Directorate for Cultural Heritage stated in their letter of permission dated 08.06.2005 that if the environmental monitoring provided data indicating destruction of the wreck documented to be most probably caused by the pipeline project, the developer would be ordered to secure the heritage site. The intention with the monitoring project was thus to document whether the construction of the pipelines adjacent to the shipwreck would affect the site to such a degree that it caused deterioration to the protection of the cultural heritage monument.

The monitoring project was established in 2005, and the first survey conducted in 2006. Since then the surveys were carried out in 2007, 2008, 2009, 2011, 2012 (spring) and 2012 (autumn). The methodology has been thoroughly presented in this report, and it aimed to gather valid documentation relating to the sedimentation and scouring processes on the site. This was done by collecting sediments in a sediment trap, collecting data on the currents situation using a current meter, installing sediment indicators for visual observation of net rate of sedimentation and, finally, by conducting visual video surveys of the site.

Important information regarding the levels of sedimentation and situation of currents has been collected throughout the course of the project. The data collected in general show fairly stable and similar results regarding both currents and sediments. There are fluctuations within the survey periods, but mainly throughout the year, with annual peaks in the period between August and October. The underwater terrain itself is rugged and naturally prone to creating underwater currents. It must also be noted that the wreck was uncovered and its state of equilibrium disturbed during the excavations in 2004 and 2005, and was only covered up afterwards by fanning the loose sediments back over the hull. It will naturally take some years after it was covered up in 2005 for the sediment to reach a new level of equilibrium. Until then the fine sand sediment has been shifting on the seabed, and some will have been transported into the water column to be collected by the sediment trap.

The last survey was undertaken in 2012. Prior to this NTNU University Museum and the Directorate for Cultural Heritage had agreed that the acquired data were sufficient to document the level of risk between the installed pipelines and the wreck site. The conclusion was that there was no data that documented that the pipelines were disturbing the wreck site or in conflict with the site, and thus Norske Shell AS had fulfilled their duty as the developer towards the Cultural Heritage Act and the Directorate for Cultural Heritage's letter of exemption. The Directorate concluded in their letter of January 17th 2014 (Appendix 3); "We confirm that the environmental monitoring of the shipwreck site founded on the Directorate for Cultural Heritage's letters of decision of 8.6.2005 and 27.6.2007 has been accomplished. The terms of exemption have thus been fulfilled".

Even though one would most likely have chosen supplementary types of documentation given a new deep sea monitoring effort. There is no doubt that the Ormen Lange Monitoring project first in collaboration with Hydro and later with Shell has brought knowledge and technological development regarding deep sea monitoring of cultural heritage very many steps ahead. This could not have been achieved without a very fruitful collaboration with the two clients, Hydro and Shell. We wish to thank you for this collaboration.

12. Literature

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13. Appendixes

Appendix 1 – Directorate for Cultural Heritage's letter of 8.6.2005_Excemption from the Cultural Heritage Act

Appendix 2 – Directorate for Cultural Heritage's letter of 27.6.2007_Excemption from the Cultural Heritage Act

Appendix 3 – Directorate for Cultural Heritage's letters of 8.6.2005_Statement regarding accomplishment of environmental monitoring project

Appendix 4 – NGU sediment reports 2007, 2008, 2009 and 2012

Appendix 1 – Directorate for Cultural Heritage’s letter of 8.6.2005_Excemption from the Cultural Heritage Act

SAKSBEHANDLER
Seniorkonsulent Frode Kvalø
DERES REF.

INNVALGSTELEFON
22 94 04 91
DERES DATO

TELEFAKS
22 94 04 07

RIKSANTIKVAREN

VÅR REF.
2001/2036 – 2005/656
Ark. 865.2

VÅR DATO
8 JUN 2005

GJENPART

Hydro Olje & Energi
Ormen Lange Offshore Prosjekt
N-0240 Oslo

Att: Petter Bryn

INNVILGELSE AV SØKNAD OM DISPENSASJON ETTER KULTURMINNELOVEN § 14 ANNET LEDD, ANNET PUNKTUM, ORMEN LANGE MARIN, BJØRNSUND VED BUD, FRÆNA KOMMUNE, MØRE- OG ROMSDAL FYLKE

Vi viser til søknad fra Hydro av 17.3.2004 om legging av rør og styringskabler gjennom Bjørnsund ved Bu, Fræna kommune, Møre og Romsdal fylke, og brev fra NTNU Vitenskapsmuseet av 4.4.2005.

Tiltaket vil berøre et skipsfunn som er vernet i medhold av lov om kulturminner av 1978 nr. 50 (kml) § 14 første ledd. I henhold til kml § 14 annet ledd, annet punktum er inngrep i skipsfunn forbudt med mindre det foreligger tillatelse fra rette myndighet. Forskrift om faglig ansvarsfordeling mv. etter kulturminneloven § 1 pkt. 1, fastsetter at Riksantikvaren er rette myndighet til å gi slik tillatelse.

Vedtak
Med hjemmel i kml § 14 annet ledd, annet punktum fatter Riksantikvaren følgende vedtak:

> *Hydro gis tillatelse til legging av ledninger i Bjørnsund, Fræna kommune, Møre og Romsdal fylke, jf. avmerking på vedlagte kart, stemplet og datert 11.5.2005. Tiltaket vil medføre inngrep i skipsfunn med registreringsnummer **91448**.*
>
> Tillatelsen gis på følgende vilkår:
>
> *NTNU Vitenskapsmuseet skal før anleggsstart foreta en faglig granskning av det nevnte kulturminnet i henhold til vedlagt prosjektplan.*
>
> *Omfanget av den faglige granskningen er kostnadsberegnet til **inntil kr 10 913 044,-**, jf. vedlagt budsjett. Budsjettet forutsetter at de geofysiske anomaliene påvist i trasen ikke er deler av skipsfunnet. En eventuell funnbehandling her vil kunne kreve en utvidelse av budsjettrammen.*

Riksantikvaren
Dronningens gate 13
Postboks 8196 Dep, 0034 Oslo
Telefon: 22 94 04 00 Telefaks: 22 94 04 04 E-post: riksantikvaren@ra.no

Tiltakshaver skal inkludere videoopptak av kulturminnet, innhenting av data fra strømmåler og visuell kontroll av sedimentasjon, som en del av tiltakshavers inspeksjonsprogram for ledningstraseen i driftsfasen. En marinarkeolog fra NTNU Vitenskapsmuseet skal veilede, og delta i, dette miljøovervåkningsarbeidet på kulturminnet, samt overta den innhentede dokumentasjonen.

Tiltakshaver bekoster de arkeologiske arbeidene, jf. kml § 10.

Det skal ikke etableres steinfyllinger i områder avgrenset på kart, se vedlegg 4.

Tiltaket har ikke dispensasjon til å skade hovedkonsentrasjonen av skipsfunnet.

Tillatelsen gjelder bare det omsøkte tiltaket. Tillatelsen bortfaller dersom tiltaket ikke er iverksatt innen 3 år fra mottakelsen av dette brev.

Klageadgang
Vedtaket kan påklages i medhold av forvaltningsloven § 28. En eventuell klage stiles til Miljøverndepartementet, men sendes til Riksantikvaren. Før oversendelse til Miljøverndepartementet skal Riksantikvaren uttale seg til klagen og vurdere eventuelt grunnlag for omgjøring av vedtaket. Klagefristen er 3 uker fra mottakelsen av dette brevet, jf. forvaltningsloven §§ 28 og 29.

Framdrift og gjennomføring
I henhold til avtale med partene gjennomføres den faglige granskningen snarest mulig, og feltarbeidsdelen av granskningen skal avsluttes senest høsten 2005.

Tiltakshaver må varsle NTNU Vitenskapsmuseet i god tid før inspeksjoner av ledningstraseen gjennom kulturminnet skal gjennomføres.

Tiltaket skal gjennomføres som vist på vedlagte kart. Mindre endringer/avvik kan klareres med NTNU Vitenskapsmuseet. Større endringer i det omsøkte tiltaket krever ny søknad til Riksantikvaren.

Beskrivelse av kulturminnet
Skipsfunnet fremstår som tilnærmet helhetlig deponert, med en klar konsentrasjon av et omfattende gjenstandsmateriale rundt delvis synlige og sammenhengende skrogelementer. Et større område rundt denne konsentrasjonen har gjenstandsfunn som kan stamme fra samme forlis. Geofysiske undersøkelser indikerer også steder med tildekket materiale som kan være en del av funnet. Dette er ennå ikke verifisert og kan medføre en utvidet gransking. Kulturminnet dekker et område på omkring 200 x 400 m.

Skipsklokken, som ble funnet in situ, har innpreget årstallet 1745. Det gjenstandsmaterialet som er undersøkt til nå indikerer at forliset skjedde mellom år 1770 og 1810. Gjenstandene har ulike opprinnelsessteder. Skrogelementer er ikke opphavsbestemt.

Funnet ble gjort av NTNU Vitenskapsmuseet ved befaring av deler at de planlagte rørtraseene for Ormen Lange-utbyggingen, i henhold til undersøkelsesplikten i kml § 9.

Beskrivelse av det omsøkte tiltaket
Ormen Lange feltet ligger på vanndyp mellom 700 og 1100 m ca 120 km vest for Kristiansund. Utbyggingskonseptet for Ormen Lang består av et undervannsanlegg på feltet og rørledninger til Nyhamna på Gossen utenfor Molde der det bygges et prosesseringsanlegg for gassen. Fra Nyhamna vil den prosesserte gassen bli transportert til Sleipner og videre til Easington i England. Feltet planlegges ferdig utbygd i 2007 med forventet produksjonsstart høsten 2007.

For kulturminnet innebærer Ormen Lange-utbyggingen en konflikt med den såkalte hjelpetraseen, dvs. spyling av fire sjakter av en meters bredde gjennom den lengste aksen av kulturminnets utstrekning. I sjaktene skal det plasseres to glykolrør og to styringskabler. Samlet bredde på korridoren er ikke endelig avklart av Hydro, men utgangspunktet er en korridor på ca. 40 m bredde gjennom kulturminnet syd for skipsfunnets hovedkonsentrasjon.

Hydro har søkt alternative traseer for ledningene uten å lykkes. Bjørnsund er relativt smalt og har en undervannstopografi som innsnevrer mulighetene for alternative traseer. Det er også flere kulturminner i sundet. Ledningene er imidlertid flyttet så langt vekk fra kulturminnets hovedkonsentrasjon som topografien tillater. Avstanden mellom ledningene skal også gjøres så liten som mulig.

Ledningene skal i utgangspunktet tildekkes med stein for å sikre dem mot skade ved bruk av bunnredskap, nødankring m.v. Hydro, Riksantikvaren og NTNU Vitenskapsmuseet avtalte i møte 26. januar 2005 å avgrense et område ved kulturminnet hvor det ikke skal dumpes stein, for å unngå det skadepotensialet tildekkingen ville medføre for kulturminnet.

Tiltaket gir irreversible inngrep i kulturminnet. Foruten skade på deler av lokaliteten, vil både selve leggearbeide med ledningene, fremtidige inspeksjoner og mulige vedlikehold/reparasjonsarbeider medføre aktivitet i og rundt kulturminnet. Det er usikkert hvor omfattende denne aktiviteten blir, og hvilke skadevirkninger den eventuelt vil kunne ha på kulturminnet.

Museet bemerker
Vitenskapsmuseet vurderer kulturminnet som svært viktig, godt bevart og representativt for vraklokaliteter på dypt vann i Norge. Det understrekes imidlertid at vi kjenner meget få slike dypvannslokaliteter.

Museet tilskriver kulturminnet høy verdi som kilde til kunnskap om den lokale og regionale kulturhistorien og kulturlandskapet, og også som kilde til kunnskap om internasjonal handel og transport på overgangen til det nittende århundre.

Museet fremhever at den generelle kunnskapen om kulturminnelokaliteter på dypt vann er svært liten, og at langtidsvirkningene av den typen tiltak som er planlagt her ikke tidligere er dokumentert under sammenlignbare forhold.

Museet mener at det planlagte tiltaket vil skade kulturminnet gjennom kortsiktige og langsiktige effekter av etablering og drift av ledningstraseen. Museet forutsetter dog at tiltaket ikke vil skade hovedkonsentrasjonen i kulturminnet.

Vitenskapsmuseet konkluderer med å tilrå dispensasjon med vilkår om arkeologiske undersøkelser forut for tiltaket og overvåkning av kulturminnet i tiltakets driftsfase.

Riksantikvarens vurdering og begrunnelse for vedtaket
Riksantikvaren skal verne om kulturminner og kulturmiljøer som ikke-fornybare ressurser. Kulturminnelovens bestemmelser og miljømål vedrørende skipsfunn innebærer at inngrep bare bør tillates i de tilfeller et avslag vil medføre så store negative private eller samfunnsmessige konsekvenser at det ikke står i et rimelig forhold til betydningen av å bevare kulturminnet på stedet.

Skipsfunnet har nasjonal interesse som kilde til en hendelse, der et større skipssamfunn er gått tapt ved forlis i åpen sjø, og som kilde til det maritime transport- og verdiskapningssystemet som var et sentralt kulturelement i Nord-Europa i det 18. og 19. århundre. Kulturminnet er også en dypvannslokalitet, hvor en del deponerings- og postdeponeringsfaktorer, som har virket sterkt inn på det funnbildet vi dokumenterer i vår tid, er annerledes enn de faktorene vi kjenner fra lokaliteter på grunt vann. Skipsfunn på dypt vann er svakt representert i den kjente kulturminnebestanden og dette kulturminnet er derfor en meget viktig tilvekst og har en høy verdi som referanselokalitet for kulturminner i tilsvarende funnmiljø.

Ormen Lange-utbyggingen er et viktig energiproduksjonstiltak med betydelige samfunnsøkonomiske ringvirkninger på mange nivåer. Samfunnsnytten av tiltaket veier følgelig tungt i Riksantikvarens vurdering av denne saken. Direktoratet legger også vekt på at Hydro i høy grad har søkt å finne løsninger for å redusere konflikten med kulturminnet, jf. pkt. om *Beskrivelse av det omsøkte tiltaket.*

Riksantikvaren legger til grunn at tiltaket medfører irreversible inngrep i deler av lokaliteten og i miljøkonteksten på stedet. Den sentrale delen av lokaliteten blir ikke direkte berørt ved inngrepet, men det er usikkerhet knyttet til om tiltaket på lengre sikt kan medføre skadevirkninger også der.

Etter en helhetsvurdering finner Riksantikvaren at det kan innvilges dispensasjon for det omsøkte tiltaket på de vilkår som fremgår av vårt vedtak.

Kulturminneforvaltningen har et ansvar for kulturminner på dypt vann, men har foreløpig hatt liten aktivitet på dette området. Vi mangler derfor en del av det nødvendige empiriske, teoretiske og metodiske grunnlaget for å kunne oppfylle de nasjonale resultatmålene også i dette funnmiljøet. Undersøkelsene av dette kulturminnet er derfor å regne som nybrottsarbeid i kulturminneforvaltningen og vil således være et pilotprosjekt for fremtidige forvaltningsgrep om kulturminner på dypt vann.

Riksantikvaren sier seg enig i NTNU Vitenskapsmuseets prioritering av oversiktskunnskap, gjennom ikke-intrusive metoder, begrenset sjakting og kun opptak av enkelte utvalgte gjenstander, samt dokumentasjon av eventuelle endringer på lokaliteten. Et vilkår om miljøovervåkning er nødvendig for å innhente data om utviklingen på lokaliteten, ettersom langtidsvirkninger av den typen tiltak som skal gjennomføres ikke tidligere er dokumentert under sammenlignbare forhold.

Hvis miljøovervåkningen gir data som indikerer at kulturminnet brytes ned i et uventet tempo eller skades på annen måte, og det kan dokumenteres at det er overveiende sannsynlig at tiltaket er årsaken til dette, vil Riksantikvaren kunne stille krav om sikring av kulturminnet overfor tiltakshaver.

Avslutningsvis gjør Riksantikvaren oppmerksom på at dersom det under den arkeologiske utgravningen, eller senere under anleggsarbeidet, oppdages/fremkommer andre automatisk fredete eller vernede kulturminner enn det tillatelsen gjelder for, skal arbeidet straks stanse i den utstrekning det kan berøre kulturminnet og NTNU Vitenskapsmuseet varsles, jf. kml §§ 8 annet ledd og 14. Riksantikvaren avgjør snarest mulig og senest innen tre uker om arbeidet kan fortsette og vilkårene for dette.

Vennlig hilsen

Ingrid Smedstad
Ingrid Smedstad (e.f.)
seksjonssjef

Frode Kvalø
Frode Kvalø

Vedlegg: 1) Kart skipsfunn 91448 stemplet Riksantikvaren og datert 3.6.2005
2) Prosjektplan NTNU datert 22.3.2005
3) Budsjett NTNU datert 6.4.2005
4) Oversikt over området hvor det ikke skal dumpes stein, stemplet Riksantikvaren og dater 3.6.2005

Gjenpart: Norges teknisk-naturvitenskapelige universitet, Vitenskapsmuseet
Institutt for arkeologi kulturhistorie, 7491 Trondheim
Fræna kommune, 6440 Elnesvågen
Møre og Romsdal fylke, Kulturavdelinga, Fylkeshuset, 6404 Molde

Appendix 2 – Directorate for Cultural Heritage's letter of 27.6.2007_Excemption from the Cultural Heritage Act

SAKSBEHANDLER
Ivar Aarrestad

VÅR REF.
06/01898-4

DERES REF.

Ark. Forvaltning
865.1

INNVALGSTELEFON

DERES DATO

VÅR DATO
27.6.2007

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postmottak@ra.no
www.riksantikvaren.no

Norsk Hydro Produksjon AS - Ormen Lange
Offshore Project

0240 OSLO

INNVILGELSE AV DISPENSASJON FRA KULTURMINNELOVEN § 14, 2. LEDD, 2. PKT. BJØRNSUNDET, FRÆNA KOMMUNE, MØRE OG ROMSDAL FYLKE

Vi viser til søknad fra Hydro olje og energi av 10.05.2007. Søker ber om at Riksantikvaren innvilger dispensasjon for tildekking av rørtrase ved skipsvrak. Videre vises det til uttalelse fra NTNU Vitenskapsmuseet. til Riksantikvaren datert 30.05.2007.

Rørtraseen ligger i influensområde til skipsvrak ID 91448, som er gjenstandsdatert til slutten av 1700- begynnelsen av 1800-tallet og tiltaket vil følgelig berøre et skipfunn som er automatisk vernet i medhold av lov om kulturminner av 1978 nr. 50 (kml) § 14 første ledd. I henhold til kml § 14 annet ledd, annet punktum er inngrep i skipsfunn forbudt med mindre det foreligger tillatelse fra rette myndighet. Forskrift om faglig ansvarsfordeling mv. etter kulturminneloven, § 1 pkt. 1. fastsetter at Riksantikvaren er rette myndighet til å gi slik tillatelse.

Vedtak
Med hjemmel i kml § 14 annet ledd ledd annet punktum fatter Riksantikvaren følgende vedtak:

Hydro Olje og Energi gis tillatelse til å tildekke rørledning gjennom Bjørnsundet. Tiltaket vil medføre inngrep i skipsfunn med ID 91448, jf. vedlagt kart stemplet Riksantikvaren og datert 27.06.2007.

Tillatelsen gis på følgende vilkår:
Det skal fylles stein kun i den omsøkte grøften opp til, men ikke høyere enn eksisterende havbunnnivå.
NTNU Vitenskapsmuseet skal overvåke steindumpingen i angitt lengde mellom KP 8.500 og KP 8.550.

Tiltakshaver bekoster den arkeologiske overvåkningen jf. kml § 10.

Omfanget av arbeidet er beregnet til inntil kr. 10.805,- eksklusiv mva. (2007 – kroner og satser), jf. vedlagt budsjett.

Dispensasjonen er gyldig i tre år fra dato.

Klageadgang
Vedtaket kan påklages i medhold av forvaltningslovens § 28. En eventuell klage stiles Miljøverndepartementet, Kulturminneavdelingen, postboks 8013 Dep. 0030 Oslo. Klagen skal sendes til Riksantikvaren, Kulturminneavdelingen, postboks 8196 Dep., 0034 Oslo. Før oversendelse til Miljøverndepartementet skal Riksantikvaren uttale seg til klagen og vurdere eventuelt grunnlag for omgjøring av vedtaket. Klagefristen er 3 uker fra mottakelsen av dette brevet, jf. forvaltningsloven §§ 28 og 29.

Framdrift og gjennomføring
Hydro Olje og Energi avtaler tid for gjennomføring av overvåkning med NTNU Vitenskapsmuseet i god tid før tiltaket er planlagt igangsatt.

Tiltaket skal gjennomføres som vist på vedlagte kart. Mindre endringer/avvik kan klareres NTNU Vitenskapsmuseet. Større endringer i forhold til det omsøkte tiltaket krever ny søknad til Riksantikvaren.

Beskrivelse av kulturminnene
I forbindelse med undersøkelser i forbindelse med forarbeidene til kabeltrase i 2003, påviste NTNU Vitenskapsmuseet et skipsvrak i umiddelbar nærhet til ønsket trase. Skipsvraket viste seg å være bunnseksjon av en seilskute, samt last. Vraket ble på bakgrunn av gjenstander om bord datert til slutten av 1700- begynnelsen av 1800-tallet. Skipsvraket var gjenstand for en begrenset arkeologisk undersøkelse i 2005.

Beskrivelse av det omsøkte tiltak
Tiltakshaver søker om å få dekke til eksisterende rør for føring av Glykol igjennom Bjørnsundet. I forbindelse med rørleggingsprosessen er det behov for å dekke til rørene i enkelte områder for å hindre at røret knekker pga såkalt "termisk ekspansjon". Tiltakshaver er oppmerksom på at det er ønskelig å begrense tiltak i det omsøkte området, og opplyser at tildekkingen er å regne som et minimum av det som må til for å kunne starte produksjonen, samtidig som man skaper minimalt med endring i erosjons- og strømforholdene i området.

NTNU Vitenskapsmuseet uttaler
NTNU Vitenskapsmuseet anser vraket som ligger i området for å ha vitenskapelige kvaliteter av internasjonalt format. Vraket ligger dypt, og det er gode bevaringsforhold i området. Ethvert tiltak i området som kan skape endringer i strømforholdene medfører en større fare for påfølgende avdekking av vraket og en forverring av bevaringsforholdene.

NTNU Vitenskapsmuseet har, på bakgrunn av tidligere undersøkelser av vraket, samt pågående miljøovervåkning i området av den oppfatning at tiltaket kan gjennomføres uten fare for en større slitasje på vraket, dersom tiltaket gjennomføres som Hydro Olje og Energi har angitt i sin søknad. NTNU Vitenskapsmuseet anbefaler Riksantikvaren å gi dispensasjon mot at arbeidene overvåkes av arkeolog og at Hydro Olje og Energi klarer å gjennomføre steinfyllingen med den presisjon det opplyses om i søknaden..

Riksantikvarens merknader og begrunnelse for vedtaket
Riksantikvaren skal verne om kulturminner og kulturmiljøer som ikke-fornybare ressurser. Skipsfunnet representerer en slik ikke fornybar ressurs og er svært sårbar for endringer i bunnforholdene. Kulturminnelovens bestemmelser og miljømål vedrørende skipsfunn innebærer at inngrep bare bør tillates i de tilfeller et avslag vil medføre så store negative private eller samfunnsmessige konsekvenser at det ikke står i et rimelig forhold til kulturminnets betydning. Vedtak om tillatelse til inngrep i skipsfunn må følgelig være grunnet i vesentlige private og samfunnsmessige hensyn. Gassfeltet Ormen Lange og landanlegget i Nyhamna er av stor betydning for norsk økonomi. En forsinkelse i oppstarten av anlegget vil medføre store negative konsekvenser internasjonalt.

Skipsvraket som ligger i området er av stor vitenskapelig verdi. Rapporten fra undersøkelsene foreligger ikke per dags dato, men preliminære rapporter viser at både materialet og skipet kan gi mye informasjon. Tiltaket kommer etter Riksantikvarens syn ikke i direkte konflikt med tiltaket, og så lenge fyllingen av stein skjer kontrollert og i tråd med det tiltakshaver opplyser om i sin søknad, anser vi farene for en forringning av bevaringsforholdene i vrakområdet som minimale.

Avslutningsvis gjør Riksantikvaren oppmerksom på at dersom det under anleggsarbeidet oppdages/fremkommer andre automatisk fredete eller vernede kulturminner enn det tillatelsen gjelder for, skal arbeidet straks stanses i den utstrekning det kan berøre kulturminnet NTNU Vitenskapsmuseet varsles, jf. kml § 8, 2. ledd og § 14. Riksantikvaren avgjør snarest mulig og senest innen tre uker om arbeidet kan fortsette og vilkårene for dette.

Vennlig hilsen

Ingrid Smedstad
Ingrid Smedstad (e.f.)
Seksjonssjef

Terje B. Haland
for Ivar Aarrestad

Vedlegg: Kart datert 27.06.2007
Budsjett NTNU Vitenskapsmuseet

Kopi til: NTNU - Vitenskapsmuseet, 7491 TRONDHEIM
Møre og Romsdal fylke, Kulturavdelinga - Fylkeshuset, 6404 Molde

Appendix 3 – Directorate for Cultural Heritage's letters of 8.6.2005_Statement regarding accomplishment of environmental monitoring project

SAKSBEHANDLER
Ivar Nesse-Aarrestad

VÅR REF.
12/02646-2

DERES REF.

ARK. Forvaltningsarkivet
865.1

INNVALGSTELEFON

DERES DATO

VÅR DATO
17.01.2014

TELEFAKS
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www.riksantikvaren.no

KOPI

As Norske Shell
Postboks 2244
6305 Kristiansund

Melding om ferdigstilt miljøovervåkning av tiltak ved skipsfunn Id 91448.

Riksantikvaren er i brev fra NTNU Vitenskapsmuseet orientert om at miljøovervåkningsprosjektet i forbindelse med legging av rørledning til Ormen Lange feltet er avsluttet.

Vi bekrefter med dette at miljøovervåkningen som er hjemlet i Riksantikvarens vedtak av 8.6.2005 og 27.6.2007 er gjennomført. Vilkårene for dispensasjonen er dermed oppfylt.

Rapporten for det arkeologiske arbeidet vil bli oversendt fra museet så snart den er ferdigstilt. Eventuelt ubrukte midler vil tilbakeføres derfra når regnskapet avsluttes.

Vennlig hilsen

Ivar Nesse-Aarrestad

Kopi til: NTNU - Vitenskapsmuseet, 7491 TRONDHEIM

Appendix 4 – NGU sediment reports 2007, 2008, 2009 and 2012

Norges geologiske undersøkelse
NGU-Lab0
Norges geologiske undersøkelse
7491 TRONDHEIM
Tlf.: 73 90 40 11
Telefaks: 73 92 16 20

KORNFORDELINGSANALYSE : COULTER LASER
GEOLOGISK MATERIALE
Analysekontraktsnr: 2007.0455

METODE (Fullstendig beskrivelse gitt i NGU-SD 5.11)
Kornfordelingsbestemmelse basert på laserdiffraksjon. Laserlys brytes i bestemte vinkler avhengig av størrelsen på partiklene, som igjen registreres av en rekke detektorer. De registrerte vinklene korresponderer med gitte partikkelstørrelser, antall partikler med en gitt størrelse er igjen relatert til intensitet for korresponderende detektorer. Kornfordelingen bestemmes således på volum-basis, med antagelse om samme tetthet på materialet vil kumulativ volum% være identisk med kumulativ masse%. Beregning på volum/masse-basis er basert på antagelse om sfæriske partikler.

INSTRUMENT TYPE : Coulter LS 200

MÅLEOMRÅDE: 0.4µm-2000µm

NB! Metoden normaliserer alle data i måleområdet til 100 % (kumulativ%). Måleområdet går kun til 0.4 µm og dette settes som nullpunkt mhp.kumulativ %. Således kan prøvene inneholde materiale finere enn 0.4µm.

ANALYSEUSIKKERHET: ± 3% [kumulativ masse(volum) %]
Bestemmelse av usikkerhet er basert på sammenligning av oppnådde resultater og sertifikatverdier for kvarts standard BCR 131, samt presisjonsdata.

MERK! Metoden tar utgangspunkt i antagelse om sfæriske partikler. For prøver som avviker fra dette kan usikkerheten være større.

PRESISJON : Det kjøres rutinemessig kontrollprøver, som føres i kontrolldiagram (X-diagram). Disse kan forevises om ønskelig..

ANTALL PRØVER: 13

FORBEHANDLING : Se Tabell 2

ANTALL SIDER (denne delrapport): 5 + 13 vedlegg (Plott av kumulativ kornfordeling med div. statistiske parametre)

ANMERKNINGER: Ingen.

Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Ferdig analysert	19.12.2007	Wieslawa Koziel
	Dato	OPERATØR

Tabell 1 Kumulativ (<) kornfordeling [(volum%(masse%)]

Prøve nr.→ Diameter(μm) ↓	Prøve nr. 1	Prøve nr. 2	Prøve nr. 3	Prøve nr. 4	Prøve nr. 5	Prøve nr. 6	Prøve nr. 7	Prøve nr. 8	Prøve nr. 9	Prøve nr. 10	Prøve nr. 11	Prøve nr. 12	Prøve nr. 13
0.375	0	0	0	0	0	0	0	0	0	0	0	0	0
0.412	0.014	0.013	0.0046	0.0085	0.0041	0.0054	0.0062	0.0081	0.0079	0.0038	0.0068	0.0058	0.0044
0.452	0.037	0.036	0.012	0.023	0.011	0.014	0.016	0.022	0.021	0.0098	0.018	0.016	0.012
0.496	0.074	0.072	0.025	0.047	0.022	0.03	0.034	0.044	0.043	0.021	0.037	0.032	0.024
0.545	0.14	0.13	0.052	0.09	0.043	0.058	0.068	0.086	0.085	0.044	0.071	0.061	0.045
0.598	0.23	0.22	0.1	0.17	0.077	0.11	0.13	0.16	0.16	0.09	0.13	0.11	0.081
0.657	0.38	0.36	0.19	0.29	0.13	0.2	0.24	0.28	0.28	0.17	0.23	0.19	0.14
0.721	0.59	0.54	0.33	0.48	0.21	0.33	0.4	0.47	0.47	0.31	0.38	0.32	0.22
0.791	0.87	0.79	0.53	0.75	0.33	0.53	0.63	0.73	0.74	0.5	0.59	0.49	0.34
0.869	1.25	1.13	0.81	1.12	0.48	0.8	0.95	1.09	1.1	0.77	0.87	0.73	0.51
0.953	1.74	1.55	1.18	1.61	0.69	1.15	1.38	1.57	1.59	1.13	1.25	1.05	0.72
1.047	2.35	2.08	1.66	2.23	0.95	1.61	1.93	2.18	2.22	1.6	1.73	1.45	0.99
1.149	3.08	2.72	2.25	3	1.27	2.17	2.61	2.93	2.99	2.19	2.31	1.94	1.32
1.261	3.95	3.48	2.96	3.91	1.65	2.84	3.43	3.83	3.91	2.88	3.01	2.52	1.71
1.385	4.93	4.34	3.78	4.97	2.08	3.61	4.38	4.87	4.97	3.68	3.82	3.19	2.17
1.52	6.02	5.29	4.7	6.16	2.58	4.49	5.44	6.04	6.16	4.59	4.72	3.95	2.67
1.669	7.2	6.32	5.7	7.45	3.11	5.44	6.6	7.32	7.45	5.57	5.69	4.77	3.23
1.832	8.45	7.41	6.77	8.82	3.69	6.47	7.84	8.67	8.83	6.61	6.73	5.65	3.82
2.01	9.74	8.54	7.88	10.2	4.29	7.54	9.13	10.1	10.2	7.69	7.8	6.57	4.44
2.207	11	9.69	9.02	11.7	4.91	8.65	10.4	11.5	11.7	8.78	8.89	7.51	5.07
2.423	12.4	10.8	10.2	13.1	5.54	9.78	11.8	13	13.1	9.89	9.99	8.47	5.72
2.66	13.7	12	11.3	14.6	6.18	10.9	13.1	14.4	14.5	11	11.1	9.44	6.37
2.92	15	13.2	12.5	16.1	6.84	12.1	14.5	15.9	16	12.1	12.2	10.4	7.04
3.206	16.4	14.4	13.7	17.5	7.5	13.3	15.9	17.5	17.4	13.3	13.3	11.4	7.73
3.519	17.7	15.6	14.9	19.1	8.18	14.5	17.3	19	18.9	14.5	14.5	12.4	8.43
3.862	19.1	16.8	16.2	20.6	8.87	15.8	18.8	20.6	20.4	15.7	15.7	13.5	9.15
4.241	20.5	18.1	17.4	22.1	9.58	17	20.3	22.2	21.9	16.9	16.9	14.5	9.89
4.656	21.9	19.4	18.7	23.7	10.3	18.3	21.8	23.9	23.4	18.2	18.2	15.6	10.6
5.111	23.3	20.8	20	25.4	11	19.6	23.4	25.5	25	19.5	19.5	16.7	11.4
5.611	24.8	22.1	21.4	27	11.8	21	25	27.2	26.5	20.9	20.8	17.9	12.2

Norges geologiske undersøkelse
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KORNFORDELINGSANALYSE : COULTER LASER
GEOLOGISK MATERIALE
Analysekontraktsnr: 2007.0455

NORSK AKKREDITERING TEST 020

6.158	26.2	23.5	22.7	28.6	12.5	22.3	26.5	28.9	28.1	22.3	22.1	19	13
6.761	27.7	24.9	24.1	30.2	13.3	23.6	28.1	30.6	29.6	23.7	23.5	20.2	13.9
7.421	29.1	26.2	25.4	31.8	14	24.9	29.6	32.2	31.1	25.2	24.9	21.3	14.7
8.147	30.5	27.5	26.8	33.4	14.8	26.1	31.1	33.7	32.5	26.6	26.2	22.5	15.6
8.944	31.9	28.9	28.1	34.9	15.5	27.4	32.5	35.3	34	28	27.6	23.7	16.4
9.819	33.2	30.2	29.4	36.5	16.3	28.7	33.9	36.7	35.4	29.4	29	24.9	17.3
10.78	34.6	31.5	30.8	38	17.1	29.9	35.3	38.2	36.8	30.9	30.4	26.2	18.3
11.83	36.1	32.8	32.2	39.6	17.9	31.2	36.7	39.7	38.2	32.3	31.9	27.5	19.2
12.99	37.6	34.3	33.7	41.2	18.8	32.6	38.2	41.2	39.6	33.8	33.4	28.8	20.3
14.26	39.2	35.8	35.3	43	19.8	34	39.8	42.8	41.2	35.4	35.1	30.3	21.4
15.65	40.9	37.5	37	44.9	20.8	35.6	41.5	44.6	42.9	37.1	36.9	31.9	22.6
17.18	42.8	39.4	38.9	47	22	37.3	43.3	46.4	44.8	38.9	38.8	33.6	24
18.86	44.8	41.4	40.9	49.2	23.3	39.1	45.3	48.4	46.7	40.9	40.9	35.5	25.4
20.7	46.9	43.5	43.1	51.5	24.6	41.1	47.3	50.4	48.7	42.9	43.1	37.5	26.9
22.73	49.1	45.6	45.3	53.8	26.1	43.1	49.4	52.5	50.6	45.1	45.5	39.5	28.6
24.95	51.3	47.8	47.5	56.1	27.6	45.2	51.5	54.5	52.6	47.3	47.8	41.7	30.3
27.38	53.6	50.1	49.8	58.4	29.3	47.3	53.6	56.6	54.6	49.6	50.3	43.9	32.1
30.07	55.9	52.4	52.3	60.8	31.1	49.6	55.8	58.7	56.7	51.9	52.9	46.3	33.9
33	58.4	54.8	54.7	63.2	33	52	58	60.9	58.8	54.3	55.5	48.7	35.9
36.24	60.9	57.3	57.3	65.6	35	54.5	60.4	63.1	60.9	56.8	58.1	51.2	37.9
39.77	63.5	59.8	59.8	68	37.2	57.1	62.8	65.4	63.2	59.3	60.8	53.7	39.9
43.66	66.2	62.4	62.5	70.4	39.6	59.8	65.3	67.8	65.4	61.9	63.5	56.3	42
47.93	69.1	65.1	65.2	72.8	42.1	62.8	68	70.4	67.8	64.6	66.3	59	44.3
52.63	72.1	68	68	75.4	45	65.9	70.8	73	70.3	67.4	69.2	61.9	46.6
57.77	75.3	70.9	71	78.1	48.1	69.3	73.8	75.9	73	70.4	72.1	64.9	49.2
63.41	78.7	74	74.1	80.8	51.5	72.9	77	78.9	75.8	73.5	75.2	67.9	51.9
69.62	81.9	77.1	77.2	83.6	55	76.5	80.2	81.8	78.6	76.6	78.1	71	54.6
76.43	85.1	80.1	80.2	86.1	58.6	79.9	83.2	84.6	81.3	79.5	80.9	73.9	57.3
83.9	87.9	82.9	83	88.3	62.1	83.1	85.9	87	83.8	82.1	83.3	76.6	59.9
92.09	90.5	85.4	85.6	90.2	65.5	85.9	88.3	89.1	85.9	84.5	85.4	79	62.3
101.1	92.8	87.6	87.9	91.8	68.7	88.3	90.3	90.9	87.8	86.5	87.3	81.1	64.6
111	94.9	89.7	90	93.2	71.9	90.5	92.1	92.4	89.4	88.4	89	83	66.9
121.8	96.7	91.6	92.1	94.6	74.9	92.4	93.7	93.9	91	90.2	90.7	84.8	69.2
133.7	98.1	93.5	94.1	95.8	77.8	94.2	95.2	95.3	92.5	91.9	92.2	86.5	71.6

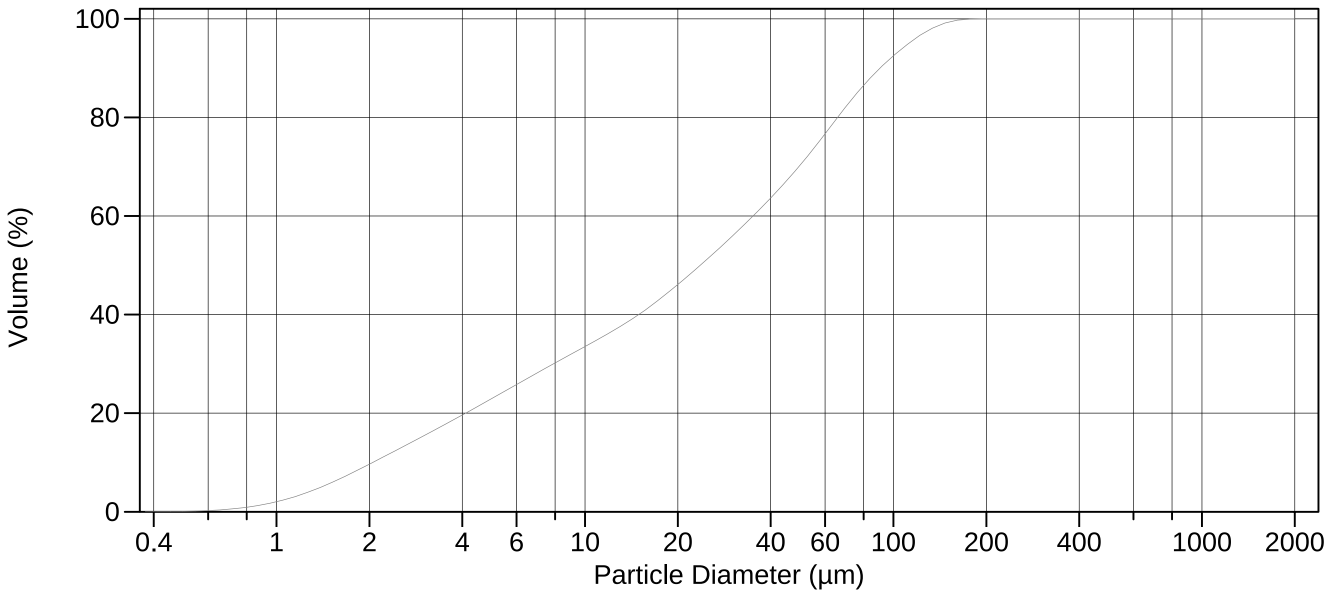
146.8	99.2	95.2	95.9	97	80.6	95.9	96.6	96.6	93.9	93.5	93.7	88.2	74
161.2	99.7	96.8	97.5	98.1	83.1	97.3	97.8	97.7	95.1	94.8	95	89.7	76.5
176.8	100	98.1	98.7	98.9	85.4	98.4	98.8	98.6	96	95.9	96.1	91	78.8
194.2	100	99	99.4	99.5	87.2	99.2	99.4	99.2	96.7	96.7	96.9	92.1	81
213.2	100	99.6	99.8	99.8	88.8	99.7	99.8	99.6	97.1	97.3	97.5	93	83
234.1	100	99.9	100	99.9	90	99.9	100	99.8	97.4	97.7	97.8	93.8	84.9
256.8	100	100	100	100	91.1	100	100	99.9	97.5	98	98.1	94.5	86.6
282.1	100	100	100	100	92.1	100	100	100	97.7	98.2	98.3	95.1	88.3
309.6	100	100	100	100	93	100	100	100	97.8	98.4	98.5	95.7	89.9
339.8	100	100	100	100	93.9	100	100	100	98	98.5	98.6	96.2	91.5
373.1	100	100	100	100	94.9	100	100	100	98.2	98.6	98.8	96.8	93
409.6	100	100	100	100	95.9	100	100	100	98.4	98.8	98.9	97.4	94.6
449.7	100	100	100	100	96.9	100	100	100	98.7	99	99.1	98	96.1
493.6	100	100	100	100	97.9	100	100	100	98.9	99.3	99.3	98.6	97.4
541.9	100	100	100	100	98.7	100	100	100	99.2	99.5	99.5	99.2	98.4
594.9	100	100	100	100	99.3	100	100	100	99.4	99.8	99.8	99.6	99.2
653	100	100	100	100	99.7	100	100	100	99.7	99.9	99.9	99.9	99.7
716.9	100	100	100	100	99.9	100	100	100	99.8	100	100	100	99.9
786.9	100	100	100	100	100	100	100	100	99.9	100	100	100	100
863.9	100	100	100	100	100	100	100	100	100	100	100	100	100
948.2	100	100	100	100	100	100	100	100	100	100	100	100	100
1041	100	100	100	100	100	100	100	100	100	100	100	100	100
1143	100	100	100	100	100	100	100	100	100	100	100	100	100
1255	100	100	100	100	100	100	100	100	100	100	100	100	100
1377	100	100	100	100	100	100	100	100	100	100	100	100	100
1512	100	100	100	100	100	100	100	100	100	100	100	100	100
1660	100	100	100	100	100	100	100	100	100	100	100	100	100
1822	100	100	100	100	100	100	100	100	100	100	100	100	100
2000	100	100	100	100	100	100	100	100	100	100	100	100	100

Norges geologiske undersøkelse
7491 TRONDHEIM
Tlf.: 73 90 40 11
Telefaks: 73 92 16 20

Tabell 2 Forbehandling, kommentarer, resultatfil m.m

Sample ID:	File name:	Comments:	Comments:	Group ID:	Operator:
Prøve nr.1	1.$02	Innvekt 0.20g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.2	2.$02	Innvekt 0.21g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.3	3.$02	Innvekt 0.20g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.4	4.$02	Innvekt 0.20g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.5	5#.$02	Innvekt 0.30g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.6	6#.$02	Innvekt 0.22g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.7	7#.$02	Innvekt 0.21g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.8	8.$02	Innvekt 0.21g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.9	9#.$02	Innvekt 0.18g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.10	10.$02	Innvekt 0.22g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.11	11.$02	Innvekt 0.19g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.12	12#.$02	Innvekt 0.22g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel
Prøve nr.13	13.$02	Innvekt 0.32g, ultralyd.	Prøven er oksydert.	2007.0455	Wieslawa Koziel

Prøve nr.1



Volume Statistics (Arithmetic) 1.$02

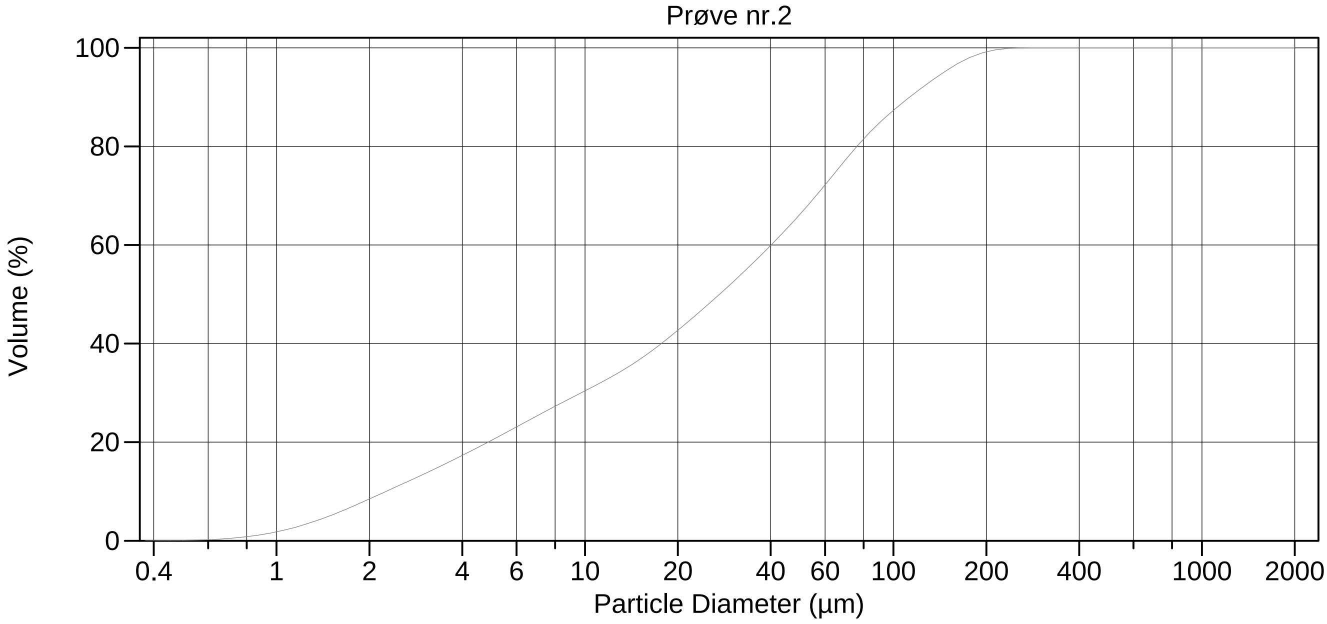
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	36.16 µm	95% Conf. Limits:	0-107.4 µm
Median:	23.65 µm	S.D.:	36.34 µm
D(3,2):	6.309 µm	Variance:	1321 µm^2
Mean/Median Ratio:	1.529	C.V.:	101%
Mode:	60.52 µm	Skewness:	1.175 Right skewed
d_{10}:	2.049 µm	Kurtosis:	0.759 Leptokurtic
d_{50}:	23.65 µm		
d_{90}:	90.48 µm		
Specific Surf. Area	9509 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.049	4.105	23.65	57.22	90.48

1.$02

Particle Diameter µm	Volume % <
2.000	9.67
5.000	23.0
10.00	33.5
15.00	40.1
20.00	46.1
50.00	70.4
60.00	76.6
63.00	78.4
70.00	82.1
75.00	84.4
90.00	89.9
125.0	97.1
200.0	100.0
250.0	100
400.0	100
500.0	100
1000	100



Volume Statistics (Arithmetic) 2.$02

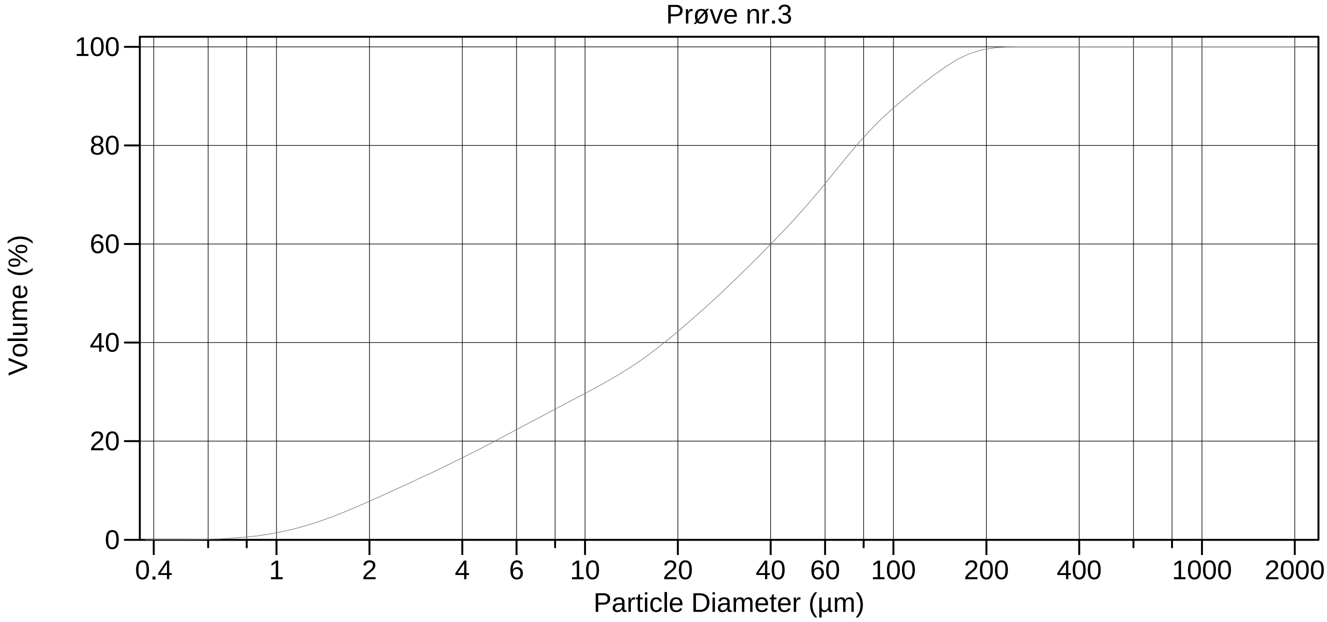
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	43.80 µm	95% Conf. Limits:	0-135.2 µm
Median:	27.30 µm	S.D.:	46.66 µm
D(3,2):	6.979 µm	Variance:	2177 µm^2
Mean/Median Ratio:	1.604	C.V.:	107%
Mode:	66.44 µm	Skewness:	1.451 Right skewed
d_{10}:	2.265 µm	Kurtosis:	1.789 Leptokurtic
d_{50}:	27.30 µm		
d_{90}:	112.8 µm		
Specific Surf. Area	8597 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.265	4.847	27.30	65.32	112.8

2.$02

Particle Diameter µm	Volume % <
2.000	8.48
5.000	20.5
10.00	30.4
15.00	36.7
20.00	42.7
50.00	66.4
60.00	72.2
63.00	73.8
70.00	77.3
75.00	79.5
90.00	84.8
125.0	92.1
200.0	99.2
250.0	100.0
400.0	100
500.0	100
1000	100



Volume Statistics (Arithmetic) 3.$02

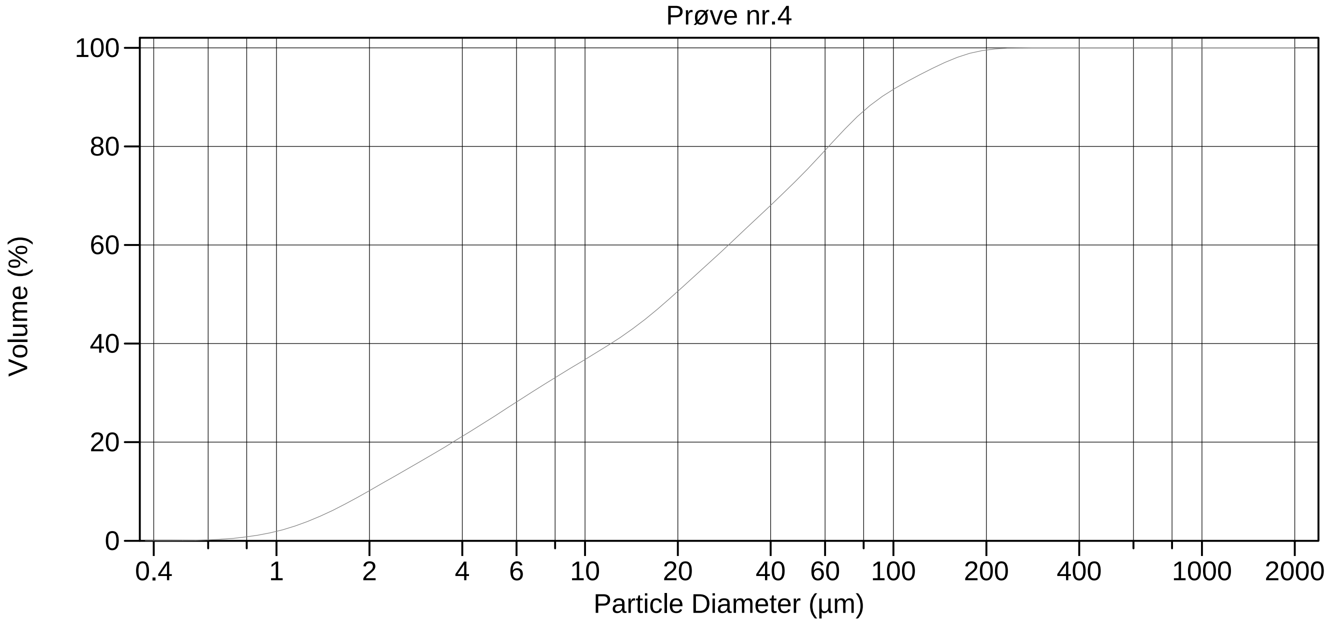
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	43.26 µm	95% Conf. Limits:	0-131.2 µm
Median:	27.55 µm	S.D.:	44.87 µm
D(3,2):	7.384 µm	Variance:	2014 µm^2
Mean/Median Ratio:	1.570	C.V.:	104%
Mode:	66.44 µm	Skewness:	1.355 Right skewed
d_{10}:	2.391 µm	Kurtosis:	1.378 Leptokurtic
d_{50}:	27.55 µm		
d_{90}:	110.8 µm		
Specific Surf. Area	8126 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.391	5.099	27.55	65.19	110.8

3.$02

Particle Diameter µm	Volume % <
2.000	7.82
5.000	19.7
10.00	29.7
15.00	36.2
20.00	42.3
50.00	66.4
60.00	72.2
63.00	73.9
70.00	77.4
75.00	79.6
90.00	84.9
125.0	92.6
200.0	99.6
250.0	100.0
400.0	100
500.0	100
1000	100



Volume Statistics (Arithmetic) 4.$02

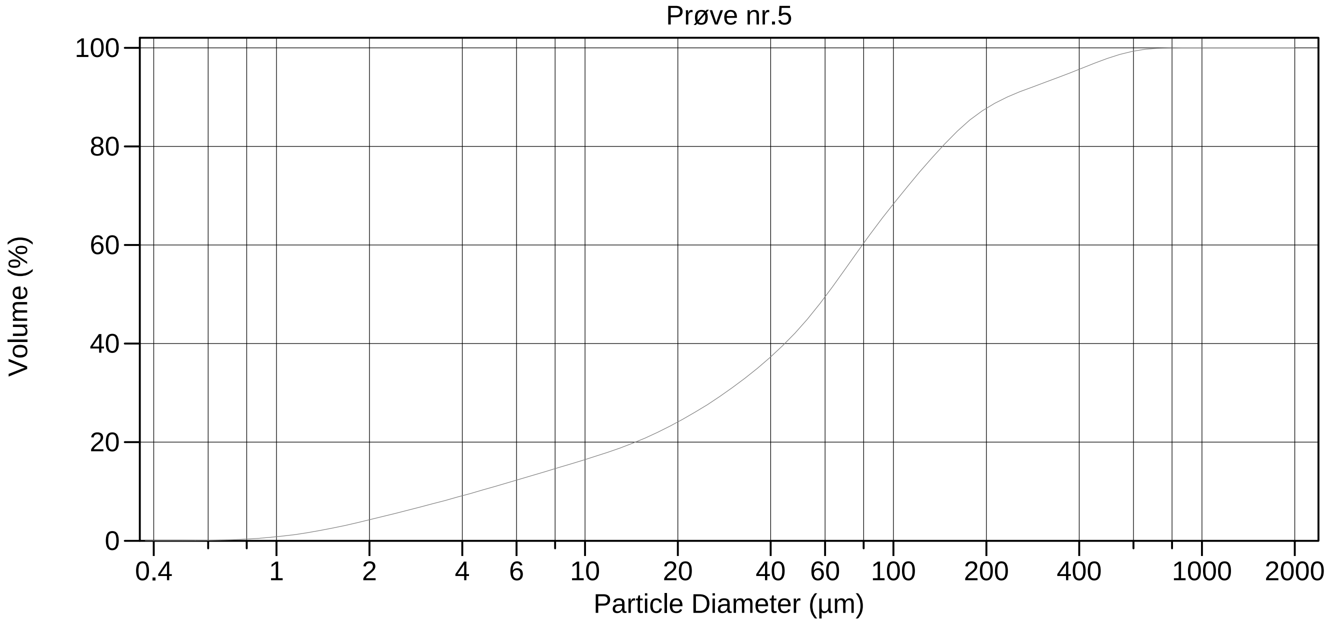
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	35.29 µm	95% Conf. Limits:	0-115.7 µm
Median:	19.51 µm	S.D.:	41.02 µm
D(3,2):	5.987 µm	Variance:	1683 µm^2
Mean/Median Ratio:	1.809	C.V.:	116%
Mode:	60.52 µm	Skewness:	1.766 Right skewed
d_{10}:	1.979 µm	Kurtosis:	3.205 Leptokurtic
d_{50}:	19.51 µm		
d_{90}:	91.28 µm		
Specific Surf. Area	10022 cm^2/ml		

% <	10	20	50	75	90
Size µm	1.979	3.731	19.51	51.89	91.28

4.$02

Particle Diameter µm	Volume % <
2.000	10.2
5.000	25.0
10.00	36.8
15.00	44.0
20.00	50.6
50.00	74.0
60.00	79.2
63.00	80.6
70.00	83.7
75.00	85.5
90.00	89.7
125.0	94.9
200.0	99.6
250.0	100.0
400.0	100
500.0	100
1000	100



Volume Statistics (Arithmetic) 5#.$02

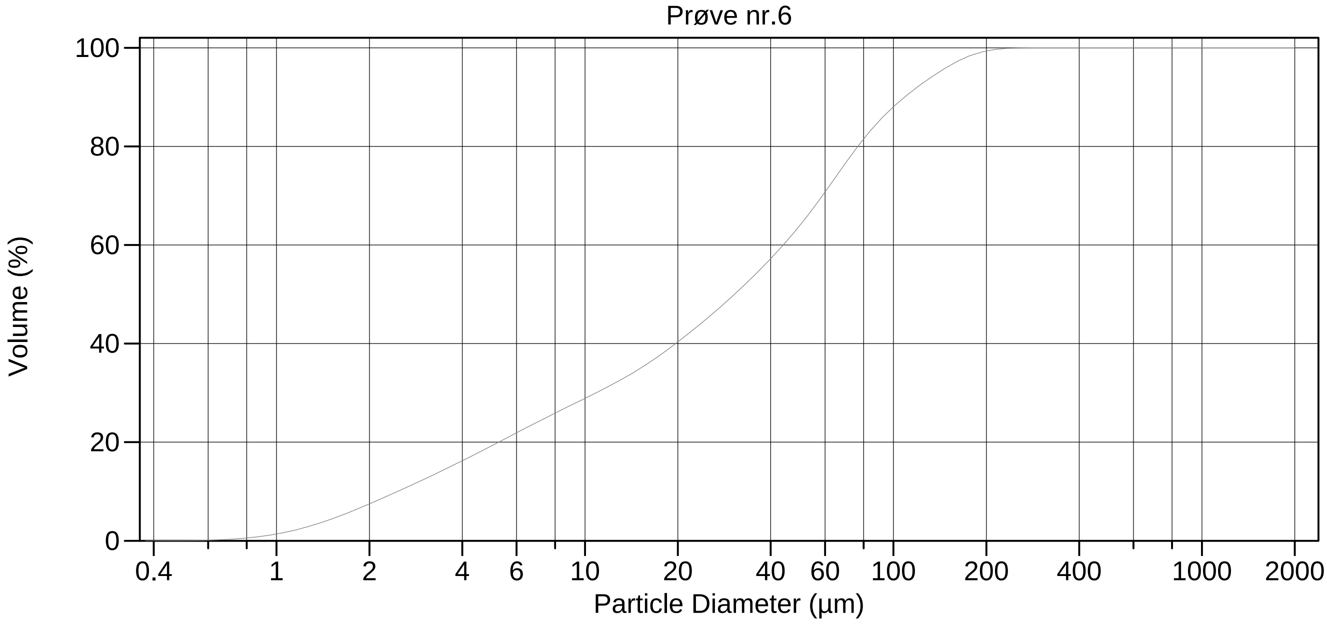
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	97.98 µm	95% Conf. Limits:	0-330.4 µm
Median:	60.92 µm	S.D.:	118.6 µm
D(3,2):	12.46 µm	Variance:	14065 µm^2
Mean/Median Ratio:	1.608	C.V.:	121%
Mode:	72.95 µm	Skewness:	2.316 Right skewed
d_{10}:	4.485 µm	Kurtosis:	5.945 Leptokurtic
d_{50}:	60.92 µm		
d_{90}:	233.4 µm		
Specific Surf. Area	4817 cm^2/ml		

% <	10	20	50	75	90
Size µm	4.485	14.54	60.92	122.3	233.4

5#.$02

Particle Diameter µm	Volume % <
2.000	4.26
5.000	10.8
10.00	16.5
15.00	20.3
20.00	24.1
50.00	43.4
60.00	49.5
63.00	51.2
70.00	55.2
75.00	57.9
90.00	64.6
125.0	75.7
200.0	87.7
250.0	90.8
400.0	95.7
500.0	98.0
1000	100



Volume Statistics (Arithmetic) 6#.$02

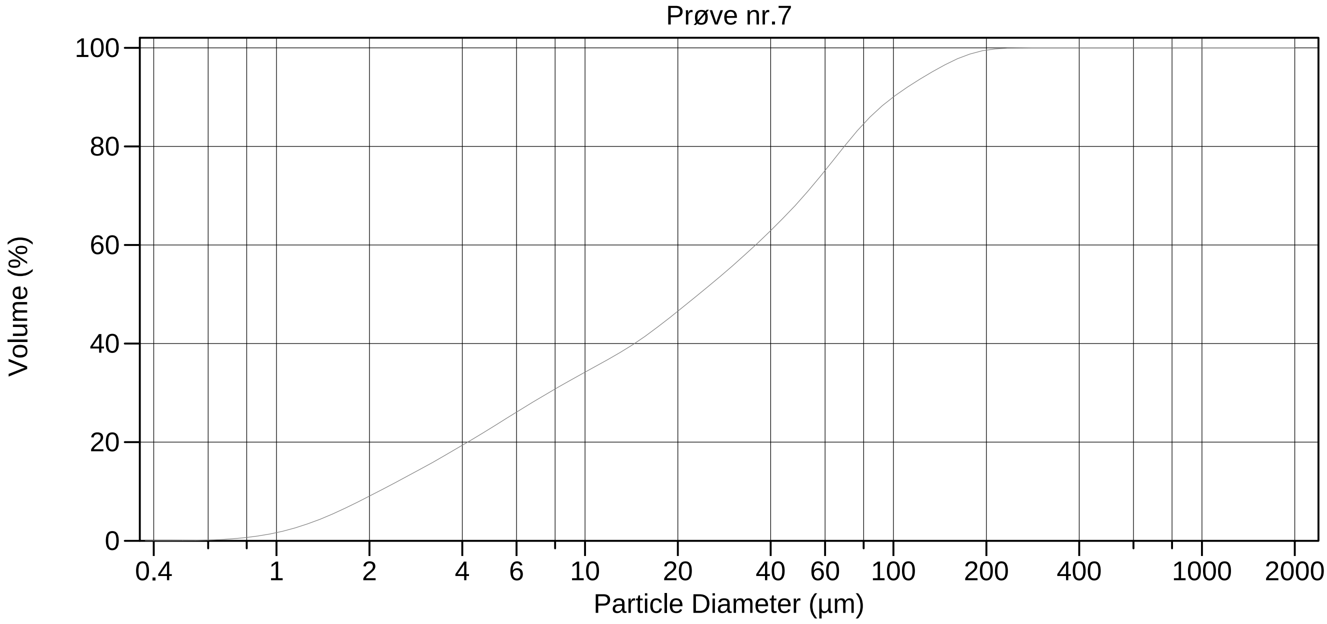
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	44.52 µm	95% Conf. Limits:	0-132.7 µm
Median:	30.54 µm	S.D.:	44.97 µm
D(3,2):	7.602 µm	Variance:	2023 µm^2
Mean/Median Ratio:	1.458	C.V.:	101%
Mode:	66.44 µm	Skewness:	1.359 Right skewed
d_{10}:	2.469 µm	Kurtosis:	1.629 Leptokurtic
d_{50}:	30.54 µm		
d_{90}:	108.7 µm		
Specific Surf. Area	7893 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.469	5.247	30.54	67.10	108.7

6#.$02

Particle Diameter µm	Volume % <
2.000	7.48
5.000	19.3
10.00	28.9
15.00	34.9
20.00	40.3
50.00	64.2
60.00	70.7
63.00	72.6
70.00	76.7
75.00	79.2
90.00	85.2
125.0	92.9
200.0	99.4
250.0	100.0
400.0	100
500.0	100
1000	100



Volume Statistics (Arithmetic) 7#.$02

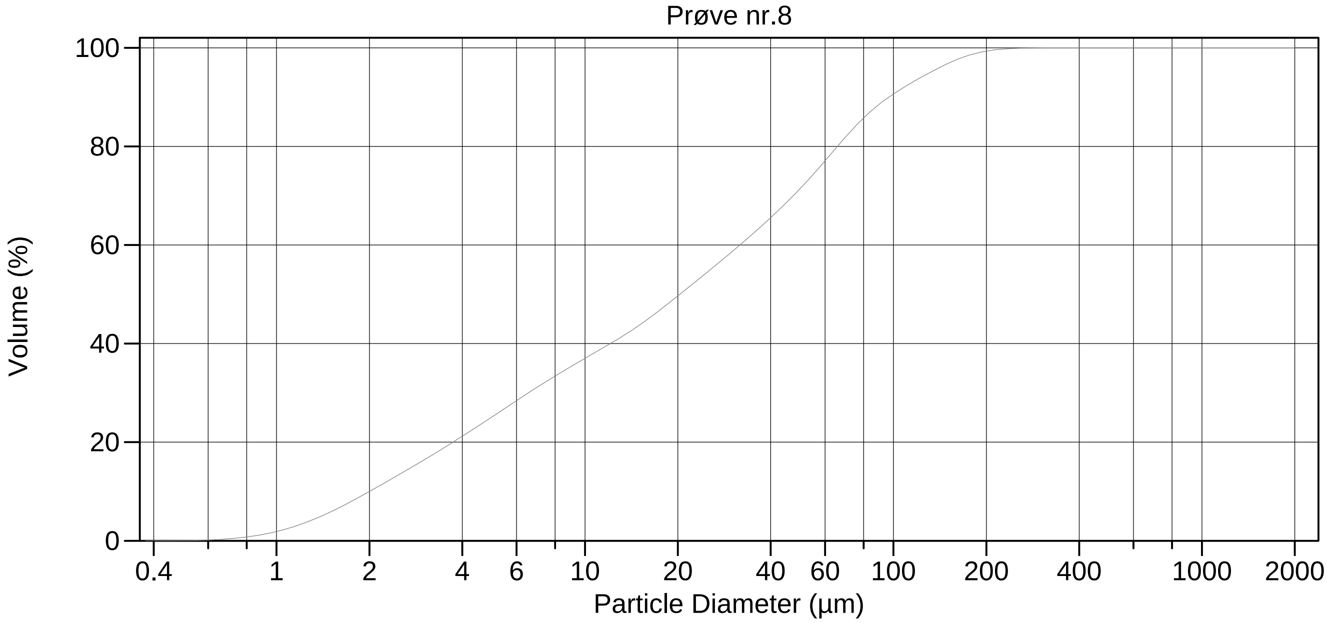
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	39.31 µm	95% Conf. Limits:	0-123.5 µm
Median:	23.38 µm	S.D.:	42.97 µm
D(3,2):	6.535 µm	Variance:	1846 µm^2
Mean/Median Ratio:	1.681	C.V.:	109%
Mode:	66.44 µm	Skewness:	1.524 Right skewed
d_{10}:	2.140 µm	Kurtosis:	2.159 Leptokurtic
d_{50}:	23.38 µm		
d_{90}:	99.74 µm		
Specific Surf. Area	9182 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.140	4.163	23.38	59.84	99.74

7#.$02

Particle Diameter µm	Volume % <
2.000	9.06
5.000	23.0
10.00	34.2
15.00	40.7
20.00	46.6
50.00	69.2
60.00	75.1
63.00	76.8
70.00	80.4
75.00	82.6
90.00	87.7
125.0	94.1
200.0	99.5
250.0	100.0
400.0	100
500.0	100
1000	100



Volume Statistics (Arithmetic) 8.$02

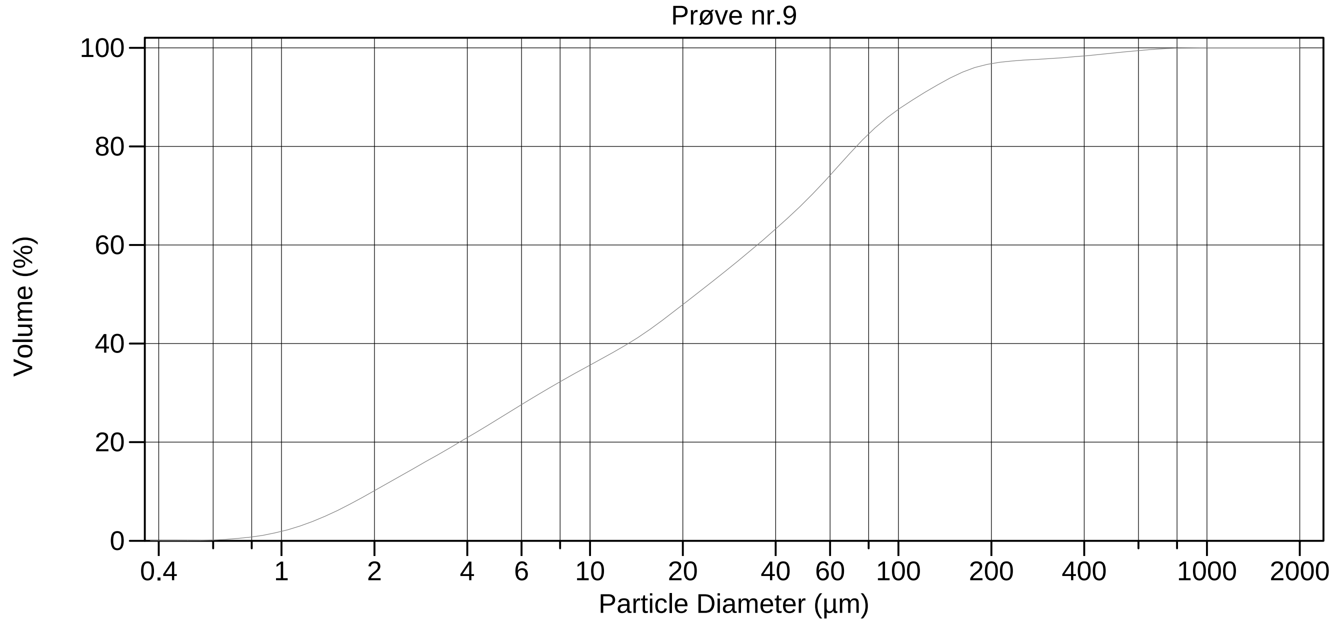
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	37.33 µm	95% Conf. Limits:	0-122.1 µm
Median:	20.29 µm	S.D.:	43.27 µm
D(3,2):	6.040 µm	Variance:	1872 µm^2
Mean/Median Ratio:	1.839	C.V.:	116%
Mode:	60.52 µm	Skewness:	1.736 Right skewed
d_{10}:	2.000 µm	Kurtosis:	3.215 Leptokurtic
d_{50}:	20.29 µm		
d_{90}:	96.69 µm		
Specific Surf. Area	9934 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.000	3.734	20.29	56.16	96.69

8.$02

Particle Diameter µm	Volume % <
2.000	10.0
5.000	25.1
10.00	37.0
15.00	43.7
20.00	49.7
50.00	71.5
60.00	77.1
63.00	78.6
70.00	81.9
75.00	84.0
90.00	88.6
125.0	94.3
200.0	99.3
250.0	99.9
400.0	100
500.0	100
1000	100



Volume Statistics (Arithmetic) 9#.$02

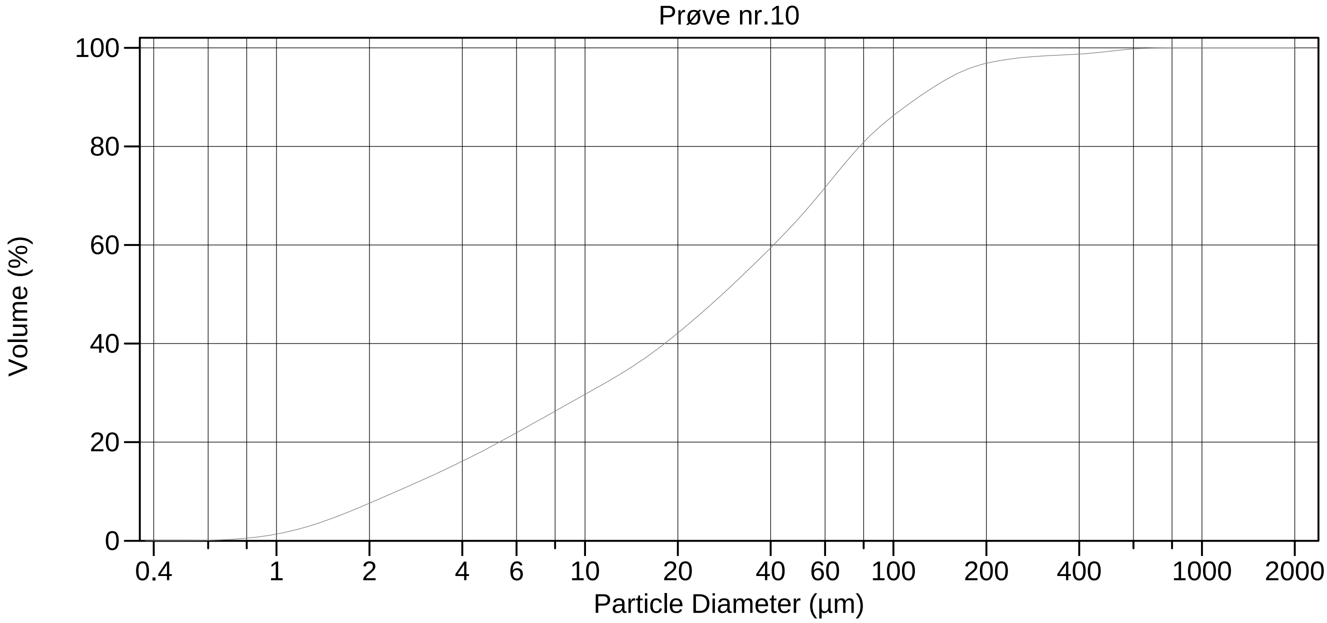
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	49.43 µm	95% Conf. Limits:	0-215.6 µm
Median:	22.07 µm	S.D.:	84.80 µm
D(3,2):	6.131 µm	Variance:	7191 $µm^2$
Mean/Median Ratio:	2.240	C.V.:	172%
Mode:	66.44 µm	Skewness:	4.598 Right skewed
d_{10}:	1.980 µm	Kurtosis:	27.51 Leptokurtic
d_{50}:	22.07 µm		
d_{90}:	114.9 µm		
Specific Surf. Area	9787 cm^2/ml		

% <	10	20	50	75	90
Size µm	1.980	3.777	22.07	61.78	114.9

9#.$02

Particle Diameter µm	Volume % <
2.000	10.2
5.000	24.6
10.00	35.6
15.00	42.1
20.00	47.9
50.00	68.9
60.00	74.1
63.00	75.6
70.00	78.8
75.00	80.8
90.00	85.3
125.0	91.4
200.0	96.8
250.0	97.5
400.0	98.4
500.0	99.0
1000	100.0



Volume Statistics (Arithmetic) 10.$02

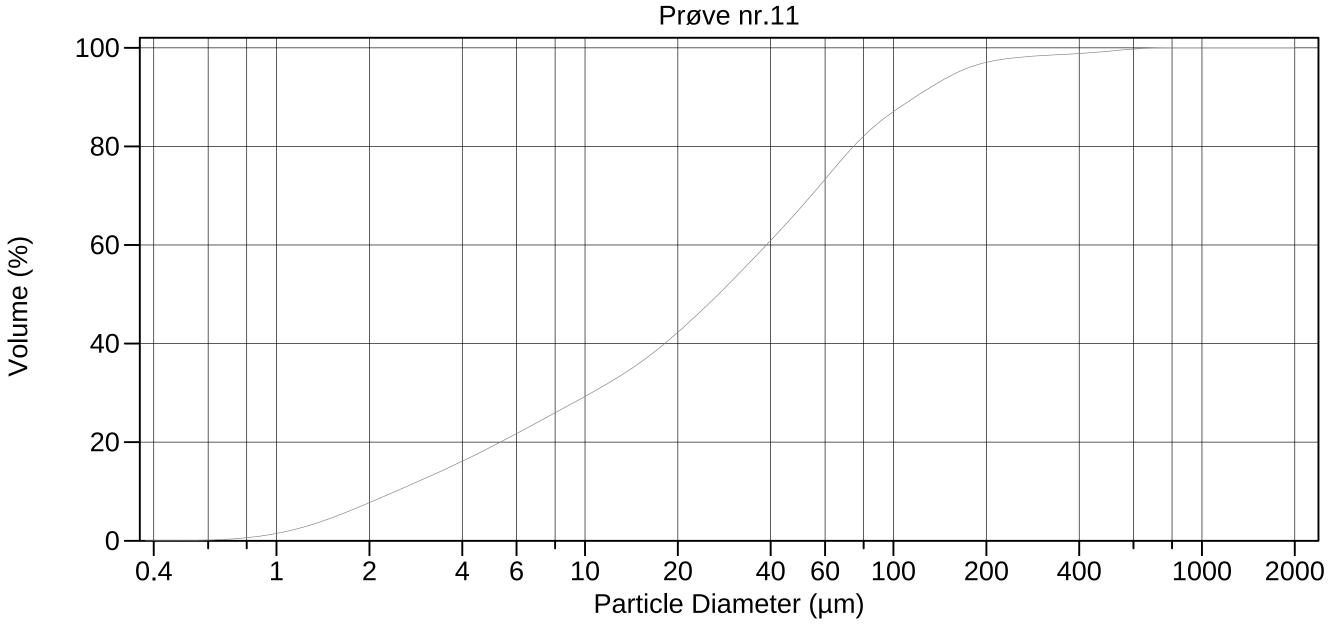
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	51.24 µm	95% Conf. Limits:	0-197.6 µm
Median:	27.89 µm	S.D.:	74.69 µm
D(3,2):	7.517 µm	Variance:	5579 µm^2
Mean/Median Ratio:	1.837	C.V.:	146%
Mode:	60.52 µm	Skewness:	3.987 Right skewed
d_{10}:	2.446 µm	Kurtosis:	22.00 Leptokurtic
d_{50}:	27.89 µm		
d_{90}:	120.6 µm		
Specific Surf. Area	7982 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.446	5.277	27.89	66.40	120.6

10.$02

Particle Diameter µm	Volume % <
2.000	7.63
5.000	19.2
10.00	29.7
15.00	36.3
20.00	42.1
50.00	65.8
60.00	71.6
63.00	73.3
70.00	76.8
75.00	78.9
90.00	83.9
125.0	90.6
200.0	96.9
250.0	97.9
400.0	98.7
500.0	99.3
1000	100



Volume Statistics (Arithmetic) 11.$02

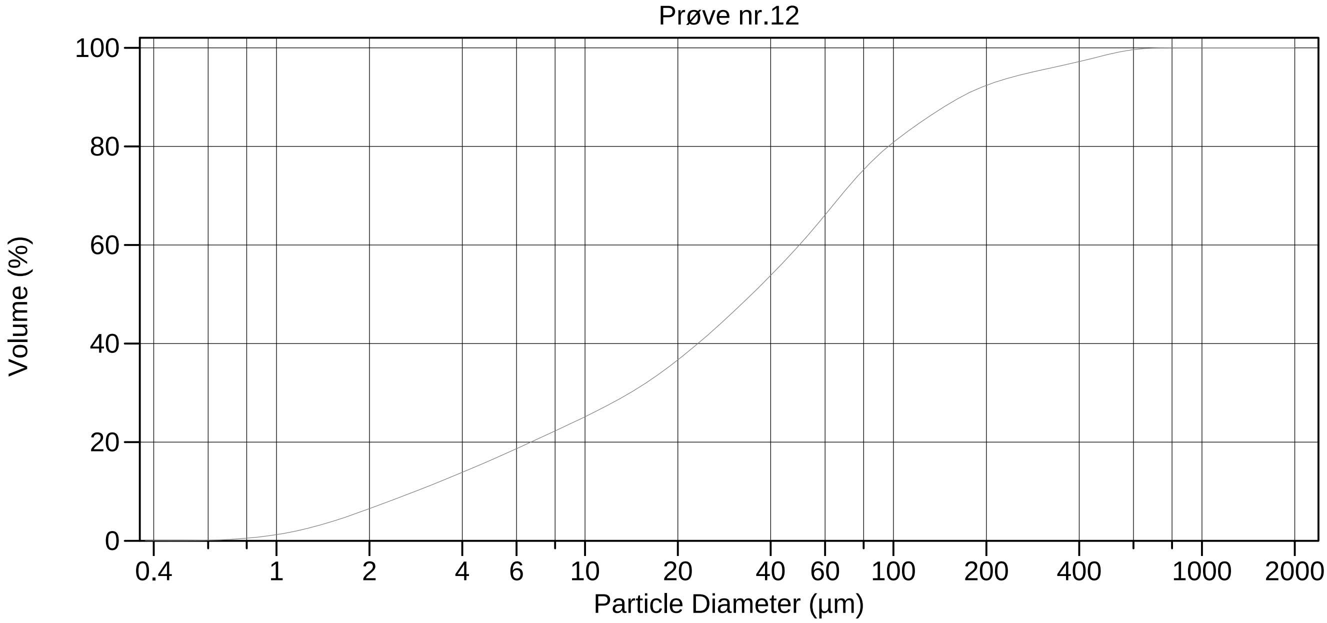
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	49.60 µm	95% Conf. Limits:	0-192.9 µm
Median:	27.07 µm	S.D.:	73.09 µm
D(3,2):	7.430 µm	Variance:	5343 µm^2
Mean/Median Ratio:	1.832	C.V.:	147%
Mode:	60.52 µm	Skewness:	4.154 Right skewed
d_{10}:	2.425 µm	Kurtosis:	24.12 Leptokurtic
d_{50}:	27.07 µm		
d_{90}:	117.5 µm		
Specific Surf. Area	8075 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.425	5.316	27.07	63.12	117.5

11.$02

Particle Diameter µm	Volume % <
2.000	7.74
5.000	19.1
10.00	29.3
15.00	36.0
20.00	42.3
50.00	67.6
60.00	73.3
63.00	74.9
70.00	78.3
75.00	80.3
90.00	84.9
125.0	91.1
200.0	97.1
250.0	98.0
400.0	98.9
500.0	99.3
1000	100



Volume Statistics (Arithmetic) 12#.$02

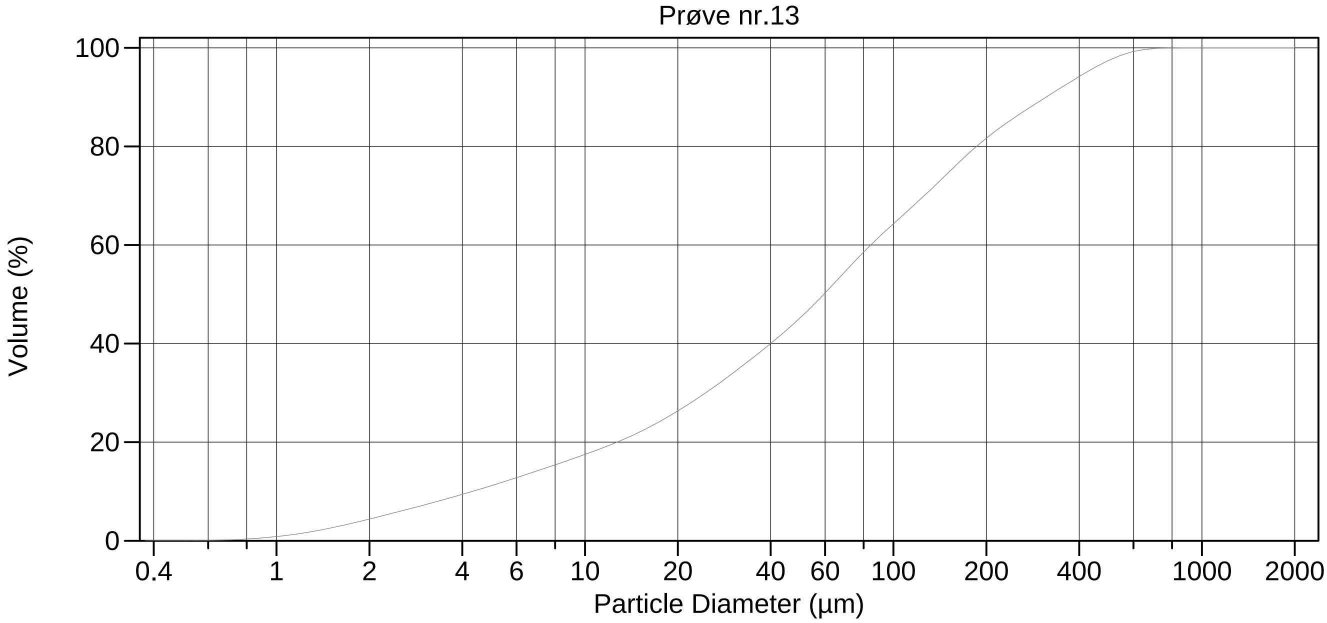
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	68.76 µm	95% Conf. Limits:	0-266.3 µm
Median:	34.72 µm	S.D.:	100.8 µm
D(3,2):	8.572 µm	Variance:	10158 µm^2
Mean/Median Ratio:	1.981	C.V.:	147%
Mode:	60.52 µm	Skewness:	2.976 Right skewed
d_{10}:	2.809 µm	Kurtosis:	10.19 Leptokurtic
d_{50}:	34.72 µm		
d_{90}:	165.2 µm		
Specific Surf. Area	7000 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.809	6.672	34.72	79.39	165.2

12#.$02

Particle Diameter µm	Volume % <
2.000	6.51
5.000	16.5
10.00	25.2
15.00	31.2
20.00	36.7
50.00	60.3
60.00	66.1
63.00	67.7
70.00	71.2
75.00	73.3
90.00	78.4
125.0	85.3
200.0	92.4
250.0	94.3
400.0	97.2
500.0	98.7
1000	100



Volume Statistics (Arithmetic) 13.$02

Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	111.8 µm	95% Conf. Limits:	0-375.0 µm
Median:	59.49 µm	S.D.:	134.3 µm
D(3,2):	12.02 µm	Variance:	18042 µm^2
Mean/Median Ratio:	1.879	C.V.:	120%
Mode:	66.44 µm	Skewness:	1.810 Right skewed
d_{10}:	4.303 µm	Kurtosis:	3.047 Leptokurtic
d_{50}:	59.49 µm		
d_{90}:	312.2 µm		
Specific Surf. Area	4993 cm^2/ml		

% <	10	20	50	75	90
Size µm	4.303	12.68	59.49	152.5	312.2

13.$02

Particle Diameter µm	Volume % <
2.000	4.40
5.000	11.2
10.00	17.5
15.00	22.0
20.00	26.4
50.00	45.3
60.00	50.2
63.00	51.7
70.00	54.7
75.00	56.7
90.00	61.7
125.0	69.8
200.0	81.6
250.0	86.1
400.0	94.2
500.0	97.5
1000	100

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Telefaks: 73 92 16 20

Geologisk materiale
Analysekontrakt nr. 2007.0455

Operatør: Wieslawa Koziel

Prøve nr.	Tørrvekt (g)
1	42.71
2	47.52
3	32.24
4	31.83
5	73.25
6	28.33
7	33.71
8	30.32
9	54.22
10	42.92
11	62.54
12	79.92
13	16.46

Ferdig analysert:10.12.2007

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KORNFORDELINGSANALYSE : COULTER LASER
GEOLOGISK MATERIALE
Analysekontraktsnr: 2008.0345

NORSK AKKREDITERING TEST 020

METODE (Fullstendig beskrivelse gitt i NGU-SD 5.11)
Kornfordelingsbestemmelse basert på laserdiffraksjon. Laserlys brytes i bestemte vinkler avhengig av størrelsen på partiklene, som igjen registreres av en rekke detektorer. De registrerte vinklene korresponderer med gitte partikkelstørrelser, antall partikler med en gitt størrelse er igjen relatert til intensitet for korresponderende detektorer.
Kornfordelingen bestemmes således på volum-basis, med antagelse om samme tetthet på materialet vil kumulativ volum% være identisk med kumulativ masse%. Beregning på volum/masse-basis er basert på antagelse om sfæriske partikler.

INSTRUMENT TYPE : Coulter LS 200

MÅLEOMRÅDE: 0.4µm-2000µm

NB! Metoden normaliserer alle data i måleområdet til 100 % (kumulativ%). Måleområdet går kun til 0.4 µm og dette settes som nullpunkt mhp.kumulativ %. Således kan prøvene inneholde materiale finere enn 0.4µm.

ANALYSEUSIKKERHET: ± 10% [kumulativ masse(volum) %]
Bestemmelse av usikkerhet er basert på sammenligning av oppnådde resultater og sertifikatverdier for kvarts standard BCR 131, samt presisjonsdata.
Det er her oppgitt usikkerhet med dekningsfaktor 2 (jfr. 2 standard avvik), noe som da korresponderer med et konfidensintervall på 95 %

MERK! Metoden tar utgangspunkt i antagelse om sfæriske partikler. For prøver som avviker fra dette kan usikkerheten være større.

PRESISJON : Det kjøres rutinemessig kontrollprøver, som føres i kontrolldiagram (X-diagram). Disse kan forevises om ønskelig..

ANTALL PRØVER: 11 prøver analysert – prøve nr. 12 – gav ikke tilstrekkelig materiale for kornfordelingsanalyse.

FORBEHANDLING : Se Tabell 2

ANTALL SIDER (denne delrapport): 5 + 11 vedlegg (Plott av kumulativ kornfordeling med div. statistiske parametre)

ANMERKNINGER: Data for fraksjoner >2000 µm er fremkommet fra gravimetriske bestemmelser.

Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Ferdig analysert	26.11.2008	Wieslawa Koziel
	Dato	OPERATØR

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KORNFORDELINGSANALYSE : COULTER LASER
GEOLOGISK MATERIALE
Analysekontraktsnr: 2008.0345

NORSK AKKREDITERING TEST 020

Tabell 1 Kumulativ (<) kornfordeling [(volum%(masse%)]

Prøve nr.→ Diameter(μm) ↓	1	2	3	4	5	6	7	8	9	10	11
0.375	0	0	0	0	0	0	0	0	0	0	0
0.412	0	0	0	0	0	0	0	0	0	0	0
0.452	0	0	0	0	0	0	0	0	0	0	0
0.496	0	0	0	0	0	0	0	0	0	0	0
0.545	0	0	0	0	0	0	0	0	0	0	0
0.598	0	0.00033	0	0	0	0	0	0	0	0.00023	0
0.657	0.000085	0.0046	0.00022	0	0.000057	0.00044	0.00045	0.00031	0	0.0037	0.00036
0.721	0.0017	0.028	0.0036	0.00022	0.0018	0.0064	0.0064	0.0052	0.00049	0.025	0.0055
0.791	0.012	0.093	0.023	0.0034	0.015	0.039	0.039	0.034	0.0064	0.090	0.034
0.869	0.045	0.22	0.082	0.022	0.064	0.13	0.13	0.12	0.038	0.23	0.12
0.953	0.12	0.43	0.20	0.079	0.18	0.30	0.30	0.30	0.12	0.47	0.28
1.047	0.24	0.73	0.41	0.20	0.39	0.58	0.57	0.61	0.28	0.83	0.55
1.149	0.43	1.15	0.71	0.40	0.71	0.99	0.97	1.06	0.53	1.34	0.94
1.261	0.70	1.70	1.12	0.69	1.15	1.53	1.49	1.67	0.88	2.00	1.47
1.385	1.04	2.37	1.65	1.09	1.73	2.22	2.17	2.46	1.35	2.83	2.15
1.520	1.47	3.17	2.29	1.60	2.45	3.06	2.98	3.43	1.93	3.81	2.96
1.669	1.98	4.07	3.04	2.21	3.30	4.03	3.92	4.55	2.63	4.93	3.90
1.832	2.56	5.08	3.90	2.93	4.27	5.13	4.98	5.81	3.42	6.16	4.95
2.010	3.21	6.16	4.83	3.73	5.35	6.32	6.14	7.19	4.32	7.49	6.09
2.207	3.92	7.30	5.84	4.62	6.51	7.60	7.38	8.66	5.29	8.89	7.28
2.423	4.68	8.49	6.91	5.59	7.76	8.95	8.70	10.2	6.35	10.3	8.53
2.660	5.50	9.73	8.03	6.64	9.08	10.4	10.1	11.8	7.49	11.8	9.82
2.920	6.38	11.0	9.21	7.76	10.5	11.9	11.5	13.5	8.70	13.4	11.2
3.206	7.30	12.4	10.5	8.96	11.9	13.4	13.1	15.3	10.00	14.9	12.5
3.519	8.29	13.8	11.8	10.3	13.5	15.0	14.6	17.1	11.4	16.6	14.0
3.862	9.33	15.2	13.1	11.6	15.1	16.7	16.3	19.0	12.8	18.3	15.4
4.241	10.4	16.7	14.5	13.1	16.8	18.5	18.0	21.0	14.4	20.0	16.9
4.656	11.6	18.2	16.0	14.6	18.6	20.3	19.8	23.0	16.0	21.8	18.5
5.111	12.7	19.8	17.5	16.1	20.4	22.2	21.7	25.0	17.7	23.6	20.0
5.611	14.0	21.4	19.0	17.8	22.3	24.1	23.6	27.1	19.5	25.4	21.6

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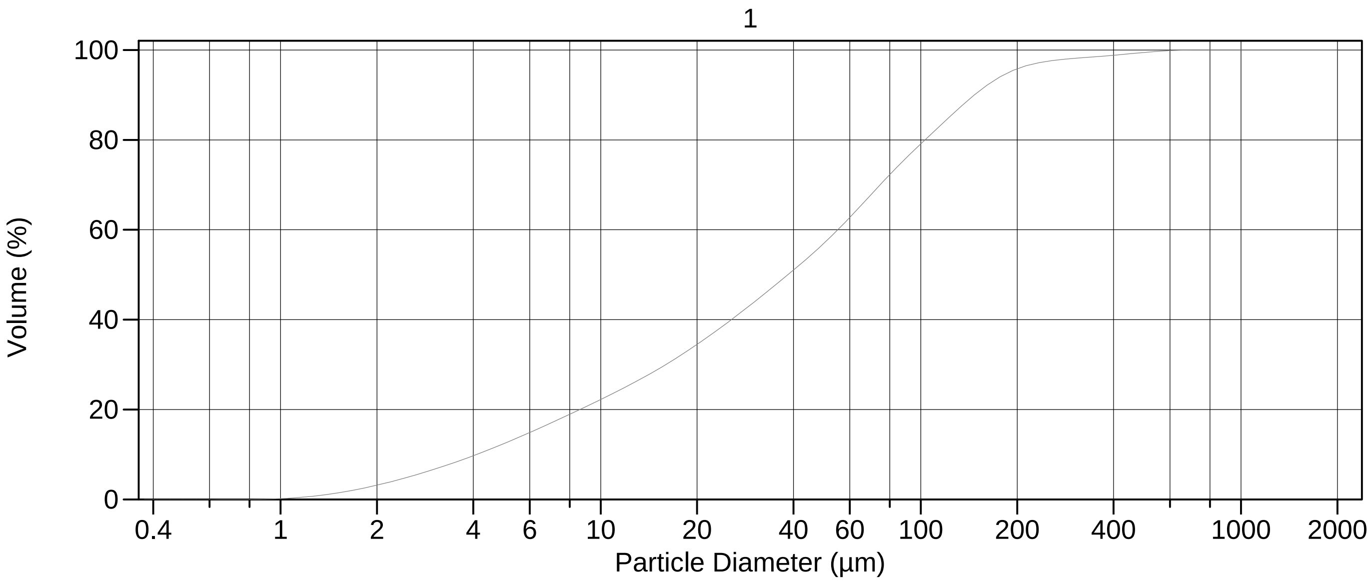
6.158	15.2	23.1	20.6	19.5	24.1	26.1	25.5	29.1	21.3	27.2	23.2
6.761	16.5	24.7	22.2	21.2	26.1	28.1	27.4	31.2	23.2	29.0	24.7
7.421	17.8	26.4	23.8	22.9	28.0	30.0	29.4	33.3	25.1	30.8	26.3
8.147	19.2	28.0	25.4	24.7	29.9	32.0	31.3	35.3	27.0	32.6	27.8
8.944	20.6	29.7	27.0	26.4	31.8	34.0	33.3	37.3	29.0	34.4	29.3
9.819	22.0	31.3	28.6	28.2	33.7	36.1	35.3	39.2	31.0	36.1	30.8
10.78	23.4	32.9	30.2	30.0	35.5	38.1	37.2	41.2	33.0	37.8	32.2
11.83	24.8	34.6	31.8	31.8	37.4	40.1	39.2	43.1	35.0	39.5	33.6
12.99	26.4	36.2	33.4	33.6	39.3	42.2	41.2	45.0	37.0	41.3	35.1
14.26	27.9	38.0	35.1	35.4	41.3	44.4	43.3	47.0	39.1	43.1	36.6
15.65	29.6	39.9	36.8	37.3	43.3	46.6	45.6	49.1	41.3	45.1	38.2
17.18	31.4	41.8	38.7	39.4	45.4	49.1	47.9	51.4	43.6	47.2	39.9
18.86	33.3	43.9	40.7	41.4	47.7	51.5	50.4	53.7	45.9	49.4	41.7
20.70	35.2	46.1	42.8	43.5	49.9	54.1	52.9	56.0	48.2	51.7	43.5
22.73	37.3	48.2	44.9	45.7	52.2	56.6	55.4	58.3	50.6	53.9	45.3
24.95	39.4	50.4	47.0	47.8	54.5	59.1	57.9	60.5	52.9	56.1	47.1
27.38	41.6	52.6	49.1	49.9	56.7	61.5	60.3	62.6	55.2	58.3	48.9
30.07	43.8	54.8	51.2	52.0	58.8	63.9	62.7	64.7	57.5	60.5	50.7
33.00	46.2	57.0	53.4	54.1	60.9	66.2	65.1	66.7	59.7	62.6	52.5
36.24	48.5	59.2	55.5	56.1	62.9	68.4	67.3	68.7	61.8	64.7	54.2
39.77	50.9	61.3	57.5	58.0	64.9	70.5	69.5	70.6	63.8	66.8	56.0
43.66	53.3	63.6	59.6	60.0	66.7	72.5	71.6	72.4	65.8	68.7	57.8
47.93	55.9	65.9	61.8	61.9	68.6	74.6	73.7	74.2	67.8	70.8	59.6
52.63	58.6	68.3	64.0	63.9	70.6	76.6	75.8	76.0	69.8	72.8	61.5
57.77	61.5	70.9	66.4	66.1	72.6	78.8	78.0	78.0	71.9	75.0	63.6
63.41	64.6	73.6	69.0	68.3	74.7	81.0	80.3	79.9	74.0	77.2	65.8
69.62	67.7	76.3	71.6	70.6	76.9	83.1	82.5	81.9	76.2	79.4	68.0
76.43	70.8	78.9	74.2	72.8	78.9	85.0	84.5	83.7	78.3	81.5	70.1
83.90	73.8	81.4	76.6	74.8	80.7	86.7	86.3	85.4	80.1	83.4	72.1
92.09	76.7	83.7	78.9	76.7	82.4	88.2	87.8	86.8	81.7	85.1	74.0
101.1	79.5	85.7	81.0	78.5	83.9	89.5	89.2	88.0	83.2	86.5	75.7
111.0	82.2	87.6	83.1	80.2	85.4	90.7	90.4	89.3	84.7	87.9	77.4
121.8	84.8	89.5	85.2	82.0	86.9	91.9	91.7	90.5	86.1	89.3	79.1
133.7	87.5	91.3	87.2	83.8	88.5	93.3	92.9	91.8	87.7	90.8	80.9

146.8	90.0	92.9	89.3	85.7	90.1	94.6	94.2	93.1	89.3	92.2	82.7
161.2	92.2	94.3	91.2	87.5	91.7	95.8	95.3	94.4	90.9	93.6	84.5
176.8	94.1	95.5	92.9	89.1	93.2	96.8	96.3	95.5	92.3	94.7	86.0
194.2	95.5	96.4	94.3	90.5	94.5	97.5	97.1	96.4	93.6	95.6	87.2
213.2	96.5	97.0	95.4	91.7	95.5	98.0	97.7	97.1	94.6	96.3	88.2
234.1	97.2	97.4	96.3	92.7	96.2	98.4	98.1	97.6	95.4	96.9	89.0
256.8	97.6	97.7	96.9	93.5	96.8	98.6	98.3	98.0	96.1	97.3	89.6
282.1	98.0	97.9	97.5	94.2	97.2	98.7	98.5	98.3	96.6	97.7	90.2
309.6	98.2	98.1	97.9	94.8	97.6	98.9	98.6	98.5	97.1	98.1	90.7
339.8	98.4	98.3	98.2	95.4	97.9	99.0	98.7	98.7	97.4	98.4	91.2
373.1	98.7	98.5	98.5	95.9	98.1	99.1	98.8	98.8	97.7	98.6	91.7
409.6	98.9	98.7	98.8	96.4	98.4	99.2	98.8	99.0	98.0	98.9	92.3
449.7	99.2	99.0	99.0	96.9	98.7	99.4	98.9	99.1	98.3	99.1	92.8
493.6	99.4	99.3	99.3	97.4	99.1	99.5	99.1	99.2	98.5	99.3	93.2
541.9	99.7	99.6	99.6	97.8	99.4	99.7	99.3	99.4	98.8	99.5	93.7
594.9	99.9	99.8	99.8	98.3	99.6	99.9	99.5	99.5	99.1	99.7	94.1
653.0	100	99.9	99.9	98.6	99.8	100	99.7	99.7	99.4	99.9	94.6
716.9	100	100	100	98.9	99.9	100	99.9	99.8	99.7	100	95.0
786.9	100	100	100	99.1	100	100	100	99.9	99.8	100	95.3
863.9	100	100	100	99.3	100	100	100	99.9	99.9	100	95.7
948.2	100	100	100	99.5	100	100	100	100	100	100	96.0
1041	100	100	100	99.7	100	100	100	100	100	100	96.4
1143	100	100	100	99.8	100	100	100	100	100	100	96.8
1255	100	100	100	99.9	100	100	100	100	100	100	97.1
1377	100	100	100	100	100	100	100	100	100	100	97.3
1512	100	100	100	100	100	100	100	100	100	100	97.4
1660	100	100	100	100	100	100	100	100	100	100	97.4
1822	100	100	100	100	100	100	100	100	100	100	97.4
2000	100	100	100	100	100	100	100	100	100	100	97.4
4000											98.0
8000											99.1
16000											100

Tabell 2 Forbehandling, kommentarer, resultatfil m.m

Sample ID:	File name:	Comments:	Comments:	Group ID:	Operator:
1	1#.$02	Innvekt 0.24g, ultralyd.		2008.0345	Wieslawa Koziel
2	2#.$02	Innvekt 0.20g, ultralyd.		2008.0345	Wieslawa Koziel
3	3#.$02	Innvekt 0.20g, ultralyd.		2008.0345	Wieslawa Koziel
4	4.$02	Innvekt 0.16g, ultralyd.		2008.0345	Wieslawa Koziel
5	5#.$02	Innvekt 0.18g, ultralyd.		2008.0345	Wieslawa Koziel
6	6.$02	Innvekt 0.18g, ultralyd.		2008.0345	Wieslawa Koziel
7	7.$02	Innvekt 0.18g, ultralyd.		2008.0345	Wieslawa Koziel
8	8#.$02	Innvekt 0.16g, ultralyd.		2008.0345	Wieslawa Koziel
9	9.$02	Innvekt 0.17g, ultralyd.		2008.0345	Wieslawa Koziel
10	10.$02	Innvekt 0.17g, ultralyd.		2008.0345	Wieslawa Koziel
11	11a.$02	Innvekt 0.16g, ultralyd.	8mm - 0.25g,4mm - 1.02g, 2mm - 0.64g, <2mm - 25.91g, total vekt for analyse 26.6g	2008.0345	Wieslawa Koziel
12		Total vekt 0.06g	Prøven gav ikke tilstrekkelig materiale for analyse.	2008.0345	Wieslawa Koziel



Volume Statistics (Arithmetic) 1#.$02

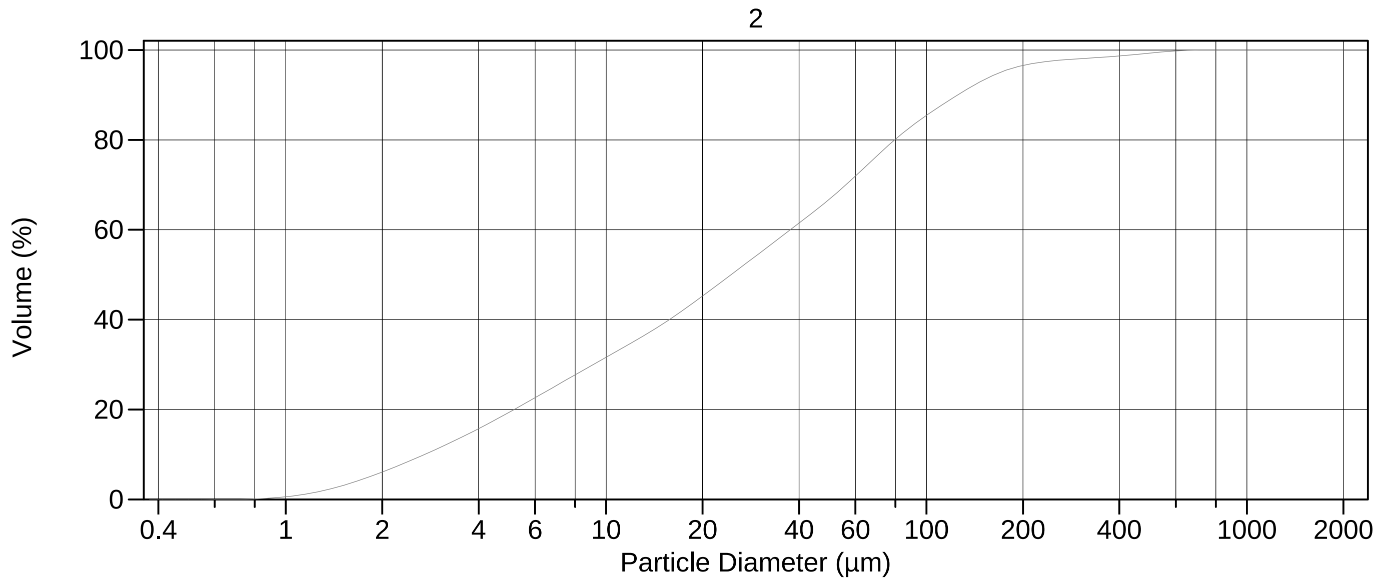
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	63.01 µm	95% Conf. Limits:	0-214.2 µm
Median:	38.46 µm	S.D.:	77.13 µm
D(3,2):	11.71 µm	Variance:	5949 µm^2
Mean/Median Ratio:	1.638	C.V.:	122%
Mode:	66.44 µm	Skewness:	3.044 Right skewed
d_{10}:	4.096 µm	Kurtosis:	13.84 Leptokurtic
d_{50}:	38.46 µm		
d_{90}:	146.9 µm		
Specific Surf. Area	5125 cm^2/ml		

% <	10	20	50	75	90
Size µm	4.096	8.616	38.46	87.21	146.9

1#.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	3.17	1000	100
5.000	12.4	2000	100
10.00	22.2	4000	100
15.00	28.8	8000	100
20.00	34.5		
50.00	57.1		
60.00	62.7		
63.00	64.3		
70.00	67.9		
75.00	70.2		
90.00	76.0		
125.0	85.6		
200.0	95.8		
250.0	97.5		
400.0	98.8		
500.0	99.5		



Volume Statistics (Arithmetic) 2#.$02

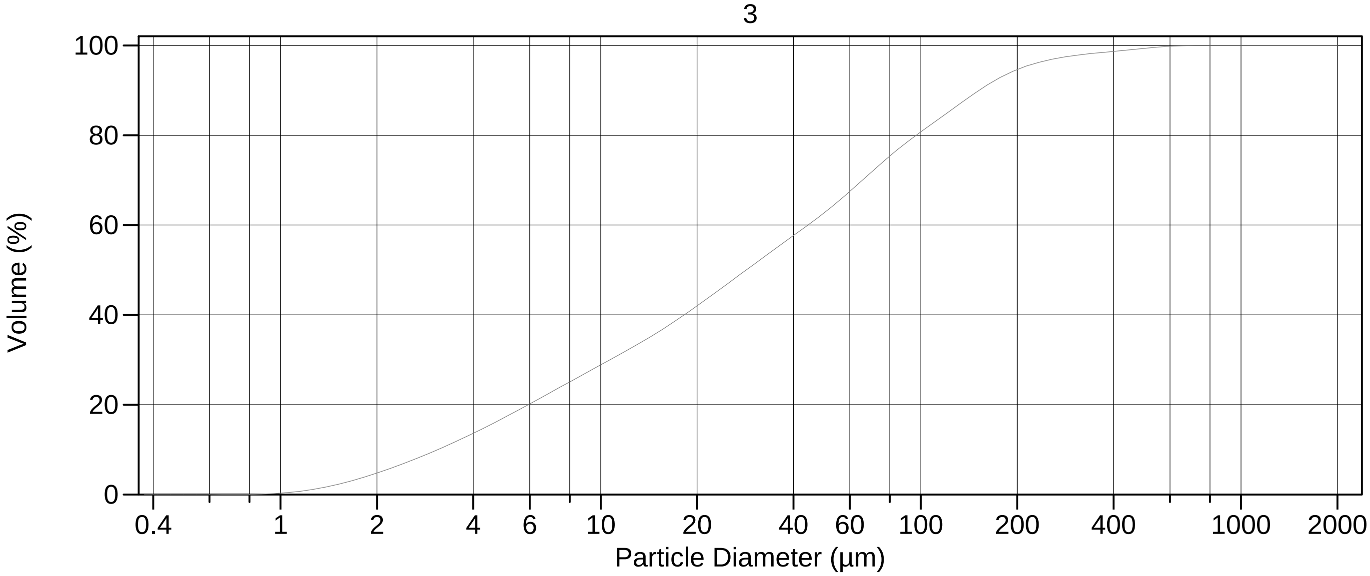
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	51.38 µm	95% Conf. Limits:	0-202.4 µm
Median:	24.55 µm	S.D.:	77.04 µm
D(3,2):	8.047 µm	Variance:	5935 µm^2
Mean/Median Ratio:	2.093	C.V.:	150%
Mode:	66.44 µm	Skewness:	3.790 Right skewed
d_{10}:	2.714 µm	Kurtosis:	19.49 Leptokurtic
d_{50}:	24.55 µm		
d_{90}:	125.3 µm		
Specific Surf. Area	7456 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.714	5.165	24.55	66.69	125.3

2#.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	6.10	1000	100
5.000	19.4	2000	100
10.00	31.6	4000	100
15.00	39.0	8000	100
20.00	45.2		
50.00	66.9		
60.00	71.9		
63.00	73.4		
70.00	76.4		
75.00	78.4		
90.00	83.1		
125.0	90.0		
200.0	96.5		
250.0	97.6		
400.0	98.7		
500.0	99.3		



Volume Statistics (Arithmetic) 3#.$02

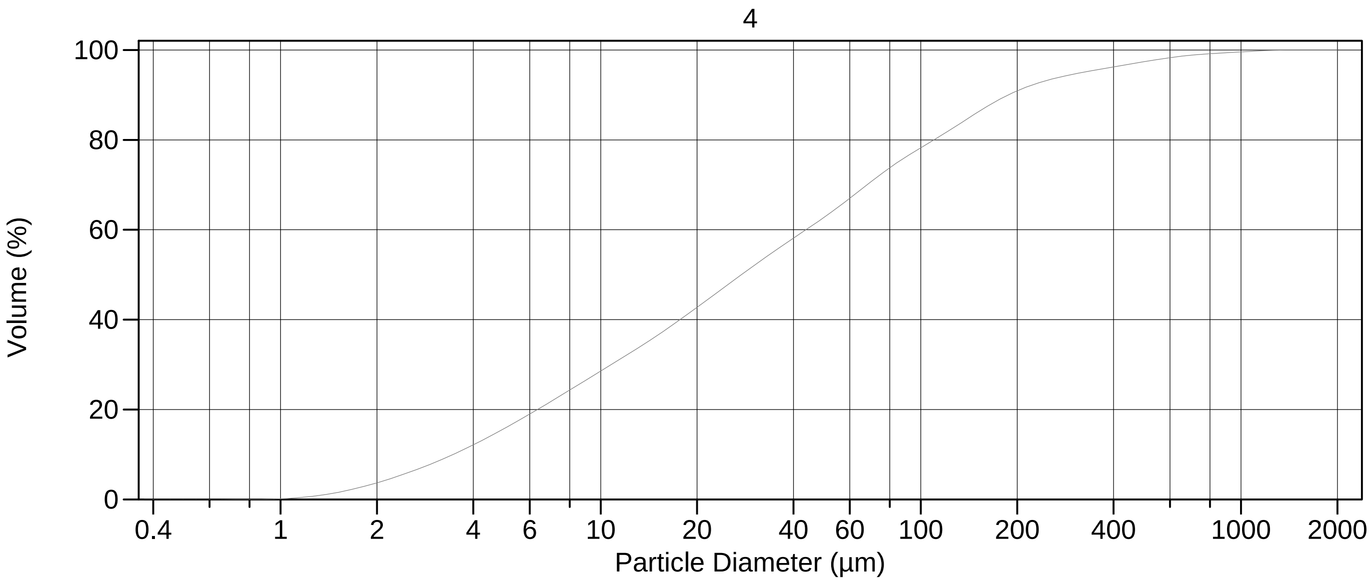
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	59.77 µm	95% Conf. Limits:	0-222.7 µm
Median:	28.52 µm	S.D.:	83.14 µm
D(3,2):	9.165 µm	Variance:	6912 µm^2
Mean/Median Ratio:	2.096	C.V.:	139%
Mode:	66.44 µm	Skewness:	3.077 Right skewed
d_{10}:	3.101 µm	Kurtosis:	13.11 Leptokurtic
d_{50}:	28.52 µm		
d_{90}:	152.2 µm		
Specific Surf. Area	6547 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.101	5.947	28.52	78.92	152.2

3#.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.78	1000	100
5.000	17.1	2000	100
10.00	28.9	4000	100
15.00	36.0	8000	100
20.00	42.0		
50.00	62.8		
60.00	67.5		
63.00	68.8		
70.00	71.8		
75.00	73.6		
90.00	78.3		
125.0	85.7		
200.0	94.6		
250.0	96.7		
400.0	98.7		
500.0	99.4		



Volume Statistics (Arithmetic) 4.$02

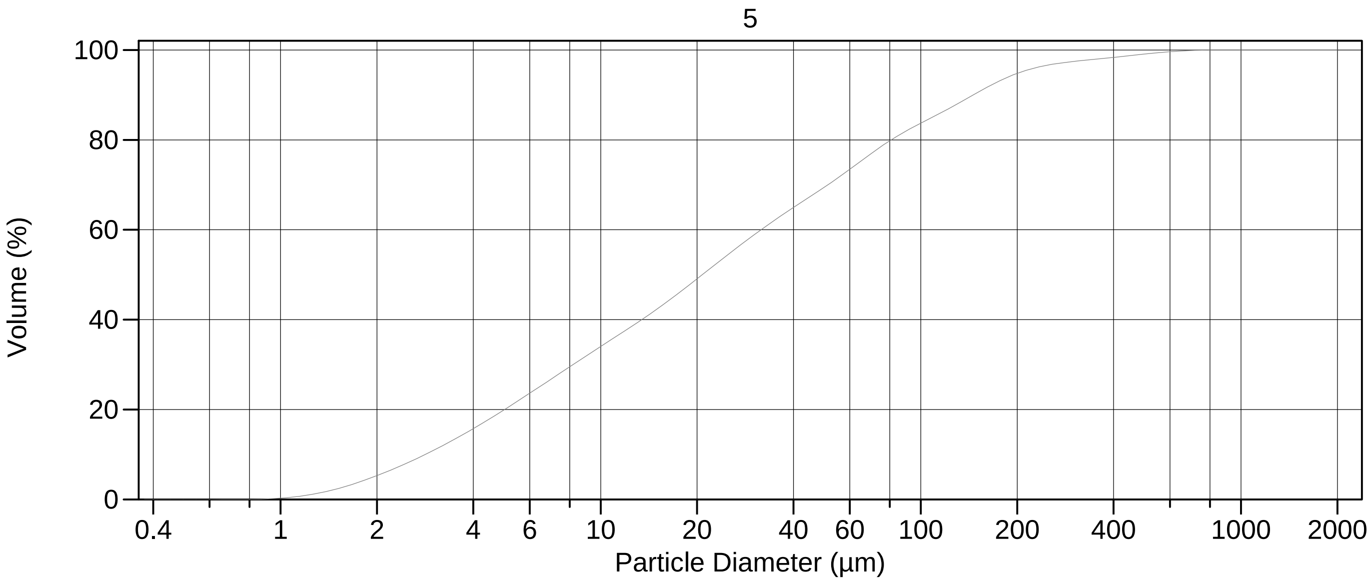
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	78.00 µm	95% Conf. Limits:	0-353.7 µm
Median:	27.50 µm	S.D.:	140.6 µm
D(3,2):	9.899 µm	Variance:	19781 $µm^2$
Mean/Median Ratio:	2.836	C.V.:	180%
Mode:	66.44 µm	Skewness:	4.148 Right skewed
d_{10}:	3.458 µm	Kurtosis:	22.39 Leptokurtic
d_{50}:	27.50 µm		
d_{90}:	187.7 µm		
Specific Surf. Area	6061 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.458	6.346	27.50	84.59	187.7

4.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	3.69	1000	99.6
5.000	15.8	2000	100
10.00	28.5	4000	100
15.00	36.4	8000	100
20.00	42.7		
50.00	62.8		
60.00	67.0		
63.00	68.2		
70.00	70.7		
75.00	72.3		
90.00	76.2		
125.0	82.5		
200.0	90.9		
250.0	93.3		
400.0	96.2		
500.0	97.4		



Volume Statistics (Arithmetic) 5#.$02

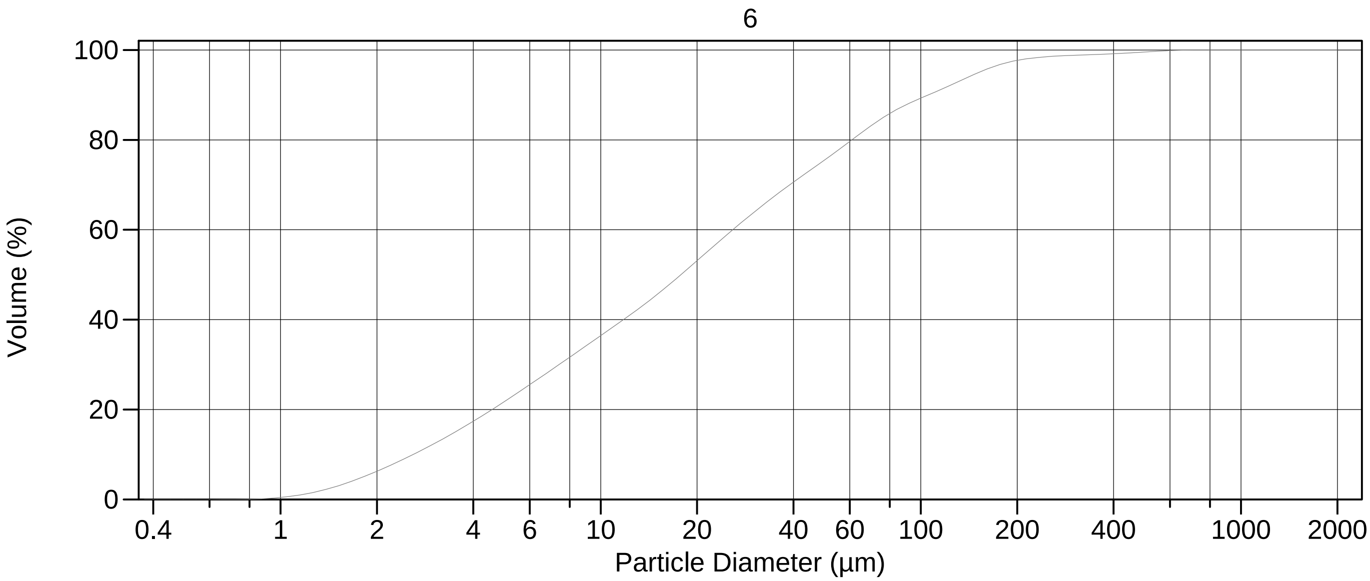
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	54.36 µm	95% Conf. Limits:	0-227.4 µm
Median:	20.75 µm	S.D.:	88.30 µm
D(3,2):	8.102 µm	Variance:	7797 $µm^2$
Mean/Median Ratio:	2.620	C.V.:	162%
Mode:	19.76 µm	Skewness:	3.605 Right skewed
d_{10}:	2.832 µm	Kurtosis:	17.07 Leptokurtic
d_{50}:	20.75 µm		
d_{90}:	145.7 µm		
Specific Surf. Area	7406 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.832	5.013	20.75	64.19	145.7

5#.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	5.29	1000	100.0
5.000	19.9	2000	100
10.00	34.0	4000	100
15.00	42.3	8000	100
20.00	49.1		
50.00	69.5		
60.00	73.4		
63.00	74.6		
70.00	77.0		
75.00	78.5		
90.00	82.0		
125.0	87.3		
200.0	94.8		
250.0	96.6		
400.0	98.4		
500.0	99.1		



Volume Statistics (Arithmetic) 6.$02

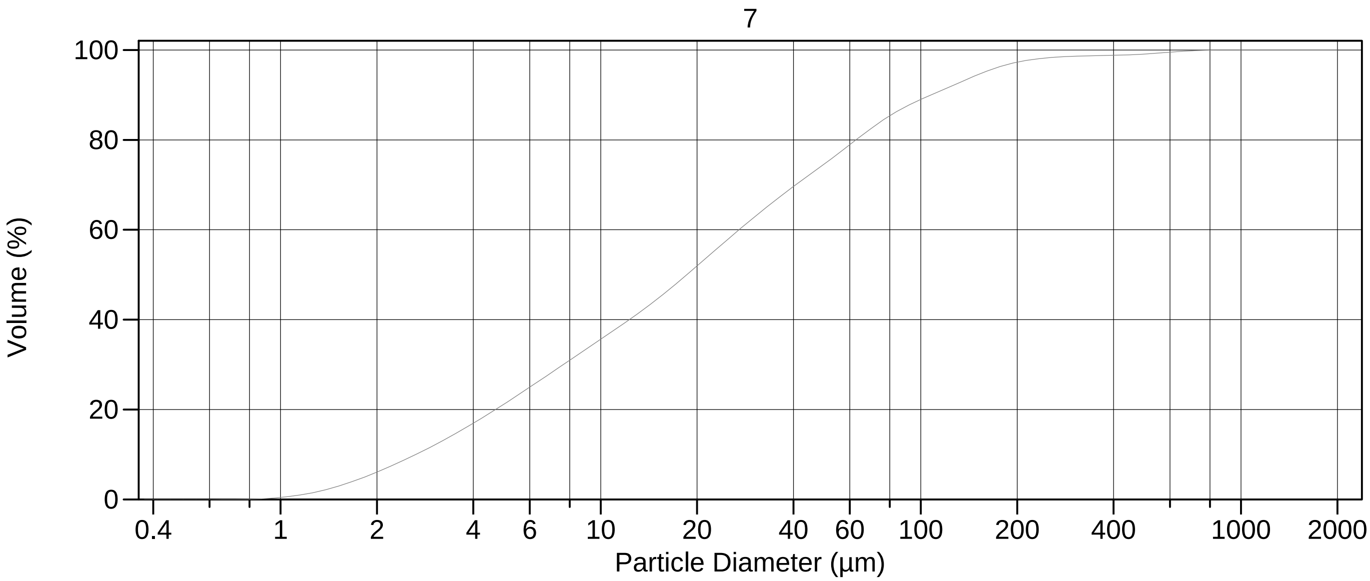
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	40.76 µm	95% Conf. Limits:	0-169.8 µm
Median:	17.82 µm	S.D.:	65.82 µm
D(3,2):	7.347 µm	Variance:	4332 μm^2
Mean/Median Ratio:	2.288	C.V.:	161%
Mode:	19.76 µm	Skewness:	4.346 Right skewed
d_{10}:	2.598 µm	Kurtosis:	26.82 Leptokurtic
d_{50}:	17.82 µm		
d_{90}:	105.5 µm		
Specific Surf. Area	8167 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.598	4.582	17.82	48.92	105.5

6.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	6.26	1000	100
5.000	21.7	2000	100
10.00	36.4	4000	100
15.00	45.6	8000	100
20.00	53.1		
50.00	75.5		
60.00	79.6		
63.00	80.8		
70.00	83.2		
75.00	84.6		
90.00	87.8		
125.0	92.3		
200.0	97.7		
250.0	98.5		
400.0	99.2		
500.0	99.6		



Volume Statistics (Arithmetic) 7.$02

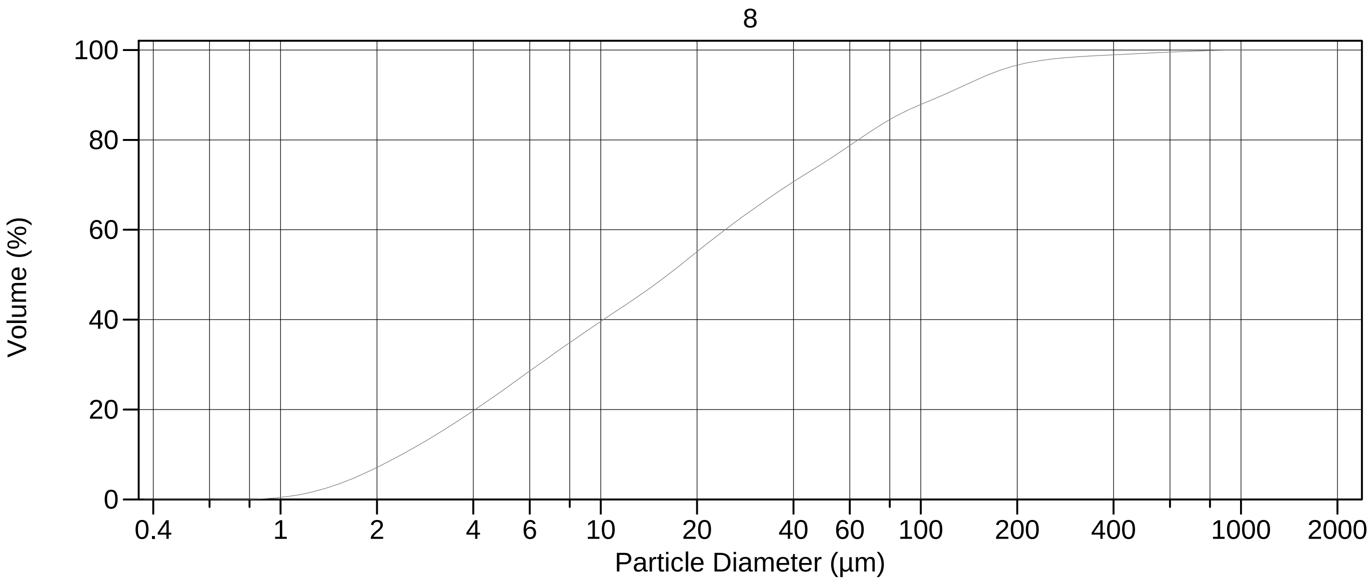
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	43.64 µm	95% Conf. Limits:	0-194.6 µm
Median:	18.59 µm	S.D.:	77.03 µm
D(3,2):	7.504 µm	Variance:	5933 µm^2
Mean/Median Ratio:	2.347	C.V.:	177%
Mode:	19.76 µm	Skewness:	5.048 Right skewed
d_{10}:	2.646 µm	Kurtosis:	34.04 Leptokurtic
d_{50}:	18.59 µm		
d_{90}:	107.7 µm		
Specific Surf. Area	7996 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.646	4.696	18.59	50.79	107.7

7.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	6.08	1000	100.0
5.000	21.2	2000	100
10.00	35.6	4000	100
15.00	44.5	8000	100
20.00	51.9		
50.00	74.6		
60.00	78.9		
63.00	80.1		
70.00	82.6		
75.00	84.1		
90.00	87.4		
125.0	92.0		
200.0	97.3		
250.0	98.3		
400.0	98.8		
500.0	99.1		



Volume Statistics (Arithmetic) 8#.$02

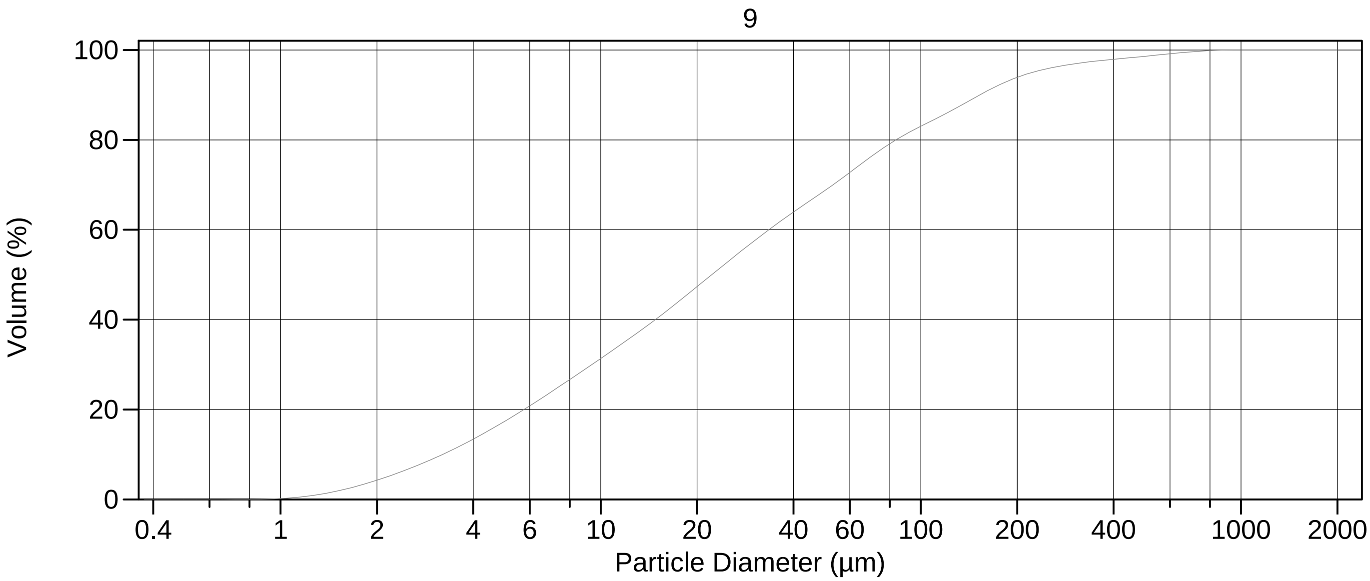
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	44.18 µm	95% Conf. Limits:	0-201.6 µm
Median:	16.24 µm	S.D.:	80.32 µm
D(3,2):	6.801 µm	Variance:	6451 µm^2
Mean/Median Ratio:	2.721	C.V.:	182%
Mode:	19.76 µm	Skewness:	4.962 Right skewed
d_{10}:	2.394 µm	Kurtosis:	34.86 Leptokurtic
d_{50}:	16.24 µm		
d_{90}:	117.5 µm		
Specific Surf. Area	8823 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.394	4.056	16.24	49.98	117.5

8#.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	7.11	1000	100.0
5.000	24.5	2000	100
10.00	39.6	4000	100
15.00	48.2	8000	100
20.00	55.1		
50.00	75.0		
60.00	78.7		
63.00	79.8		
70.00	82.0		
75.00	83.3		
90.00	86.4		
125.0	90.8		
200.0	96.6		
250.0	97.9		
400.0	98.9		
500.0	99.3		



Volume Statistics (Arithmetic) 9.$02

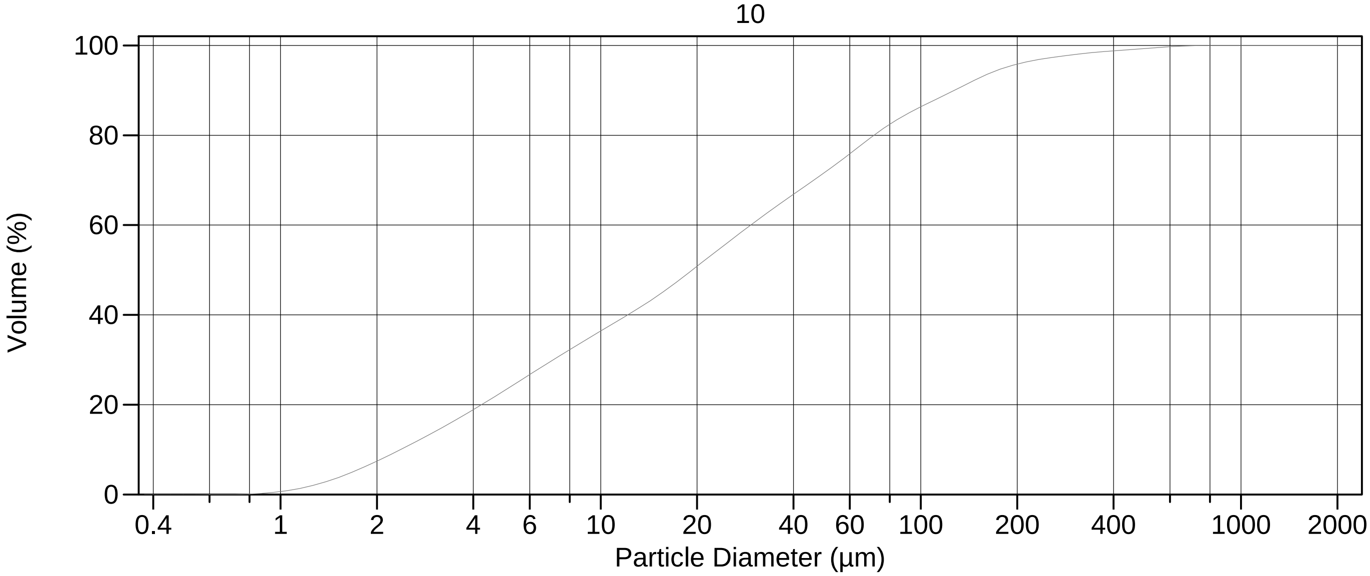
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	59.13 µm	95% Conf. Limits:	0-256.8 µm
Median:	22.23 µm	S.D.:	100.9 µm
D(3,2):	8.966 µm	Variance:	10175 µm^2
Mean/Median Ratio:	2.660	C.V.:	171%
Mode:	19.76 µm	Skewness:	3.910 Right skewed
d_{10}:	3.207 µm	Kurtosis:	19.61 Leptokurtic
d_{50}:	22.23 µm		
d_{90}:	153.0 µm		
Specific Surf. Area	6692 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.207	5.762	22.23	66.16	153.0

9.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.27	1000	100.0
5.000	17.3	2000	100
10.00	31.3	4000	100
15.00	40.3	8000	100
20.00	47.3		
50.00	68.6		
60.00	72.7		
63.00	73.9		
70.00	76.3		
75.00	77.8		
90.00	81.3		
125.0	86.6		
200.0	93.9		
250.0	95.9		
400.0	97.9		
500.0	98.6		



Volume Statistics (Arithmetic) 10.$02

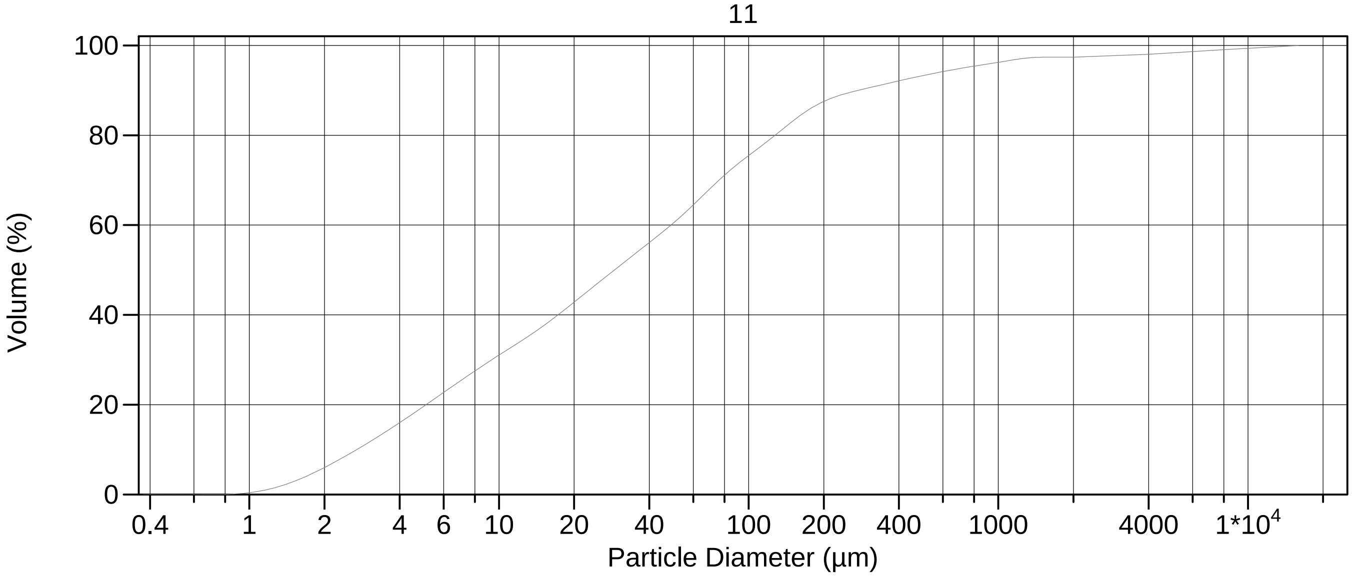
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	48.42 µm	95% Conf. Limits:	0-204.5 µm
Median:	19.34 µm	S.D.:	79.62 µm
D(3,2):	7.012 µm	Variance:	6340 $µm^2$
Mean/Median Ratio:	2.504	C.V.:	164%
Mode:	19.76 µm	Skewness:	3.854 Right skewed
d_{10}:	2.373 µm	Kurtosis:	19.96 Leptokurtic
d_{50}:	19.34 µm		
d_{90}:	127.3 µm		
Specific Surf. Area	8557 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.373	4.244	19.34	57.83	127.3

10.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	7.42	1000	100
5.000	23.1	2000	100
10.00	36.4	4000	100
15.00	44.2	8000	100
20.00	50.8		
50.00	71.7		
60.00	75.9		
63.00	77.1		
70.00	79.6		
75.00	81.1		
90.00	84.6		
125.0	89.7		
200.0	95.8		
250.0	97.2		
400.0	98.8		
500.0	99.3		



Volume Statistics (Arithmetic) 11a.$02

Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	271.2 µm	95% Conf. Limits:	0-2710 µm
Median:	29.05 µm	S.D.:	1244 µm
D(3,2):	8.350 µm	Variance:	1548345 μm^2
Mean/Median Ratio:	9.337	C.V.:	459%
Mode:	66.44 µm	Skewness:	7.452 Right skewed
d_{10}:	2.695 µm	Kurtosis:	59.00 Leptokurtic
d_{50}:	29.05 µm		
d_{90}:	274.6 µm		
Specific Surf. Area	7185 cm^2/ml		

% <	10	20	50	75	90
Size µm	2.695	5.106	29.05	97.56	274.6

11a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	6.02	1000	96.2
5.000	19.6	2000	97.4
10.00	31.0	4000	98.0
15.00	37.5	8000	99.1
20.00	42.8		
50.00	60.5		
60.00	64.5		
63.00	65.6		
70.00	68.1		
75.00	69.7		
90.00	73.5		
125.0	79.6		
200.0	87.5		
250.0	89.4		
400.0	92.1		
500.0	93.3		

7491 TRONDHEIM
Tlf.: 73 90 40 00
Telefaks: 73 92 16 20

Tørrvekt
Geologisk materiale
Analysekontrakt nr.
2008.0345

Operatør: Wieslawa Koziel

Prøve nr.	Tørrvekt (g)
1	45.96
2	3.20
3	5.85
4	53.22
5	3.47
6	3.32
7	3.35
8	5.30
9	9.04
10	15.73
11	75.62
12	0.06

NGU Norges geologiske undersøkelse
7491 TRONDHEIM
Tlf.: 73 90 40 00
Telefaks: 73 92 16 20

Kornfordelingsanalyser: Coulter laser partikkelteller
GEOLOGISK MATERIALE
Analysekontrakt nr. 2010.0018

INSTRUMENT: **Coulter LS 200**

METODE: **Metodeoppsettet er beskrevet i NGU-SD 5.11: Kornfordelingsanalyser: Coulter laser partikkelteller.**
Kornfordelingsbestemmelse basert på laserdiffraksjon. Laserlys brytes i ulike vinkler avhengig av størrelsen på partiklene, og registreres så av en rekke detektorer. De registrerte vinklene tilsvarer gitte partikkelstørrelser, og antall partikler er relatert til den intensiteten som den korresponderende detektoren registrerer. Kornfordelingen bestemmes således på volum-basis, med antagelse om ens tetthet på materialet vil kumulativ volum% være identisk med kumulativ masse%.
Beregning på volum/masse-basis er basert på antagelse om sfæriske partikler.

MÅLEOMRÅDE : **0.4 µm - 2000 mm** **NB !** Metoden normaliserer alle data i måleområdet til sum 100 % (kumulativ %).
Måleområdet går kun ned til 0.4 µm og dette settes som nullpunkt mhp. kumulativ %.
Prøvene kan derfor inneholde materiale finere enn 0.4 µm.

ANALYSEUSIKKERHET: **± 10 % [kumulativ masse(volum) %]** *Usikkerheten er oppgitt med dekningsfaktor 2, tilsvarende et konfidensintervall på 95 %*
Bestemmelse av usikkerhet er basert på sammenligning av oppnådde resultater med sertifikatverdier for kvartsstandard BCR-131, samt presisjonsdata.
MERK! Metoden tar utgangspunkt i antagelse om sfæriske partikler. For prøver som avviker fra dette kan usikkerheten være større.

PRESISJON: **Det analyseres rutinemessig kontrollprøver som føres i kontrolldiagram (X-diagram). Disse kan forevises om ønskelig.**

FORBEHANDLING: Ingen

ANTALL PRØVER: 13

ANMERKNINGER: Data for fraksjoner >2000 µm er fremkommet ved gravimetriske bestemmelser.

Gjengivelse av analysedata skal skje på en slik måte at meningsinnholdet i rapporten ikke endres.

Ferdig analysert	25-Jan-10	Wieslawa Koziel
	Dato	OPERATØR

Kornfordelingsanalyser: Coulter laser partikkelteller
GELOGISK MATERIALE
Analysekontrakt nr. 2010.0018

NGU Norges geologiske undersøkelse
7491 TRONDHEIM
Tlf.: 73 90 40 00
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Coulter data (Kumulativ volum % <)

Prøve nr. → Diameter(µm) ↓	1	2	3	4	5	6	7	8	9	10	11	12	13
0.375	0	0	0	0	0	0	0	0	0	0	0	0	0
0.412	0	0	0	0	0	0	0	0	0	0	0	0	0
0.452	0	0	0	0	0	0	0	0	0	0	0	0	0
0.496	0	0	0	0	0	0	0	0	0	0	0	0	0
0.545	0	0	0	0	0	0	0	0	0	0	0	0	0
0.598	0	0	0	0	0	0	0	0	0	0	0	0	0
0.657	0.000099	0	0	0	0	0	0.00012	0	0.000097	0.000027	0	0.000023	0.000037
0.721	0.0022	0.00022	0.00014	0	0	0.00056	0.0024	0.00042	0.0021	0.001	0.00018	0.001	0.00078
0.791	0.017	0.0032	0.0026	0	0.00048	0.0073	0.017	0.0056	0.015	0.0087	0.0028	0.0094	0.0056
0.869	0.066	0.02	0.018	0.0001	0.0071	0.043	0.066	0.033	0.06	0.039	0.018	0.043	0.022
0.953	0.18	0.068	0.067	0.0021	0.044	0.14	0.17	0.11	0.16	0.11	0.062	0.13	0.057
1.047	0.37	0.17	0.18	0.015	0.15	0.31	0.36	0.25	0.33	0.24	0.15	0.28	0.12
1.149	0.67	0.32	0.36	0.056	0.36	0.59	0.64	0.47	0.6	0.44	0.31	0.51	0.21
1.261	1.07	0.55	0.64	0.14	0.7	0.97	1.03	0.78	0.96	0.73	0.53	0.83	0.35
1.385	1.6	0.86	1.02	0.29	1.18	1.48	1.53	1.18	1.43	1.1	0.83	1.26	0.53
1.52	2.24	1.25	1.51	0.51	1.79	2.12	2.15	1.69	2.01	1.55	1.21	1.78	0.75
1.669	3	1.72	2.1	0.81	2.56	2.87	2.88	2.3	2.69	2.1	1.67	2.4	1.02
1.832	3.85	2.26	2.8	1.18	3.45	3.74	3.72	3	3.45	2.71	2.2	3.11	1.34
2.01	4.78	2.87	3.58	1.64	4.47	4.7	4.64	3.77	4.29	3.4	2.81	3.89	1.7
2.207	5.77	3.54	4.46	2.18	5.59	5.75	5.65	4.62	5.2	4.15	3.47	4.74	2.1
2.423	6.82	4.27	5.41	2.82	6.81	6.87	6.73	5.52	6.15	4.95	4.2	5.64	2.55
2.66	7.92	5.04	6.44	3.54	8.13	8.07	7.88	6.49	7.16	5.8	4.98	6.59	3.02
2.92	9.06	5.87	7.54	4.34	9.53	9.33	9.1	7.53	8.21	6.69	5.82	7.6	3.54
3.206	10.3	6.75	8.73	5.24	11	10.7	10.4	8.62	9.31	7.65	6.72	8.66	4.09
3.519	11.5	7.69	9.99	6.22	12.6	12.1	11.8	9.78	10.5	8.65	7.68	9.78	4.69
3.862	12.8	8.69	11.3	7.29	14.3	13.5	13.2	11	11.7	9.71	8.7	10.9	5.32
4.241	14.2	9.73	12.7	8.45	16.1	15.1	14.7	12.3	12.9	10.8	9.78	12.2	5.99
4.656	15.6	10.8	14.2	9.68	17.9	16.6	16.3	13.6	14.2	12	10.9	13.4	6.69
5.111	17	12	15.7	11	19.8	18.3	18	15	15.6	13.2	12.1	14.7	7.42
5.611	18.5	13.2	17.3	12.4	21.8	20	19.7	16.5	16.9	14.4	13.3	16.1	8.18
6.158	20	14.4	19	13.8	23.8	21.7	21.5	18	18.3	15.7	14.6	17.5	8.96
6.761	21.5	15.6	20.7	15.3	25.8	23.4	23.3	19.5	19.7	17	15.9	18.9	9.77
7.421	23	16.9	22.4	16.9	27.9	25.2	25.2	21.1	21.2	18.3	17.2	20.3	10.6
8.147	24.6	18.2	24.1	18.5	29.9	27	27.1	22.7	22.6	19.6	18.6	21.7	11.4
8.944	26.1	19.5	25.9	20.2	32	28.8	29	24.3	24.1	21	20	23.1	12.2
9.819	27.6	20.8	27.6	22	34	30.6	31	25.9	25.5	22.4	21.4	24.6	13.1
10.78	29.2	22.1	29.4	23.8	36	32.4	32.9	27.5	27	23.7	22.8	26	13.9
11.83	30.8	23.4	31.2	25.7	38	34.3	34.9	29.2	28.5	25.2	24.3	27.4	14.8
12.99	32.3	24.8	33	27.7	40	36.2	37	30.9	30	26.6	25.8	28.9	15.6
14.26	34	26.2	34.9	29.8	42	38.1	39.1	32.6	31.6	28.1	27.3	30.5	16.5
15.65	35.8	27.7	36.8	32.1	44.1	40.2	41.3	34.5	33.3	29.7	28.9	32.1	17.4
17.18	37.6	29.3	38.8	34.5	46.3	42.4	43.6	36.4	35.2	31.4	30.6	33.9	18.4
18.86	39.6	31	40.9	37	48.6	44.7	46	38.3	37.1	33.2	32.4	35.7	19.4
20.7	41.6	32.7	43	39.6	50.9	47	48.4	40.3	39	35	34.2	37.6	20.4
22.73	43.6	34.4	45.1	42.4	53.2	49.3	50.8	42.4	41	36.9	36.1	39.5	21.5
24.95	45.7	36.2	47.2	45.2	55.4	51.7	53.2	44.4	43	38.7	37.9	41.4	22.5
27.38	47.8	37.9	49.3	48	57.7	54	55.6	46.4	45	40.6	39.8	43.4	23.6
30.07	49.9	39.7	51.4	50.8	59.9	56.4	57.9	48.3	46.9	42.5	41.7	45.3	24.7
33	52	41.5	53.4	53.6	62	58.6	60.2	50.3	48.8	44.4	43.5	47.2	25.8
36.24	54.1	43.2	55.4	56.3	64.1	60.8	62.3	52.1	50.7	46.3	45.3	49.1	26.9
39.77	56.1	44.9	57.4	58.9	66.2	63	64.4	53.9	52.6	48.1	47.1	50.9	28.1
43.66	58.3	46.6	59.4	61.3	68.2	65.1	66.4	55.7	54.4	49.9	48.8	52.8	29.3

Kornfordelingsanalyser: Coulter laser partikkelteller
GELOGISK MATERIALE
Analysekontrakt nr. 2010.0018

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Coulter data (Kumulativ volum % <)

Prøve nr. → Diameter(µm) ↓	1	2	3	4	5	6	7	8	9	10	11	12	13
47.93	60.4	48.4	61.3	63.7	70.2	67.2	68.3	57.5	56.2	51.8	50.6	54.7	30.5
52.63	62.7	50.2	63.4	66.1	72.4	69.5	70.3	59.4	58.1	53.8	52.5	56.7	31.9
57.77	65.1	52.1	65.6	68.4	74.7	71.8	72.4	61.5	60.1	55.9	54.5	58.8	33.4
63.41	67.7	54.1	67.9	70.6	77	74.3	74.6	63.6	62.2	58.2	56.6	61.2	35.1
69.62	70.2	56.2	70.3	72.6	79.3	76.8	76.7	65.7	64.4	60.5	58.7	63.5	36.8
76.43	72.7	58.1	72.5	74.5	81.5	79.1	78.7	67.8	66.4	62.8	60.8	65.8	38.6
83.9	74.9	60	74.5	76.2	83.5	81.2	80.4	69.7	68.3	65	62.8	67.9	40.3
92.09	76.9	61.7	76.3	77.6	85.2	83.1	82	71.5	70.1	67.1	64.6	69.9	42
101.1	78.7	63.3	78	78.9	86.7	84.7	83.3	73.1	71.7	69.1	66.3	71.8	43.7
111	80.4	64.9	79.6	80.2	88.1	86.2	84.5	74.7	73.3	71.1	68	73.7	45.4
121.8	82.1	66.5	81.3	81.6	89.6	87.6	85.8	76.4	74.9	73.2	69.7	75.7	47.2
133.7	83.7	68.3	83	83.2	91.1	89.1	87.2	78.2	76.7	75.3	71.6	77.7	49.1
146.8	85.3	70.1	84.7	85	92.6	90.4	88.5	80	78.5	77.6	73.5	79.9	50.9
161.2	86.9	72	86.4	86.7	94	91.7	89.8	81.8	80.3	79.8	75.4	82	52.8
176.8	88.3	73.7	87.9	88.2	95.3	92.7	90.9	83.4	82	81.8	77.2	84	54.7
194.2	89.4	75.2	89.2	89.5	96.2	93.5	91.7	84.9	83.5	83.7	78.8	85.7	56.4
213.2	90.4	76.6	90.2	90.5	96.9	94	92.3	86.2	84.8	85.3	80.2	87.2	58
234.1	91.1	77.9	91.1	91.2	97.5	94.4	92.7	87.4	85.9	86.7	81.5	88.4	59.4
256.8	91.7	79	91.8	91.7	97.9	94.7	93.1	88.4	86.9	88	82.7	89.4	60.8
282.1	92.2	80	92.4	92.1	98.2	94.9	93.4	89.3	87.7	89.1	83.9	90.3	62.2
309.6	92.6	81	92.9	92.5	98.5	95.1	93.7	90.1	88.6	90.1	85	91.2	63.4
339.8	93.1	81.9	93.5	93	98.7	95.3	94	90.9	89.5	91	86.2	92	64.7
373.1	93.6	82.7	93.9	93.6	98.8	95.5	94.2	91.6	90.3	91.9	87.2	92.9	65.9
409.6	94.1	83.5	94.4	94.3	99	95.8	94.5	92.4	91.2	92.8	88.3	93.7	67.1
449.7	94.6	84.3	94.8	94.9	99.1	96.1	94.8	93.1	92	93.7	89.3	94.5	68.3
493.6	95.1	85.1	95.2	95.5	99.2	96.4	95.1	93.9	92.8	94.5	90.1	95.3	69.5
541.9	95.6	85.9	95.6	96	99.3	96.7	95.4	94.6	93.5	95.2	90.8	96	70.7
594.9	96.1	86.7	95.9	96.3	99.5	97	95.7	95.3	94.1	95.9	91.4	96.6	71.8
653	96.5	87.4	96.2	96.5	99.7	97.2	96	95.9	94.5	96.5	92	97	72.8
716.9	96.9	88.1	96.4	96.7	99.8	97.3	96.2	96.4	95	96.9	92.4	97.4	73.7
786.9	97.2	88.6	96.6	96.9	99.9	97.4	96.4	96.8	95.4	97.3	92.8	97.6	74.6
863.9	97.5	89.1	96.7	97.2	100	97.5	96.6	97.2	95.9	97.5	93.3	97.9	75.4
948.2	97.8	89.6	96.9	97.6	100	97.7	96.8	97.6	96.4	97.7	93.7	98.1	76.1
1041	98.1	90	97	98.2	100	97.8	96.9	98	97	97.9	94.2	98.3	76.8
1143	98.3	90.2	97.1	98.9	100	97.9	97	98.4	97.5	98.1	94.7	98.5	77.5
1255	98.5	90.4	97.2	99.5	100	98	97.1	98.6	97.8	98.3	95	98.7	78.2
1377	98.6	90.4	97.2	99.9	100	98.1	97.1	98.8	98	98.4	95.2	98.9	78.8
1512	98.6	90.4	97.2	100	100	98.1	97.1	98.8	98	98.4	95.2	98.9	79.3
1660	98.6	90.4	97.2	100	100	98.1	97.1	98.8	98	98.4	95.2	98.9	79.8
1822	98.6	90.4	97.2	100	100	98.1	97.1	98.8	98	98.4	95.2	98.9	80.3
2000	98.6	90.4	97.2	100	100	98.1	97.1	98.8	98	98.4	95.2	98.9	80.8
4000	98.8	91.4	98.6			98.7	97.6	99	98.4	98.6	95.5	99.5	82.4
8000	99.2	97.2	100			99.4	98	100	99.6	98.8	98.7	99.8	88.8
16000	100	100				100	100		100	100	100	100	100

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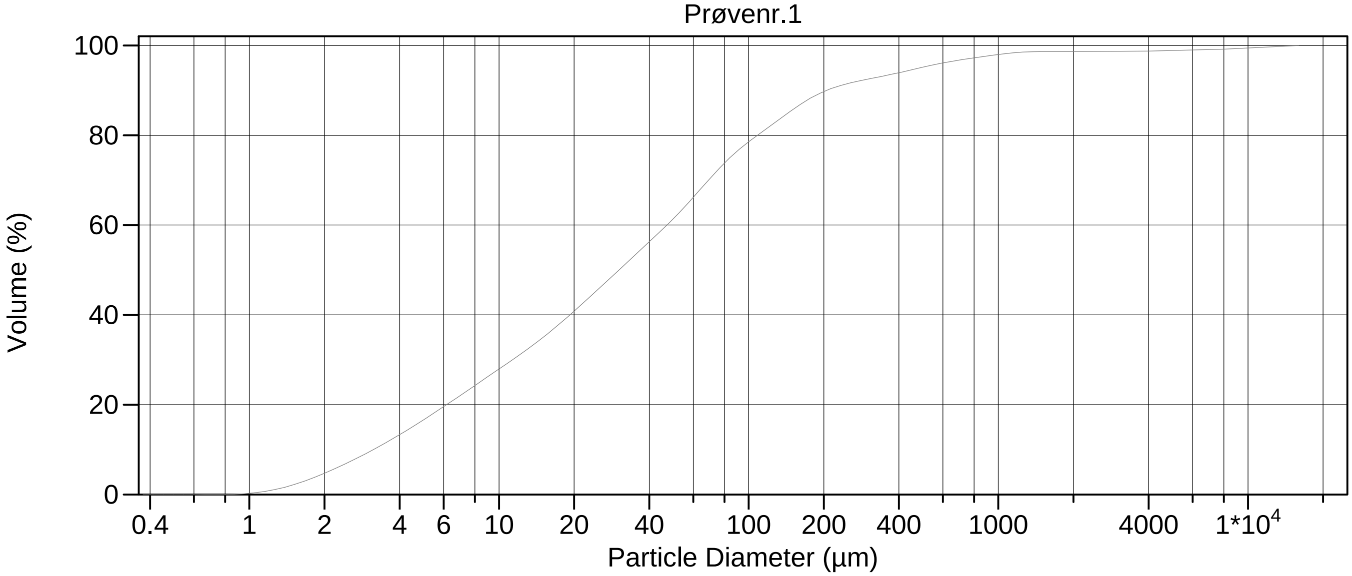
Kornfordelingsanalyser: Coulter laser partikkelteller
GEOLOGISK MATERIALE
Analysekontrakt nr. 2010.0018

File name:	1#a.$02	2#a.$02	3a.$02	4#.$02	5#.$02	6a.$02	7a.$02	8a.$02	9a.$02	10a.$02	11a.$02	12a.$02
Group ID:	2010.0018	2010.0018	2010.0018	2010.0018	2010.0018	2010.0018	2010.0018	2010.0018	2010.0018	2010.0018	2010.0018	2010.0018
Sample ID:	**Prøvenr.1**	**Prøvenr.2**	**Prøvenr.3**	**Prøvenr.4**	**Prøvenr.5**	**Prøvenr.6**	**Prøvenr.7**	**Prøvenr.8**	**Prøvenr.9**	**Prøvenr.10**	**Prøvenr.11**	**Prøvenr.12**
Operator:	W. Koziel	W.Koziel	W. Koziel	W.Koziel	W.Koziel	W. Koziel	W. Koziel	W. Koziel	W. Koziel	W. Koziel	W. Koziel	W. Koziel
Comment	0.16g, ultralyd	0.16g, ultralyd	0.18g, ultralyd	0.15g, ultralyd	0.17g, ultralyd	0.19g, ultralyd	0.18g, ultralyd	0.18g, ultralyd	0.17g, ultralyd	0.17g, ultralyd	0.17g, ultralyd	0.16g, ultralyd
Comment												
STATISTISKE PARAMETERE												
From	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
To	16000	16000	8000	2000	2000	16000	16000	8000	16000	16000	16000	16000
Volume	100	100	100	100	100	100	100	100	100	100	100	100
Mean:	202.4	777.1	187.5	98.09	48.41	181.7	323.6	164.5	232.1	253.3	449.9	153.9
Median:	30.25	52.11	28.29	29.29	20	23.34	22.04	32.59	35	43.85	46.4	38.02
D(3,2):	9.418	12.98	10.12	12.89	8.415	8.812	8.791	10.48	10.23	11.75	12.69	10.74
Mean/Median Ratio:	6.689	14.91	6.63	3.349	2.42	7.782	14.68	5.048	6.63	5.775	9.696	4.048
Mode:	66.44	5657	66.44	26.14	60.52	66.44	21.69	66.44	66.44	66.44	5657	66.44
95% Conf. Limits:	0	0	0	0	0	0	0	0	0	0	0	0
95% Conf. Limits:	2338	5146	1630	502.8	207.2	2183	3537	1332	2117	2704	3598	1429
S.D.:	1090	2229	736.1	206.5	81.03	1021	1640	595.5	961.6	1251	1606	650.5
Variance:	1.19E+06	4.97E+06	5.42E+05	42638	6566	1.04E+06	2.69E+06	3.55E+05	9.25E+05	1.56E+06	2.58E+06	4.23E+05
C.V.:	538.5	286.9	392.5	210.5	167.4	562.1	506.7	361.9	414.3	493.8	357	422.7
Skewness:	9.253	3.561	6.349	3.952	4.701	9.246	6.293	8.109	8.365	8.342	5.183	13.05
Kurtosis:	88.4	12.41	41.69	16.66	31.72	91.48	38.65	70.34	79.92	69.94	28.32	201.7
d10:	3.143	4.343	3.522	4.769	3.008	3.063	3.119	3.579	3.393	3.961	4.323	3.584
d50:	30.25	52.11	28.29	29.29	20	23.34	22.04	32.59	35	43.85	46.4	38.02
d90:	205.8	1054	209	203.9	125.3	142.6	164.4	305.1	360.4	307.5	488.4	273.6
Specific Surf. Area	6371	4623	5928	4654	7130	6809	6825	5727	5863	5108	4728	5589
% <												
10	3.143	4.343	3.522	4.769	3.008	3.063	3.119	3.579	3.393	3.961	4.323	3.584
20	6.164	9.3	6.524	8.845	5.151	5.623	5.692	6.958	6.879	8.364	8.951	7.291
50	30.25	52.11	28.29	29.29	20	23.34	22.04	32.59	35	43.85	46.4	38.02
75	84.12	191.5	86.04	78.62	58.6	65.16	64.66	112.8	122.3	131.8	158.2	118.2
90	205.8	1054	209	203.9	125.3	142.6	164.4	305.1	360.4	307.5	488.4	273.6
INTERPOLASJON												
	Volume	Volume	Volume	Volume	Volume	Volume	Volume	Volume	Volume	Volume	Volume	Volume
Particle diameter	% <	% <	% <	% <	% <	% <	% <	% <	% <	% <	% <	% <
µm												
2	4.73	2.84	3.54	1.61	4.41	4.65	4.59	3.73	4.25	3.36	2.77	3.85
5	16.7	11.7	15.4	10.7	19.4	17.9	17.6	14.7	15.2	12.9	11.8	14.4
10	27.9	21	28	22.3	34.4	30.9	31.3	26.2	25.8	22.6	21.7	24.8
15	34.9	27	35.9	31	43.1	39.2	40.3	33.6	32.5	29	28.2	31.4
20	40.8	32	42.2	38.6	50	46.1	47.5	39.6	38.3	34.3	33.5	36.9
50	61.4	49.2	62.3	64.8	71.2	68.2	69.2	58.4	57	52.7	51.5	55.5
60	66.2	52.9	66.5	69.2	75.6	72.8	73.3	62.3	61	56.8	55.3	59.8
63	67.5	54	67.8	70.4	76.8	74.1	74.4	63.4	62.1	58	56.5	61
70	70.4	56.3	70.4	72.8	79.5	76.9	76.8	65.9	64.5	60.6	58.9	63.6
75	72.2	57.7	72	74.1	81.1	78.6	78.3	67.4	66	62.3	60.4	65.3
90	76.4	61.2	75.9	77.2	84.7	82.6	81.6	71	69.6	66.6	64.1	69.4
125	82.5	67	81.7	82.1	90	88	86.2	76.9	75.4	73.8	70.2	76.2
200	89.7	75.7	89.5	89.8	96.4	93.6	91.9	85.3	83.9	84.2	79.2	86.1
250	91.5	78.7	91.6	91.5	97.8	94.6	93	88.1	86.6	87.6	82.4	89.1
400	93.9	83.3	94.3	94.1	98.9	95.7	94.4	92.2	91	92.6	88	93.5
500	95.2	85.2	95.3	95.6	99.2	96.5	95.1	94	92.9	94.6	90.2	95.4
1000	98	89.8	96.9	97.9	100	97.7	96.9	97.8	96.7	97.8	94	98.2
2000	98.6	90.4	97.2	100	100	98.1	97.1	98.8	98	98.4	95.2	98.9
4000	98.8	91.4	98.6	100	100	98.7	97.6	99	98.4	98.6	95.5	99.5
8000	99.2	97.2	100	100	100	99.4	98	100	99.6	98.8	98.7	99.8
16000	100	100	100	100	100	100	100	100	100	100	100	100



Volume Statistics (Arithmetic) 1#a.$02

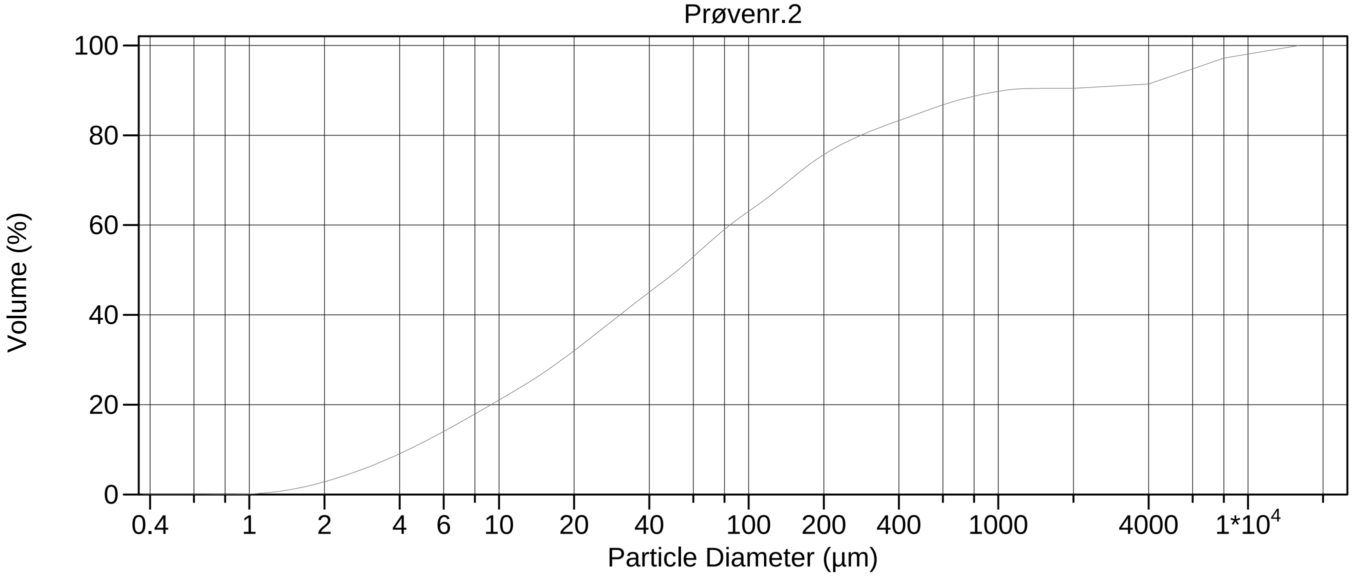
Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	202.4 µm	95% Conf. Limits:	0-2338 µm
Median:	30.25 µm	S.D.:	1090 µm
D(3,2):	9.418 µm	Variance:	1187399 µm^2
Mean/Median Ratio:	6.689	C.V.:	538%
Mode:	66.44 µm	Skewness:	9.253 Right skewed
d_{10}:	3.143 µm	Kurtosis:	88.40 Leptokurtic
d_{50}:	30.25 µm		
d_{90}:	205.8 µm		
Specific Surf. Area	6371 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.143	6.164	30.25	84.12	205.8

1#a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.73	1000	98.0
5.000	16.7	2000	98.6
10.00	27.9	4000	98.8
15.00	34.9	8000	99.2
20.00	40.8	16000	100
50.00	61.4		
60.00	66.2		
63.00	67.5		
70.00	70.4		
75.00	72.2		
90.00	76.4		
125.0	82.5		
200.0	89.7		
250.0	91.5		
400.0	93.9		
500.0	95.2		



Volume Statistics (Arithmetic) 2#a.$02

Calculations from 0.375 µm to 16000 µm

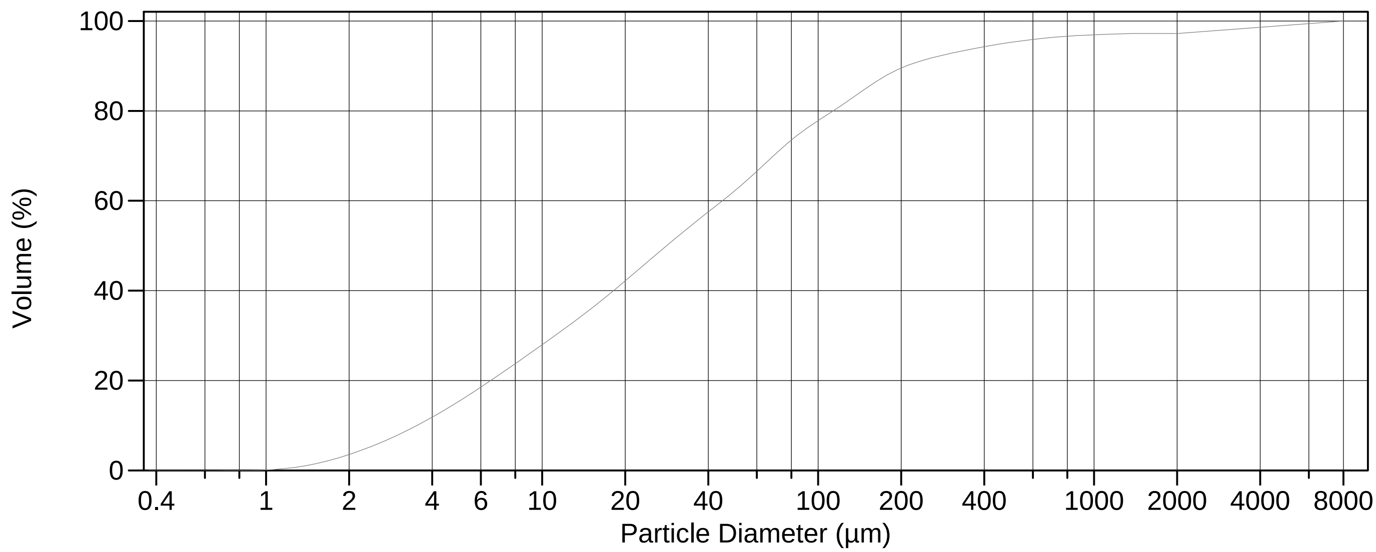
Volume	100.0%		
Mean:	777.1 µm	95% Conf. Limits:	0-5146 µm
Median:	52.11 µm	S.D.:	2229 µm
D(3,2):	12.98 µm	Variance:	4968874 $µm^2$
Mean/Median Ratio:	14.91	C.V.:	287%
Mode:	5657 µm	Skewness:	3.561 Right skewed
d_{10}:	4.343 µm	Kurtosis:	12.41 Leptokurtic
d_{50}:	52.11 µm		
d_{90}:	1054 µm		
Specific Surf. Area	4623 cm^2/ml		

% <	10	20	50	75	90
Size µm	4.343	9.300	52.11	191.5	1054

2#a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	2.84	1000	89.8
5.000	11.7	2000	90.4
10.00	21.0	4000	91.4
15.00	27.0	8000	97.2
20.00	32.0	16000	100
50.00	49.2		
60.00	52.9		
63.00	54.0		
70.00	56.3		
75.00	57.7		
90.00	61.2		
125.0	67.0		
200.0	75.7		
250.0	78.7		
400.0	83.3		
500.0	85.2		

Prøvenr.3



Volume Statistics (Arithmetic) 3a.$02

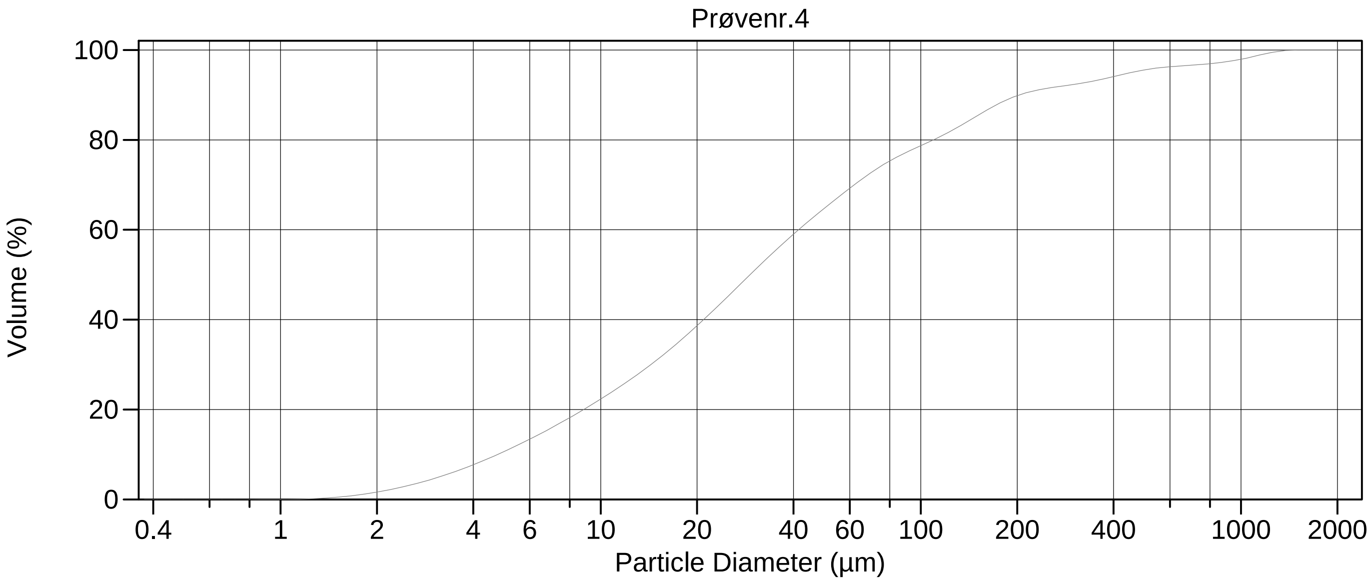
Calculations from 0.375 µm to 8000 µm

Volume	100.0%		
Mean:	187.5 µm	95% Conf. Limits:	0-1630 µm
Median:	28.29 µm	S.D.:	736.1 µm
D(3,2):	10.12 µm	Variance:	541777 μm^2
Mean/Median Ratio:	6.630	C.V.:	392%
Mode:	66.44 µm	Skewness:	6.349 Right skewed
d_{10}:	3.522 µm	Kurtosis:	41.69 Leptokurtic
d_{50}:	28.29 µm		
d_{90}:	209.0 µm		
Specific Surf. Area	5928 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.522	6.524	28.29	86.04	209.0

3a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	3.54	1000	96.9
5.000	15.4	2000	97.2
10.00	28.0	4000	98.6
15.00	35.9	8000	100
20.00	42.2	16000	100
50.00	62.3		
60.00	66.5		
63.00	67.8		
70.00	70.4		
75.00	72.0		
90.00	75.9		
125.0	81.7		
200.0	89.5		
250.0	91.6		
400.0	94.3		
500.0	95.3		



Volume Statistics (Arithmetic) 4#.$02

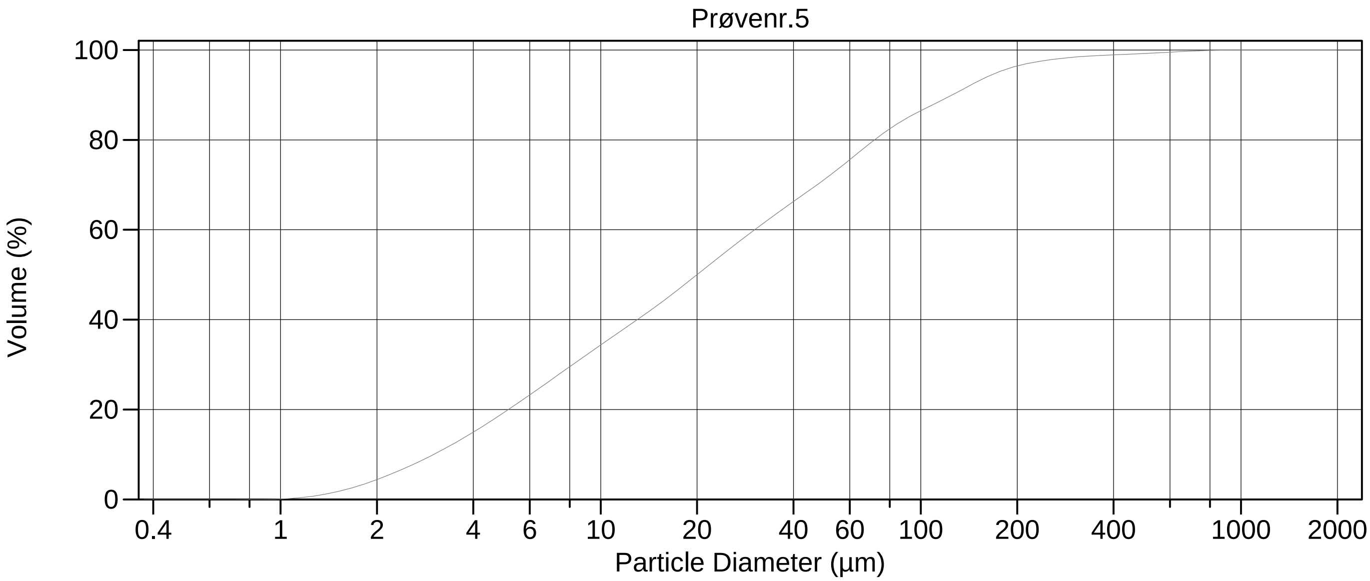
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	98.09 µm	95% Conf. Limits:	0-502.8 µm
Median:	29.29 µm	S.D.:	206.5 µm
D(3,2):	12.89 µm	Variance:	42638 $µm^2$
Mean/Median Ratio:	3.349	C.V.:	211%
Mode:	26.14 µm	Skewness:	3.952 Right skewed
d_{10}:	4.769 µm	Kurtosis:	16.66 Leptokurtic
d_{50}:	29.29 µm		
d_{90}:	203.9 µm		
Specific Surf. Area	4654 cm^2/ml		

% <	10	20	50	75	90
Size µm	4.769	8.845	29.29	78.62	203.9

4#.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	1.61	1000	97.9
5.000	10.7	2000	100
10.00	22.3	4000	100
15.00	31.0	8000	100
20.00	38.6	16000	100
50.00	64.8		
60.00	69.2		
63.00	70.4		
70.00	72.8		
75.00	74.1		
90.00	77.2		
125.0	82.1		
200.0	89.8		
250.0	91.5		
400.0	94.1		
500.0	95.6		



Volume Statistics (Arithmetic) 5#.$02

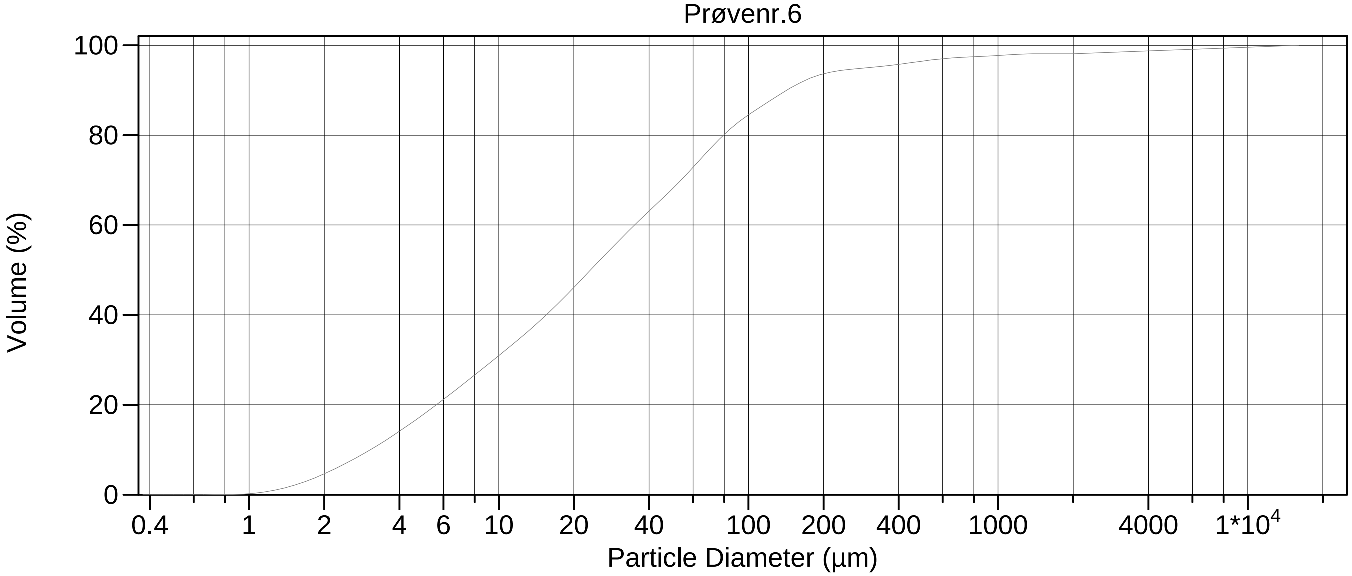
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	48.41 µm	95% Conf. Limits:	0-207.2 µm
Median:	20.00 µm	S.D.:	81.03 µm
D(3,2):	8.415 µm	Variance:	6566 µm^2
Mean/Median Ratio:	2.420	C.V.:	167%
Mode:	60.52 µm	Skewness:	4.701 Right skewed
d_{10}:	3.008 µm	Kurtosis:	31.72 Leptokurtic
d_{50}:	20.00 µm		
d_{90}:	125.3 µm		
Specific Surf. Area	7130 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.008	5.151	20.00	58.60	125.3

5#.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.41	1000	100.0
5.000	19.4	2000	100
10.00	34.4	4000	100
15.00	43.1	8000	100
20.00	50.0	16000	100
50.00	71.2		
60.00	75.6		
63.00	76.8		
70.00	79.5		
75.00	81.1		
90.00	84.7		
125.0	90.0		
200.0	96.4		
250.0	97.8		
400.0	98.9		
500.0	99.2		



Volume Statistics (Arithmetic) 6a.$02

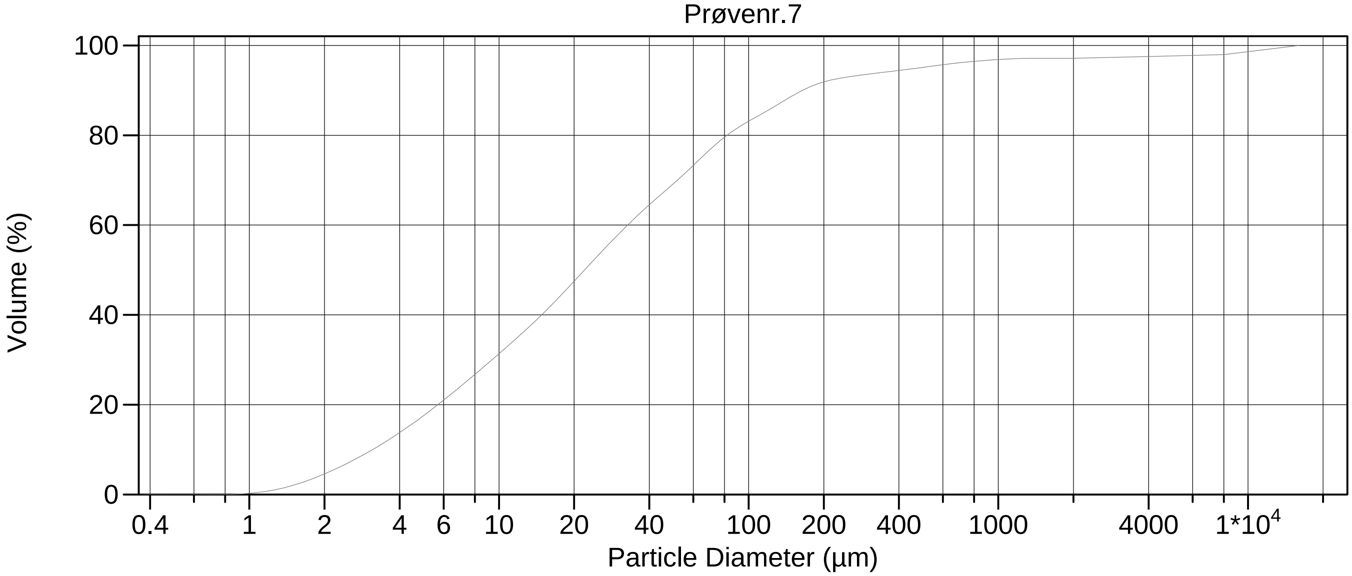
Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	181.7 µm	95% Conf. Limits:	0-2183 µm
Median:	23.34 µm	S.D.:	1021 µm
D(3,2):	8.812 µm	Variance:	1042705 µm^2
Mean/Median Ratio:	7.782	C.V.:	562%
Mode:	66.44 µm	Skewness:	9.246 Right skewed
d_{10}:	3.063 µm	Kurtosis:	91.48 Leptokurtic
d_{50}:	23.34 µm		
d_{90}:	142.6 µm		
Specific Surf. Area	6809 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.063	5.623	23.34	65.16	142.6

6a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.65	1000	97.7
5.000	17.9	2000	98.1
10.00	30.9	4000	98.7
15.00	39.2	8000	99.4
20.00	46.1	16000	100
50.00	68.2		
60.00	72.8		
63.00	74.1		
70.00	76.9		
75.00	78.6		
90.00	82.6		
125.0	88.0		
200.0	93.6		
250.0	94.6		
400.0	95.7		
500.0	96.5		



Volume Statistics (Arithmetic) 7a.$02

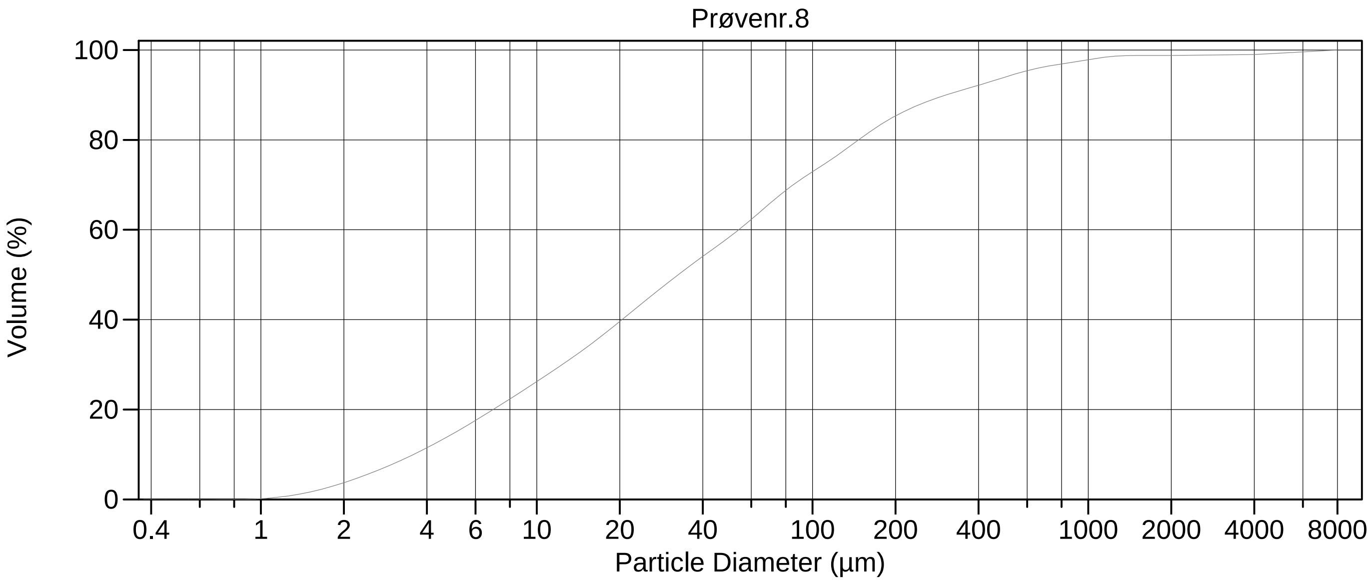
Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	323.6 µm	95% Conf. Limits:	0-3537 µm
Median:	22.04 µm	S.D.:	1640 µm
D(3,2):	8.791 µm	Variance:	2688675 $µm^2$
Mean/Median Ratio:	14.68	C.V.:	507%
Mode:	21.69 µm	Skewness:	6.293 Right skewed
d_{10}:	3.119 µm	Kurtosis:	38.65 Leptokurtic
d_{50}:	22.04 µm		
d_{90}:	164.4 µm		
Specific Surf. Area	6825 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.119	5.692	22.04	64.66	164.4

7a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.59	1000	96.9
5.000	17.6	2000	97.1
10.00	31.3	4000	97.6
15.00	40.3	8000	98.0
20.00	47.5	16000	100
50.00	69.2		
60.00	73.3		
63.00	74.4		
70.00	76.8		
75.00	78.3		
90.00	81.6		
125.0	86.2		
200.0	91.9		
250.0	93.0		
400.0	94.4		
500.0	95.1		



Volume Statistics (Arithmetic) 8a.$02

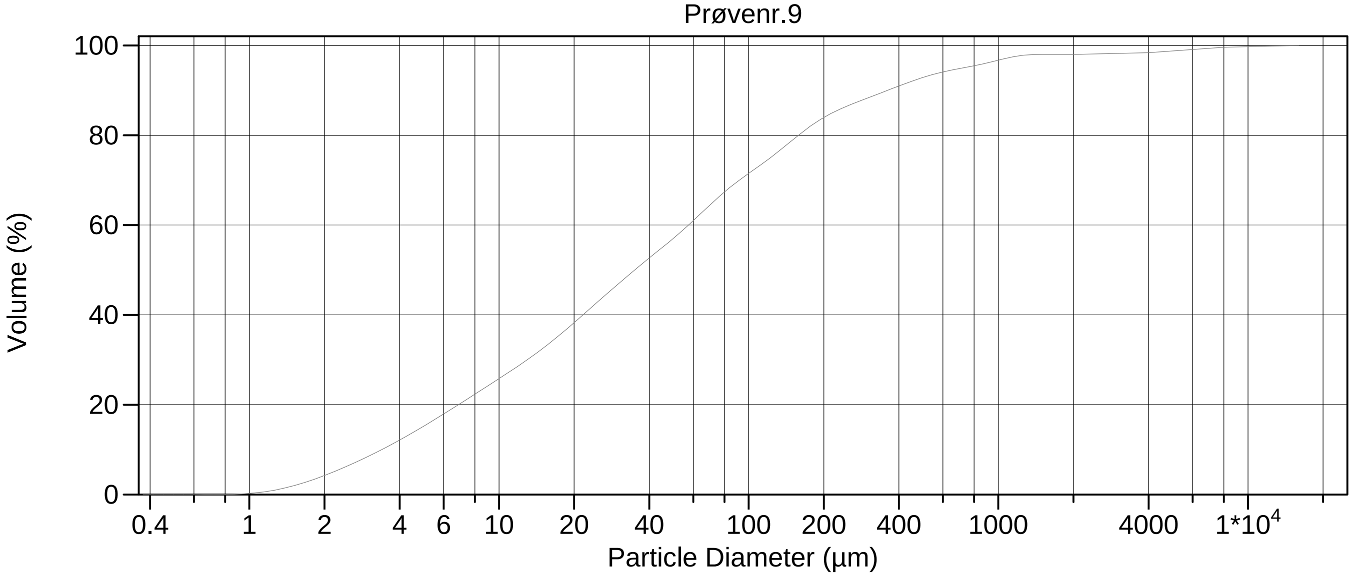
Calculations from 0.375 µm to 8000 µm

Volume	100.0%		
Mean:	164.5 µm	95% Conf. Limits:	0-1332 µm
Median:	32.59 µm	S.D.:	595.5 µm
D(3,2):	10.48 µm	Variance:	354654 μm^2
Mean/Median Ratio:	5.048	C.V.:	362%
Mode:	66.44 µm	Skewness:	8.109 Right skewed
d_{10}:	3.579 µm	Kurtosis:	70.34 Leptokurtic
d_{50}:	32.59 µm		
d_{90}:	305.1 µm		
Specific Surf. Area	5727 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.579	6.958	32.59	112.8	305.1

8a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	3.73	1000	97.8
5.000	14.7	2000	98.8
10.00	26.2	4000	99.0
15.00	33.6	8000	100
20.00	39.6	16000	100
50.00	58.4		
60.00	62.3		
63.00	63.4		
70.00	65.9		
75.00	67.4		
90.00	71.0		
125.0	76.9		
200.0	85.3		
250.0	88.1		
400.0	92.2		
500.0	94.0		



Volume Statistics (Arithmetic) 9a.$02

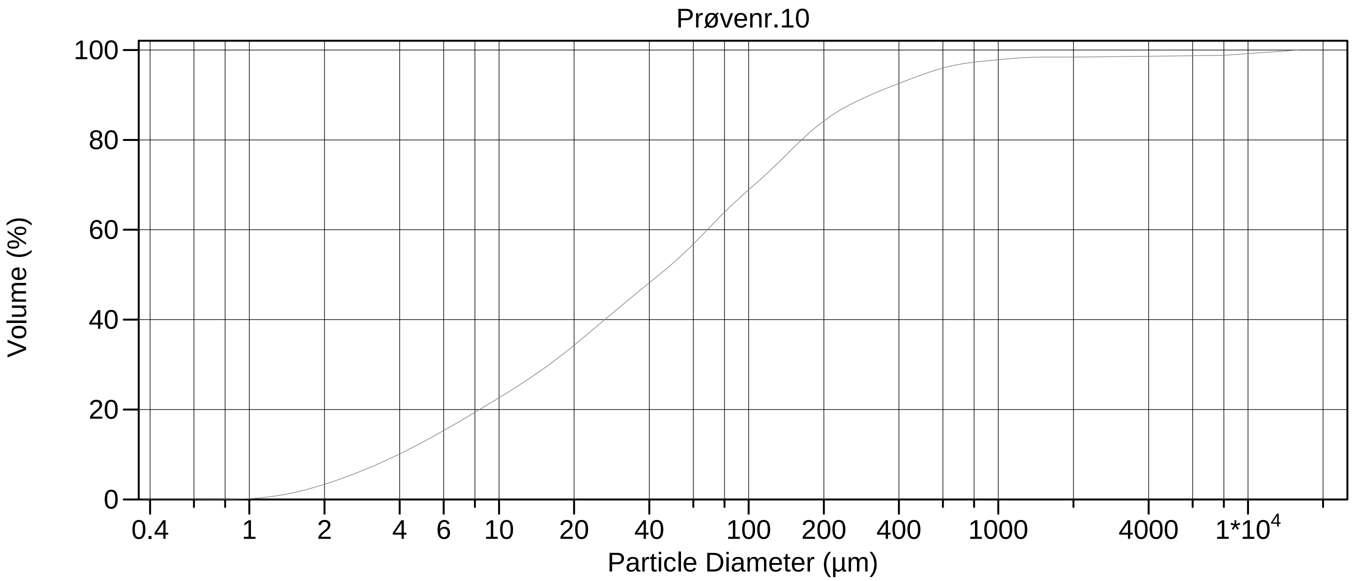
Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	232.1 µm	95% Conf. Limits:	0-2117 µm
Median:	35.00 µm	S.D.:	961.6 µm
D(3,2):	10.23 µm	Variance:	924744 μm^2
Mean/Median Ratio:	6.630	C.V.:	414%
Mode:	66.44 µm	Skewness:	8.365 Right skewed
d_{10}:	3.393 µm	Kurtosis:	79.92 Leptokurtic
d_{50}:	35.00 µm		
d_{90}:	360.4 µm		
Specific Surf. Area	5863 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.393	6.879	35.00	122.3	360.4

9a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.25	1000	96.7
5.000	15.2	2000	98.0
10.00	25.8	4000	98.4
15.00	32.5	8000	99.6
20.00	38.3	16000	100
50.00	57.0		
60.00	61.0		
63.00	62.1		
70.00	64.5		
75.00	66.0		
90.00	69.6		
125.0	75.4		
200.0	83.9		
250.0	86.6		
400.0	91.0		
500.0	92.9		



Volume Statistics (Arithmetic) 10a.$02

Calculations from 0.375 µm to 16000 µm

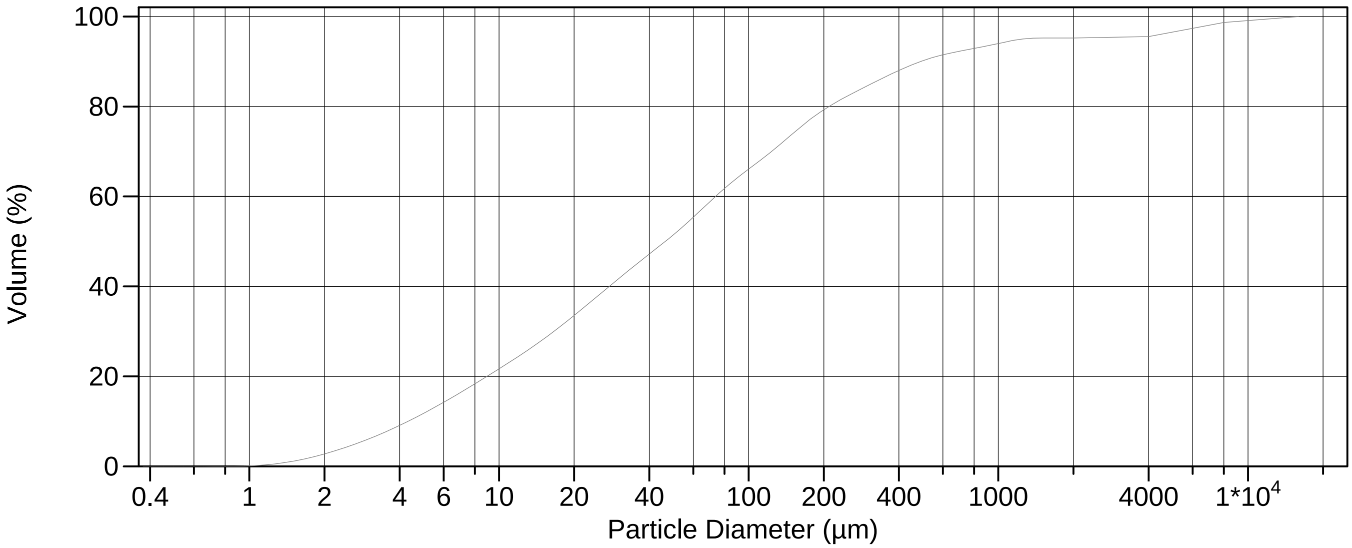
Volume	100.0%		
Mean:	253.3 µm	95% Conf. Limits:	0-2704 µm
Median:	43.85 µm	S.D.:	1251 µm
D(3,2):	11.75 µm	Variance:	1563933 µm^2
Mean/Median Ratio:	5.775	C.V.:	494%
Mode:	66.44 µm	Skewness:	8.342 Right skewed
d_{10}:	3.961 µm	Kurtosis:	69.94 Leptokurtic
d_{50}:	43.85 µm		
d_{90}:	307.5 µm		
Specific Surf. Area	5108 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.961	8.364	43.85	131.8	307.5

10a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	3.36	1000	97.8
5.000	12.9	2000	98.4
10.00	22.6	4000	98.6
15.00	29.0	8000	98.8
20.00	34.3	16000	100
50.00	52.7		
60.00	56.8		
63.00	58.0		
70.00	60.6		
75.00	62.3		
90.00	66.6		
125.0	73.8		
200.0	84.2		
250.0	87.6		
400.0	92.6		
500.0	94.6		

Prøvenr.11



Volume Statistics (Arithmetic) 11a.$02

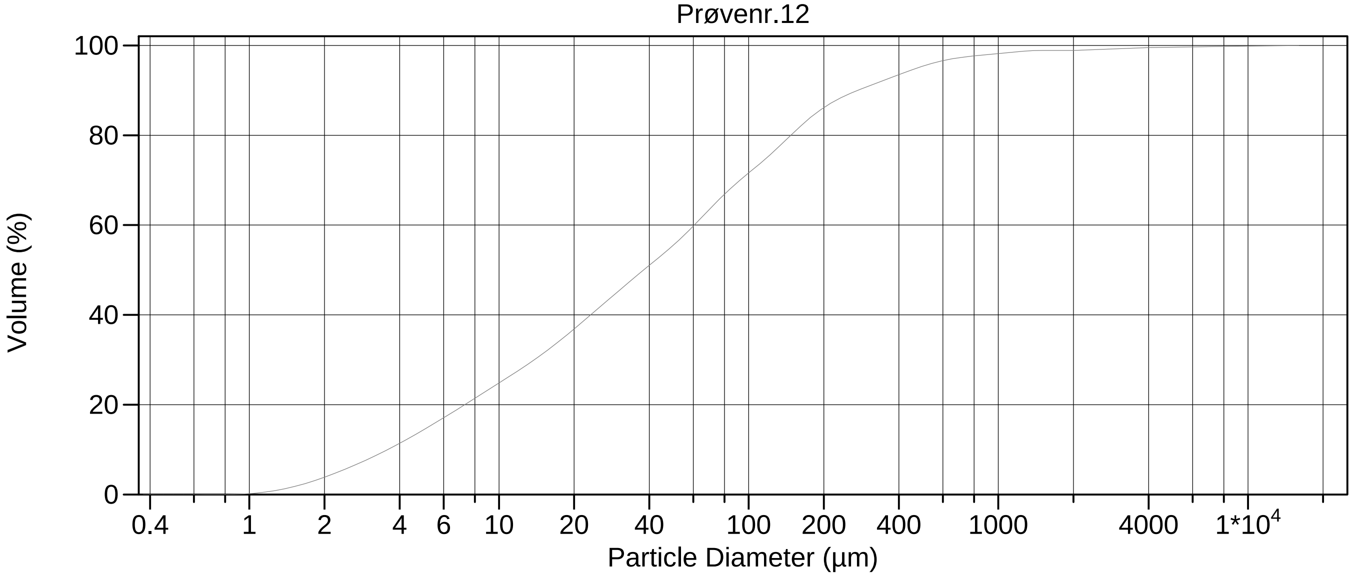
Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	449.9 µm	95% Conf. Limits:	0-3598 µm
Median:	46.40 µm	S.D.:	1606 µm
D(3,2):	12.69 µm	Variance:	2579749 $µm^2$
Mean/Median Ratio:	9.696	C.V.:	357%
Mode:	5657 µm	Skewness:	5.183 Right skewed
d_{10}:	4.323 µm	Kurtosis:	28.32 Leptokurtic
d_{50}:	46.40 µm		
d_{90}:	488.4 µm		
Specific Surf. Area	4728 cm^2/ml		

% <	10	20	50	75	90
Size µm	4.323	8.951	46.40	158.2	488.4

11a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	2.77	1000	94.0
5.000	11.8	2000	95.2
10.00	21.7	4000	95.5
15.00	28.2	8000	98.7
20.00	33.5	16000	100
50.00	51.5		
60.00	55.3		
63.00	56.5		
70.00	58.9		
75.00	60.4		
90.00	64.1		
125.0	70.2		
200.0	79.2		
250.0	82.4		
400.0	88.0		
500.0	90.2		



Volume Statistics (Arithmetic) 12a.$02

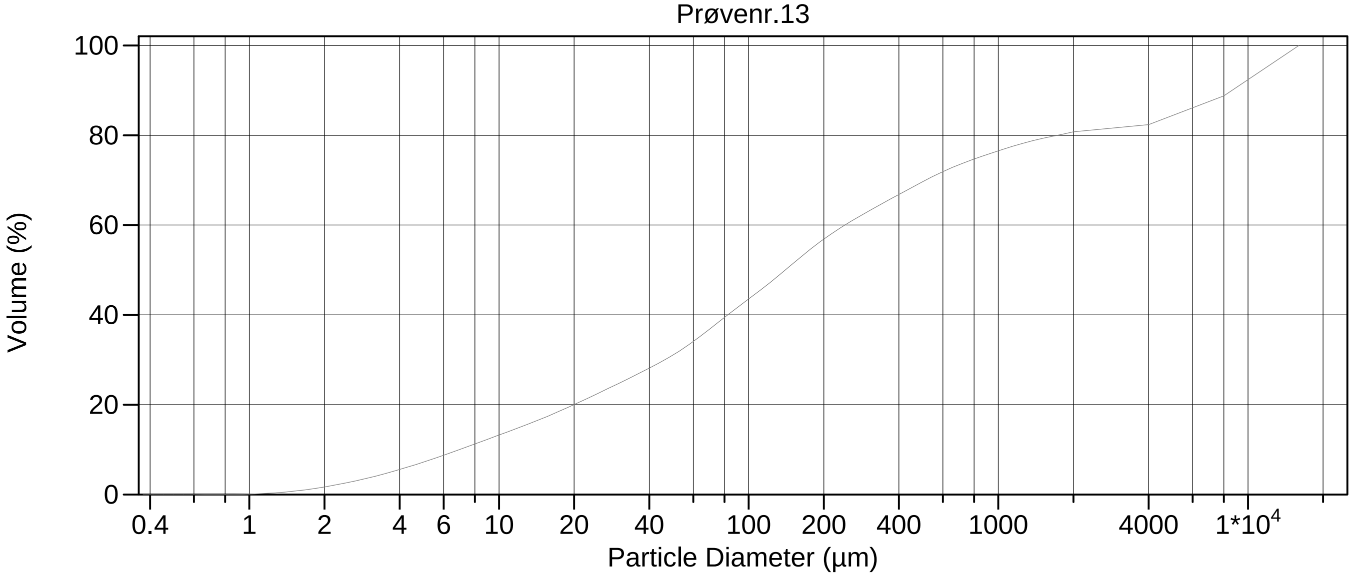
Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	153.9 µm	95% Conf. Limits:	0-1429 µm
Median:	38.02 µm	S.D.:	650.5 µm
D(3,2):	10.74 µm	Variance:	423193 $µm^2$
Mean/Median Ratio:	4.048	C.V.:	423%
Mode:	66.44 µm	Skewness:	13.05 Right skewed
d_{10}:	3.584 µm	Kurtosis:	201.7 Leptokurtic
d_{50}:	38.02 µm		
d_{90}:	273.6 µm		
Specific Surf. Area	5589 cm^2/ml		

% <	10	20	50	75	90
Size µm	3.584	7.291	38.02	118.2	273.6

12a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	3.85	1000	98.2
5.000	14.4	2000	98.9
10.00	24.8	4000	99.5
15.00	31.4	8000	99.8
20.00	36.9	16000	100
50.00	55.5		
60.00	59.8		
63.00	61.0		
70.00	63.6		
75.00	65.3		
90.00	69.4		
125.0	76.2		
200.0	86.1		
250.0	89.1		
400.0	93.5		
500.0	95.4		



Volume Statistics (Arithmetic) 13#a.$02

Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	1859 µm	95% Conf. Limits:	0-8987 µm
Median:	140.3 µm	S.D.:	3637 µm
D(3,2):	20.36 µm	Variance:	13225247 $µm^2$
Mean/Median Ratio:	13.26	C.V.:	196%
Mode:	11314 µm	Skewness:	1.963 Right skewed
d_{10}:	6.949 µm	Kurtosis:	2.241 Leptokurtic
d_{50}:	140.3 µm		
d_{90}:	8870 µm		
Specific Surf. Area	2946 cm^2/ml		

% <	10	20	50	75	90
Size µm	6.949	19.97	140.3	829.3	8870

13#a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	1.68	1000	76.5
5.000	7.24	2000	80.8
10.00	13.2	4000	82.4
15.00	17.0	8000	88.8
20.00	20.0	16000	100
50.00	31.1		
60.00	34.1		
63.00	34.9		
70.00	36.9		
75.00	38.2		
90.00	41.6		
125.0	47.7		
200.0	56.9		
250.0	60.4		
400.0	66.8		
500.0	69.7		

NGU
Norges geologiske undersøkelse
7491 TRONDHEIM
Tlf.: 73 90 40 00
Telefaks: 73 92 16 20

Tørrvekt
Geologisk materiale
Analysekontrakt nr.
2010.0018

Operatør: Wieslawa Koziel

Prøvenr.	**Tørrvekt (g)**
1	28.08
2	9.22
3	1.44
4	0.44
5	1.21
6	3.17
7	4.88
8	9.04
9	20.05
10	10.21
11	10.52
12	81.82
13	4.99

Ferdig analysert: 24.11.2008

NGU Norges geologiske undersøkelse
7491 TRONDHEIM
Tlf.: 73 90 40 00
Telefaks: 73 92 16 20

Kornfordelingsanalyser: Coulter laser partikkelteller
GEOLOGISK MATERIALE
Analysekontrakt nr.:2012.0363

INSTRUMENT: **Coulter LS 200**

METODE: **Metodeoppsettet er beskrevet i NGU-SD 5.11: Kornfordelingsanalyser: Coulter laser partikkelteller.**
Kornfordelingsbestemmelse basert på laserdiffraksjon. Laserlys brytes i ulike vinkler avhengig av størrelsen på partiklene, og registreres så av en rekke detektorer. De registrerte vinklene tilsvarer gitte partikkelstørrelser, og antall partikler er relatert til den intensiteten som den korresponderende detektoren registrerer. Kornfordelingen bestemmes således på volum-basis, med antagelse om ens tetthet på materialet vil kumulativ volum% være identisk med kumulativ masse%.
Beregning på volum/masse-basis er basert på antagelse om sfæriske partikler.

MÅLEOMRÅDE : **0.4 µm - 2000 mm** **NB !** Metoden normaliserer alle data i måleområdet til sum 100 % (kumulativ %).
Måleområdet går kun ned til 0.4 µm og dette settes som nullpunkt mhp. kumulativ %.
Prøvene kan derfor inneholde materiale finere enn 0.4 µm.

ANALYSEUSIKKERHET: **± 10 % [kumulativ masse(volum) %]** *Usikkerheten er oppgitt med dekningsfaktor 2, tilsvarende et konfidensintervall på 95 %*
Bestemmelse av usikkerhet er basert på sammenligning av oppnådde resultater med sertifikatverdier for kvartsstandard BCR-131, samt presisjonsdata.
MERK! Metoden tar utgangspunkt i antagelse om sfæriske partikler. For prøver som avviker fra dette kan usikkerheten være større.

PRESISJON: **Det analyseres rutinemessig kontrollprøver som føres i kontrolldiagram (X-diagram). Disse kan forevises om ønskelig.**

FORBEHANDLING: **Ingen**

ANTALL PRØVER: **13**

ANMERKNINGER: Data for fraksjoner >2000 µm er fremkommet ved gravimetriske bestemmelser.
Sikting over 2mm omfattes ikke akkreditering.

Gjengivelse av analysedata skal skje på en slik måte at meningsinnholdet i rapporten ikke endres.

Ferdig analysert	5-des-12	Wieslawa Koziel
	Dato	OPERATØR

NGU Norges geologiske undersøkelse

7491 TRONDHEIM
Tlf.: 73 90 40 00
Telefaks: 73 92 16 20

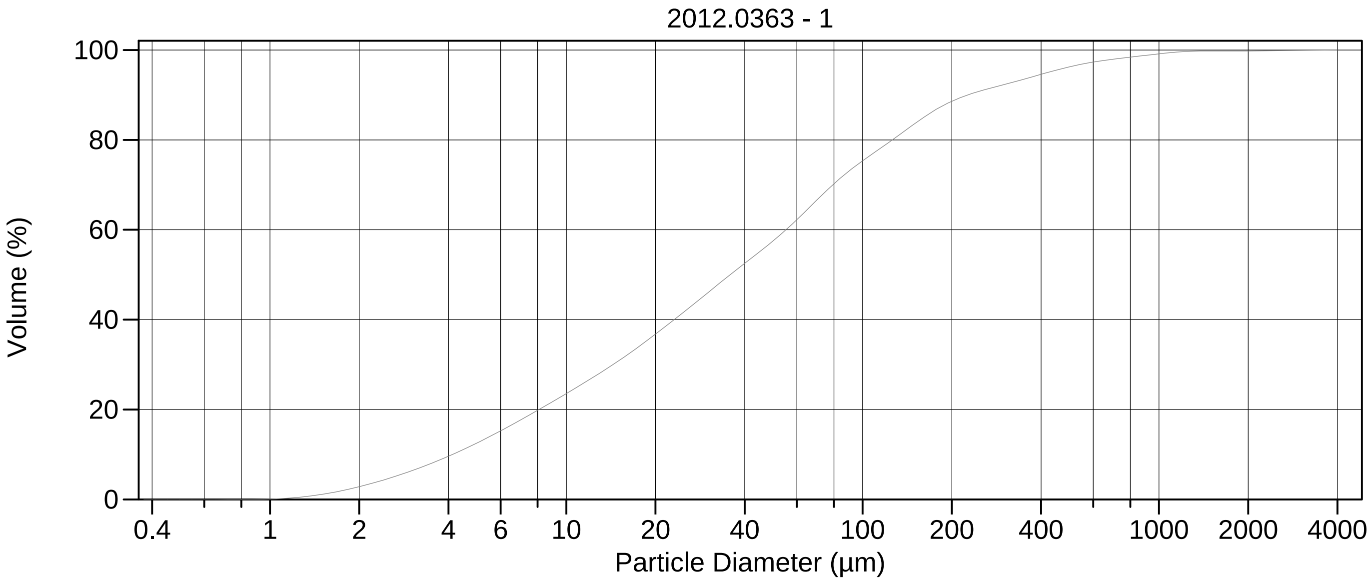
Tørrvekt
Geologisk materiale
Analysekontrakt nr.
2012.0363

Operatør: Wieslawa Koziel

Prøvenr.	Total vekt (g)	Fraksjon >8mm vekt (g)	Fraksjon >4mm vekt (g)	Fraksjon >2mm vekt (g)
1	37,46			0,08
2	14,36			
3	26,13			
4	24,33			
5	36,93			
6	19,89			
7	8,23			0,04
8	14,89			
9	13,99		0,15	0,14
10	12,75	0.02	0,11	0,07
11	21,08	0.03	0,06	0,09
12	34,47	0.16	0,21	0,20
13	52,92	0.16	0,08	0,16

Fil : //Filtj1/_perm/Lab/Korn/veiing/2012/20120363

Ferdig analysert: 3.12.2012



Volume Statistics (Arithmetic) 1a.$02

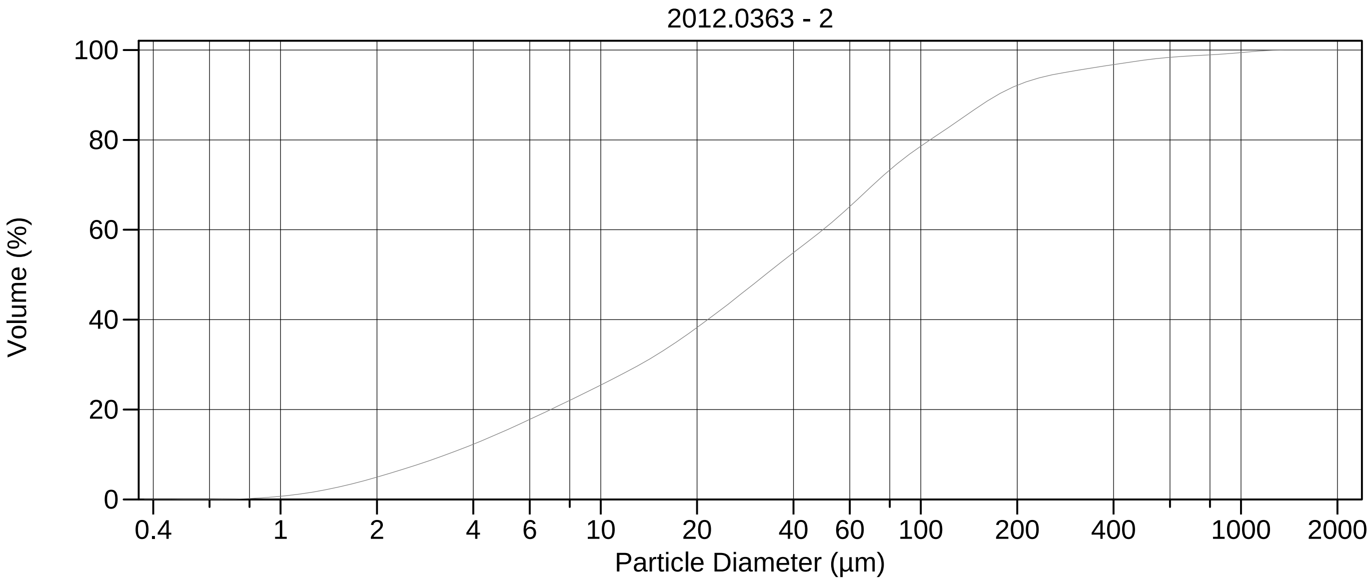
Calculations from 0.375 µm to 4000 µm

Volume	100.0%		
Mean:	98.91 µm	95% Conf. Limits:	0-501.0 µm
Median:	35.76 µm	S.D.:	205.1 µm
D(3,2):	11.78 µm	Variance:	42076 µm^2
Mean/Median Ratio:	2.766	C.V.:	207%
Mode:	66.44 µm	Skewness:	6.738 Right skewed
d_{10}:	4.128 µm	Kurtosis:	70.41 Leptokurtic
d_{50}:	35.76 µm		
d_{90}:	226.8 µm		
Specific Surf. Area	5093 cm^2/ml		

% <	10	25	50	75	90
Size µm	4.128	10.88	35.76	98.50	226.8

1a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	2.83	1000	99.1
5.000	12.6	2000	99.8
10.00	23.5	4000	100
15.00	30.8	8000	100
20.00	36.8	16000	100
50.00	57.6		
60.00	62.2		
63.00	63.6		
70.00	66.6		
75.00	68.5		
90.00	73.0		
125.0	79.8		
200.0	88.6		
250.0	90.9		
400.0	94.6		
500.0	96.3		



Volume Statistics (Arithmetic) 2.$02

Calculations from 0.375 µm to 2000 µm

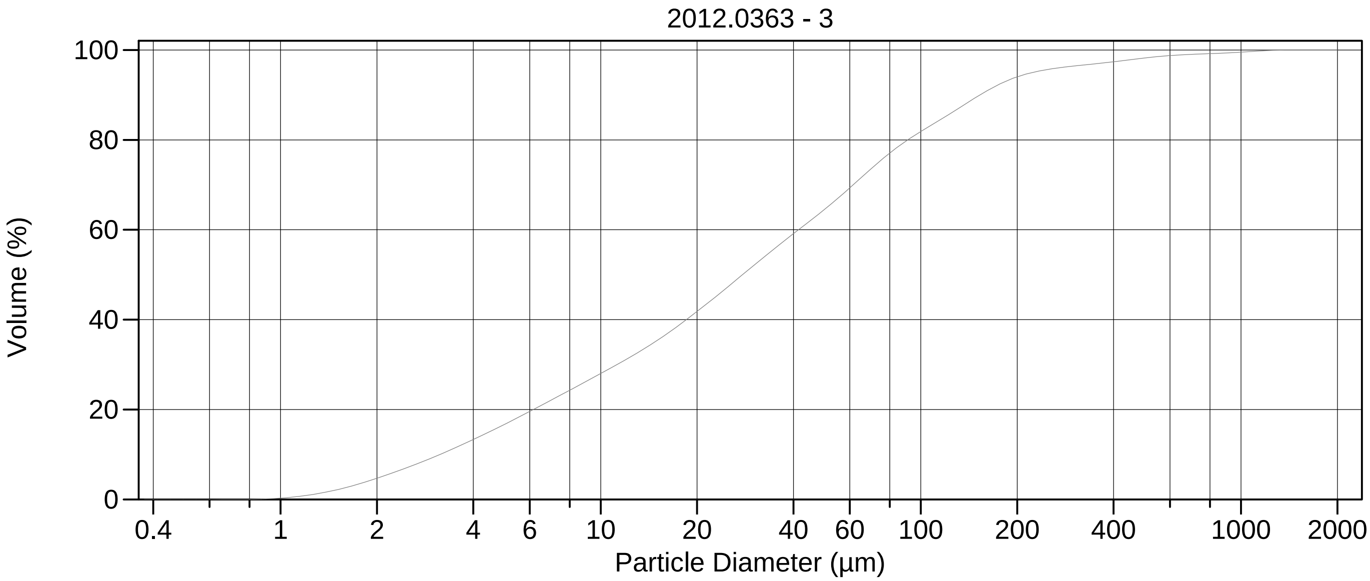
Volume	100.0%		
Mean:	77.66 µm	95% Conf. Limits:	0-352.3 µm
Median:	32.69 µm	S.D.:	140.1 µm
D(3,2):	9.569 µm	Variance:	19635 $µm^2$
Mean/Median Ratio:	2.375	C.V.:	180%
Mode:	66.44 µm	Skewness:	4.601 Right skewed
d_{10}:	3.305 µm	Kurtosis:	26.85 Leptokurtic
d_{50}:	32.69 µm		
d_{90}:	173.6 µm		
Specific Surf. Area	6270 cm^2/ml		

% <	10	25	50	75	90
Size µm	3.305	9.718	32.69	85.41	173.6

2.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.96	1000	99.4
5.000	15.2	2000	100
10.00	25.4	4000	100
15.00	32.2	8000	100
20.00	38.2	16000	100
50.00	60.3		
60.00	65.1		
63.00	66.6		
70.00	69.6		
75.00	71.6		
90.00	76.2		
125.0	83.3		
200.0	92.1		
250.0	94.3		
400.0	96.8		
500.0	97.8		

2012.0363 - 3



Volume Statistics (Arithmetic) 3#.$02

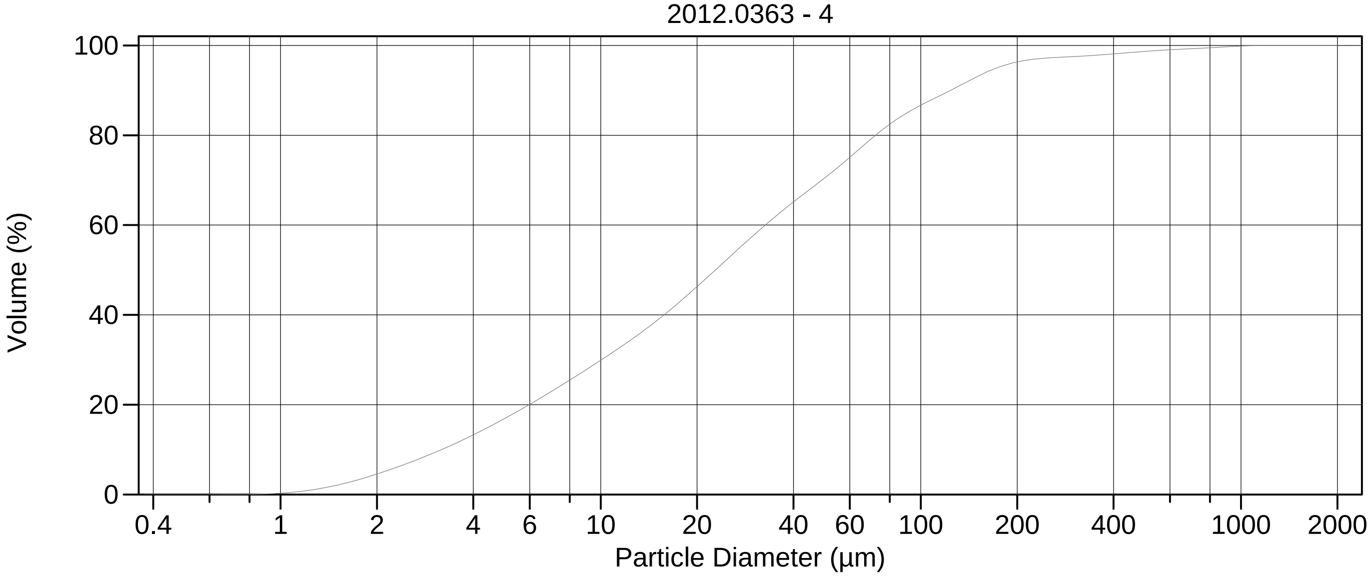
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	67.27 µm	95% Conf. Limits:	0-316.1 µm
Median:	27.74 µm	S.D.:	126.9 µm
D(3,2):	9.292 µm	Variance:	16115 μm^2
Mean/Median Ratio:	2.425	C.V.:	189%
Mode:	66.44 µm	Skewness:	5.199 Right skewed
d_{10}:	3.147 µm	Kurtosis:	35.07 Leptokurtic
d_{50}:	27.74 µm		
d_{90}:	153.2 µm		
Specific Surf. Area	6457 cm^2/ml		

% <	10	25	50	75	90
Size µm	3.147	8.362	27.74	73.80	153.2

3#.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.70	1000	99.5
5.000	16.7	2000	100
10.00	28.0	4000	100
15.00	35.3	8000	100
20.00	41.8	16000	100
50.00	64.5		
60.00	69.3		
63.00	70.7		
70.00	73.6		
75.00	75.4		
90.00	79.7		
125.0	86.1		
200.0	94.0		
250.0	95.7		
400.0	97.4		
500.0	98.2		



Volume Statistics (Arithmetic) 4.$02

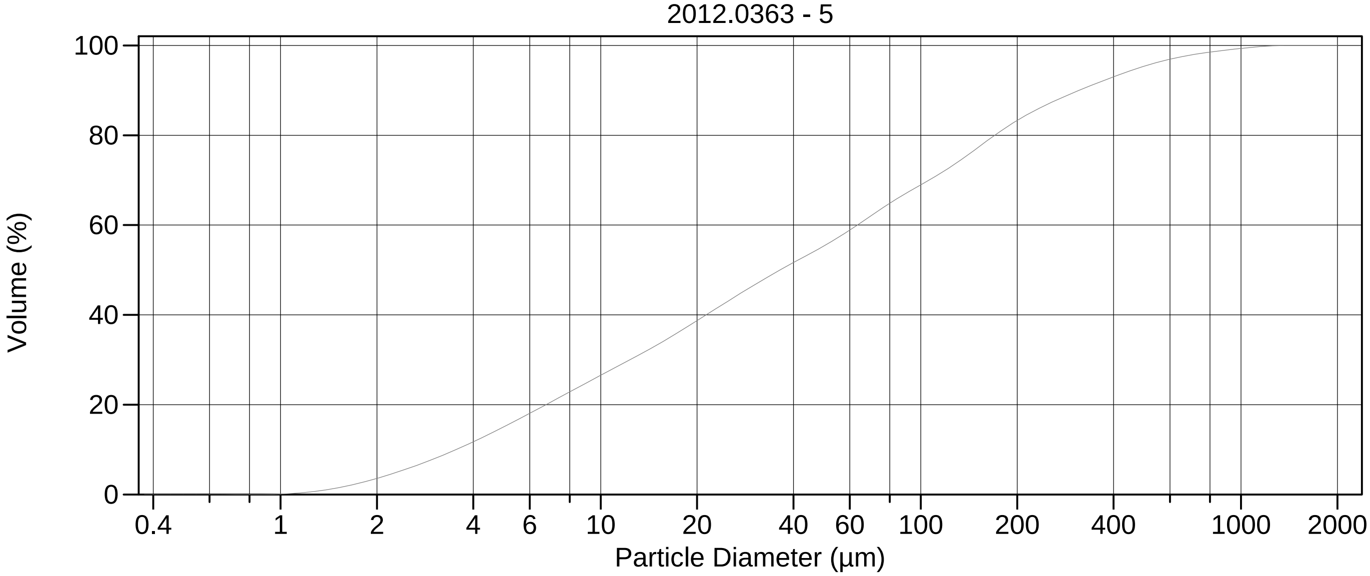
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	53.70 µm	95% Conf. Limits:	0-254.8 µm
Median:	22.81 µm	S.D.:	102.6 µm
D(3,2):	8.952 µm	Variance:	10526 µm^2
Mean/Median Ratio:	2.354	C.V.:	191%
Mode:	23.81 µm	Skewness:	5.496 Right skewed
d_{10}:	3.184 µm	Kurtosis:	38.53 Leptokurtic
d_{50}:	22.81 µm		
d_{90}:	123.8 µm		
Specific Surf. Area	6702 cm^2/ml		

% <	10	25	50	75	90
Size µm	3.184	7.818	22.81	59.85	123.8

4.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.55	1000	99.9
5.000	16.9	2000	100
10.00	29.9	4000	100
15.00	38.7	8000	100
20.00	46.3	16000	100
50.00	70.4		
60.00	75.1		
63.00	76.4		
70.00	79.2		
75.00	80.9		
90.00	84.9		
125.0	90.2		
200.0	96.3		
250.0	97.2		
400.0	98.1		
500.0	98.7		



Volume Statistics (Arithmetic) 5#.$02

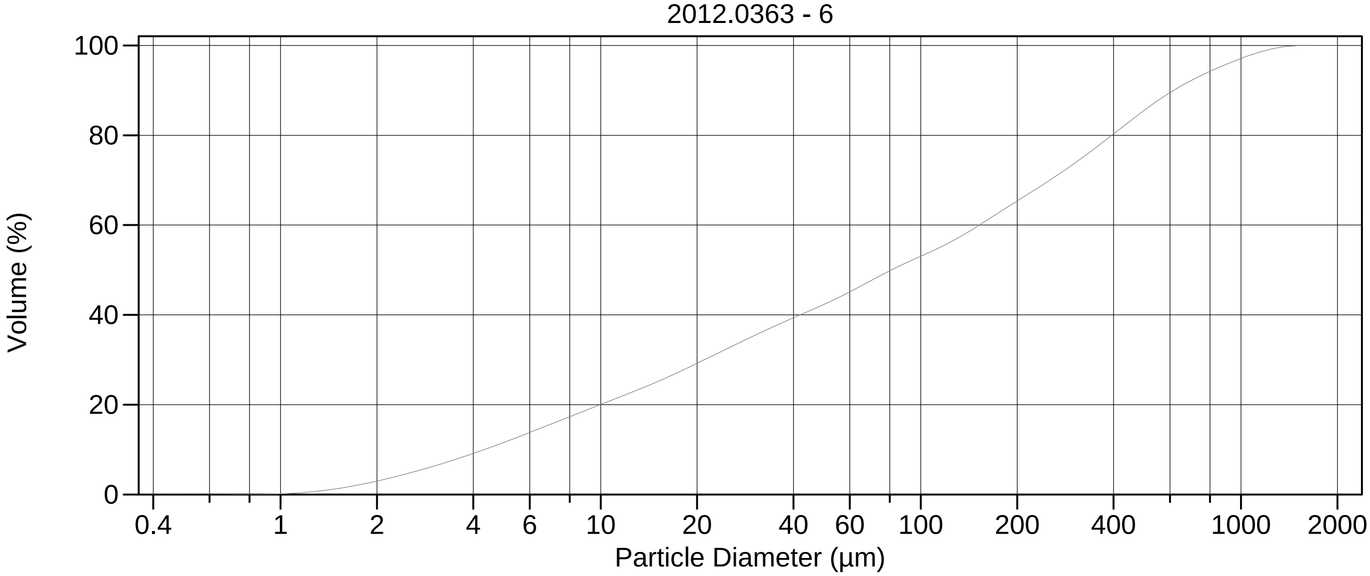
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	111.0 µm	95% Conf. Limits:	0-460.4 µm
Median:	36.31 µm	S.D.:	178.2 µm
D(3,2):	10.63 µm	Variance:	31770 µm^2
Mean/Median Ratio:	3.057	C.V.:	161%
Mode:	153.8 µm	Skewness:	2.963 Right skewed
d_{10}:	3.534 µm	Kurtosis:	10.76 Leptokurtic
d_{50}:	36.31 µm		
d_{90}:	312.1 µm		
Specific Surf. Area	5645 cm^2/ml		

% <	10	25	50	75	90
Size µm	3.534	9.113	36.31	136.5	312.1

5#.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	3.58	1000	99.3
5.000	15.1	2000	100
10.00	26.5	4000	100
15.00	33.3	8000	100
20.00	38.7	16000	100
50.00	55.4		
60.00	58.9		
63.00	59.9		
70.00	62.1		
75.00	63.6		
90.00	67.1		
125.0	73.1		
200.0	83.3		
250.0	87.0		
400.0	93.0		
500.0	95.4		



Volume Statistics (Arithmetic) 6#.$02

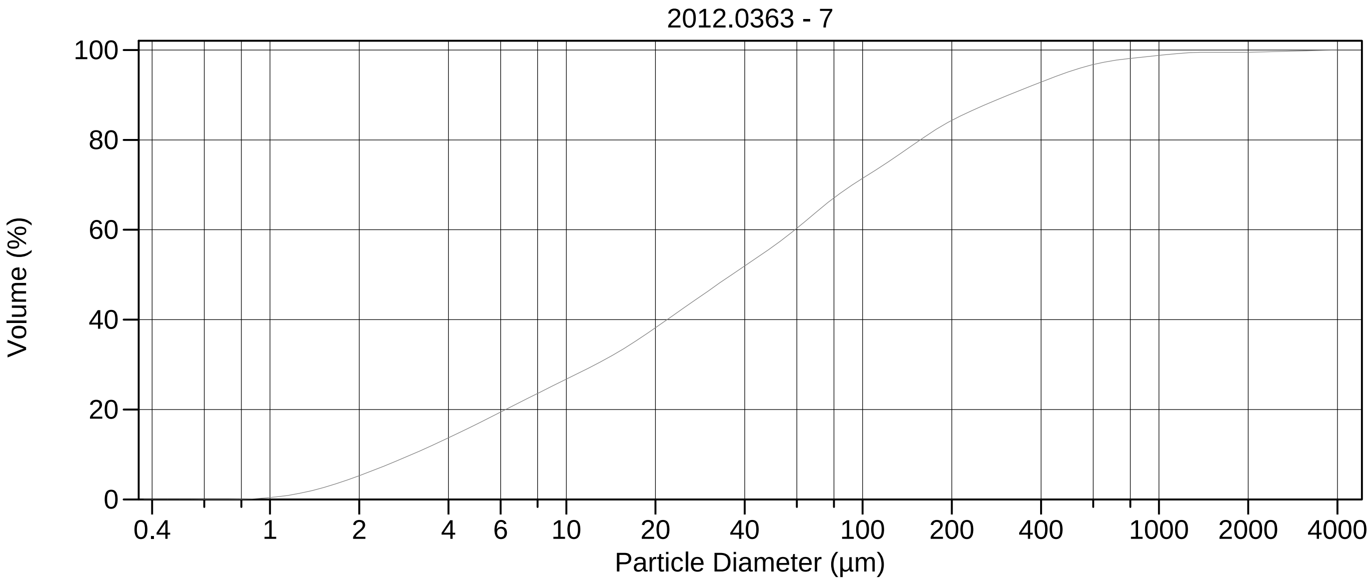
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	213.4 µm	95% Conf. Limits:	0-766.6 µm
Median:	80.95 µm	S.D.:	282.3 µm
D(3,2):	13.56 µm	Variance:	79668 µm^2
Mean/Median Ratio:	2.636	C.V.:	132%
Mode:	429.2 µm	Skewness:	1.797 Right skewed
d_{10}:	4.336 µm	Kurtosis:	3.010 Leptokurtic
d_{50}:	80.95 µm		
d_{90}:	616.4 µm		
Specific Surf. Area	4426 cm^2/ml		

% <	10	25	50	75	90
Size µm	4.336	14.93	80.95	319.4	616.4

6#.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	2.99	1000	97.1
5.000	11.6	2000	100
10.00	20.0	4000	100
15.00	25.1	8000	100
20.00	29.2	16000	100
50.00	42.4		
60.00	45.1		
63.00	45.9		
70.00	47.7		
75.00	48.8		
90.00	51.6		
125.0	56.4		
200.0	65.3		
250.0	69.8		
400.0	80.3		
500.0	85.6		



Volume Statistics (Arithmetic) 7#a.$02

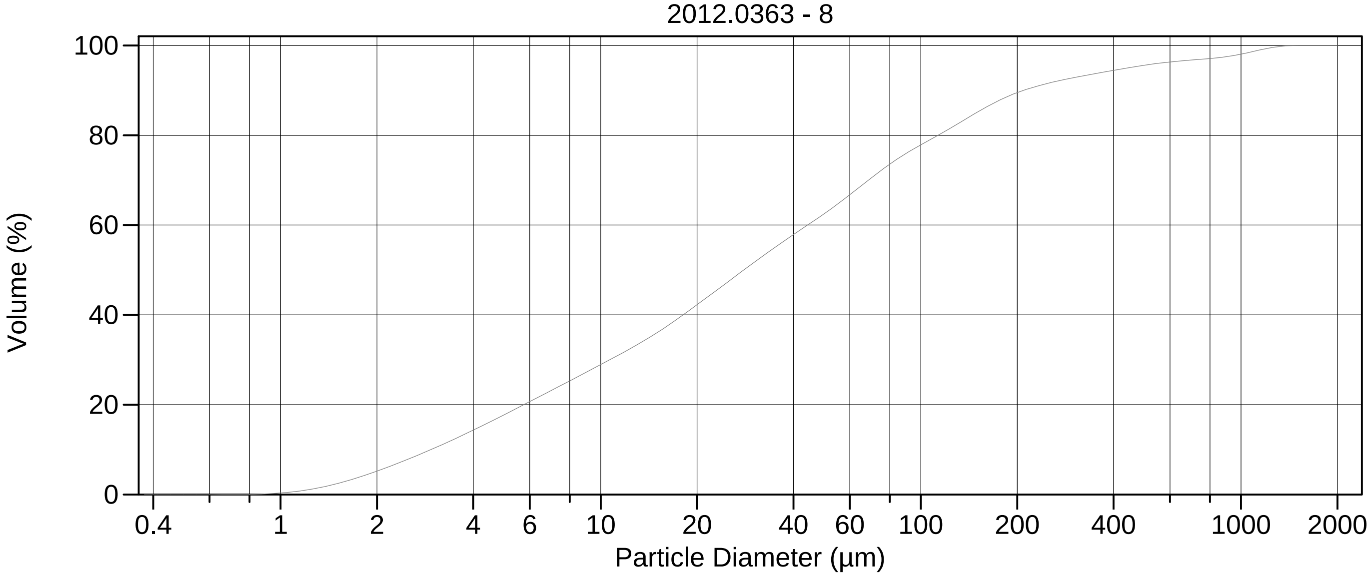
Calculations from 0.375 µm to 4000 µm

Volume	100.0%		
Mean:	118.6 µm	95% Conf. Limits:	0-624.9 µm
Median:	36.14 µm	S.D.:	258.3 µm
D(3,2):	9.422 µm	Variance:	66738 $µm^2$
Mean/Median Ratio:	3.281	C.V.:	218%
Mode:	66.44 µm	Skewness:	6.572 Right skewed
d_{10}:	3.013 µm	Kurtosis:	59.40 Leptokurtic
d_{50}:	36.14 µm		
d_{90}:	311.3 µm		
Specific Surf. Area	6368 cm^2/ml		

% <	10	25	50	75	90
Size µm	3.013	8.839	36.14	121.4	311.3

7#a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	5.27	1000	98.8
5.000	16.8	2000	99.5
10.00	26.7	4000	100
15.00	32.8	8000	100
20.00	38.2	16000	100
50.00	56.3		
60.00	60.3		
63.00	61.5		
70.00	64.0		
75.00	65.6		
90.00	69.5		
125.0	75.5		
200.0	84.3		
250.0	87.4		
400.0	92.9		
500.0	95.2		



Volume Statistics (Arithmetic) 8.$02

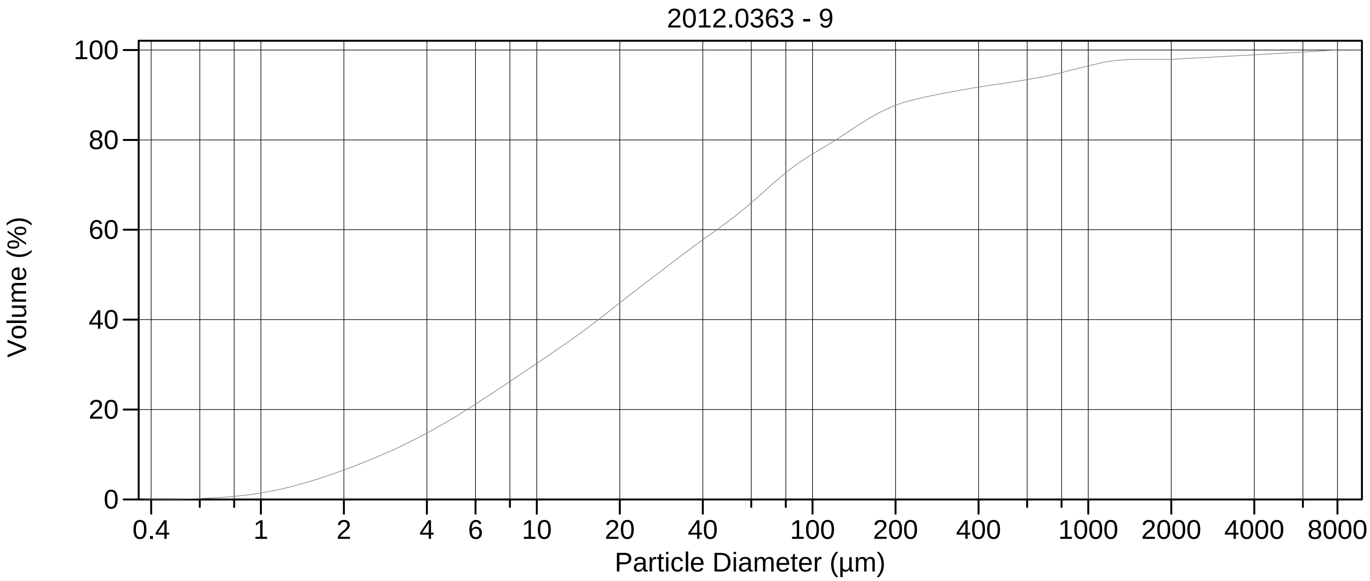
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	96.74 µm	95% Conf. Limits:	0-493.7 µm
Median:	28.02 µm	S.D.:	202.5 µm
D(3,2):	8.946 µm	Variance:	41024 µm^2
Mean/Median Ratio:	3.453	C.V.:	209%
Mode:	66.44 µm	Skewness:	3.957 Right skewed
d_{10}:	2.950 µm	Kurtosis:	16.87 Leptokurtic
d_{50}:	28.02 µm		
d_{90}:	209.5 µm		
Specific Surf. Area	6707 cm^2/ml		

% <	10	25	50	75	90
Size µm	2.950	7.858	28.02	85.72	209.5

8.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	5.20	1000	98.1
5.000	17.8	2000	100
10.00	28.9	4000	100
15.00	36.0	8000	100
20.00	42.2	16000	100
50.00	62.6		
60.00	66.7		
63.00	67.9		
70.00	70.5		
75.00	72.1		
90.00	75.9		
125.0	81.8		
200.0	89.5		
250.0	91.6		
400.0	94.4		
500.0	95.6		



Volume Statistics (Arithmetic) 9a.$02

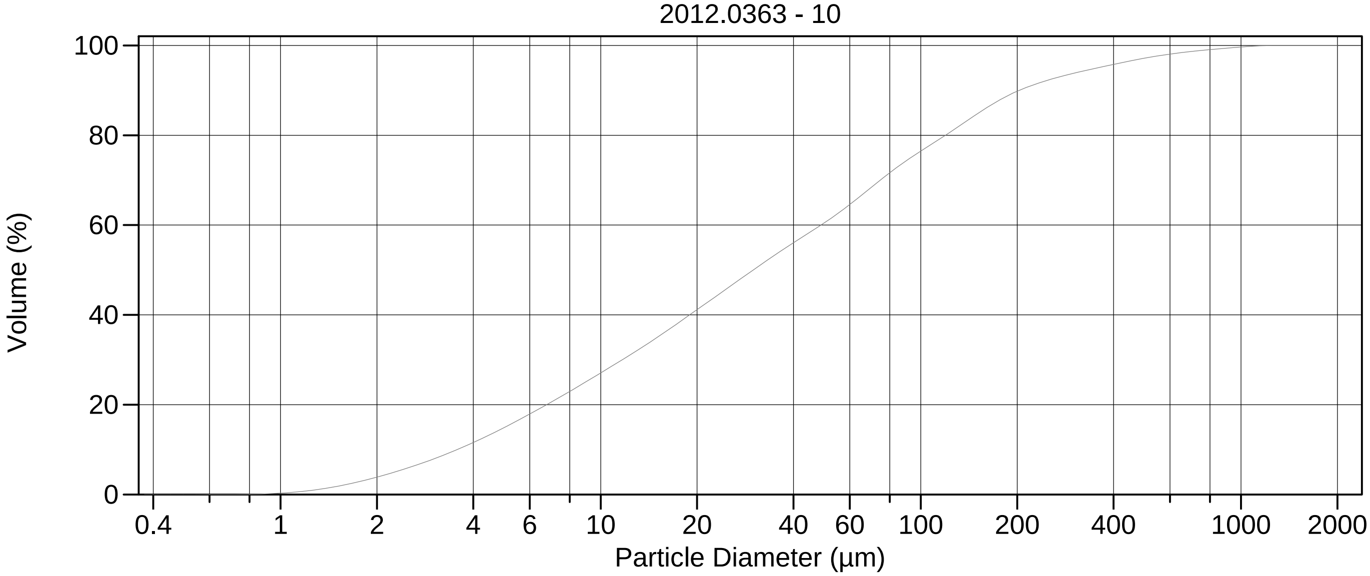
Calculations from 0.375 µm to 8000 µm

Volume	100.0%		
Mean:	184.6 µm	95% Conf. Limits:	0-1482 µm
Median:	27.14 µm	S.D.:	662.0 µm
D(3,2):	7.862 µm	Variance:	438310 µm^2
Mean/Median Ratio:	6.800	C.V.:	359%
Mode:	66.44 µm	Skewness:	6.744 Right skewed
d_{10}:	2.767 µm	Kurtosis:	49.59 Leptokurtic
d_{50}:	27.14 µm		
d_{90}:	278.4 µm		
Specific Surf. Area	7631 cm^2/ml		

% <	10	25	50	75	90
Size µm	2.767	7.460	27.14	90.02	278.4

9a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	6.56	1000	96.5
5.000	18.2	2000	97.9
10.00	30.2	4000	98.9
15.00	37.8	8000	100
20.00	43.7	16000	100
50.00	62.0		
60.00	66.0		
63.00	67.1		
70.00	69.7		
75.00	71.3		
90.00	75.0		
125.0	80.5		
200.0	87.7		
250.0	89.4		
400.0	91.7		
500.0	92.6		



Volume Statistics (Arithmetic) 10.$02

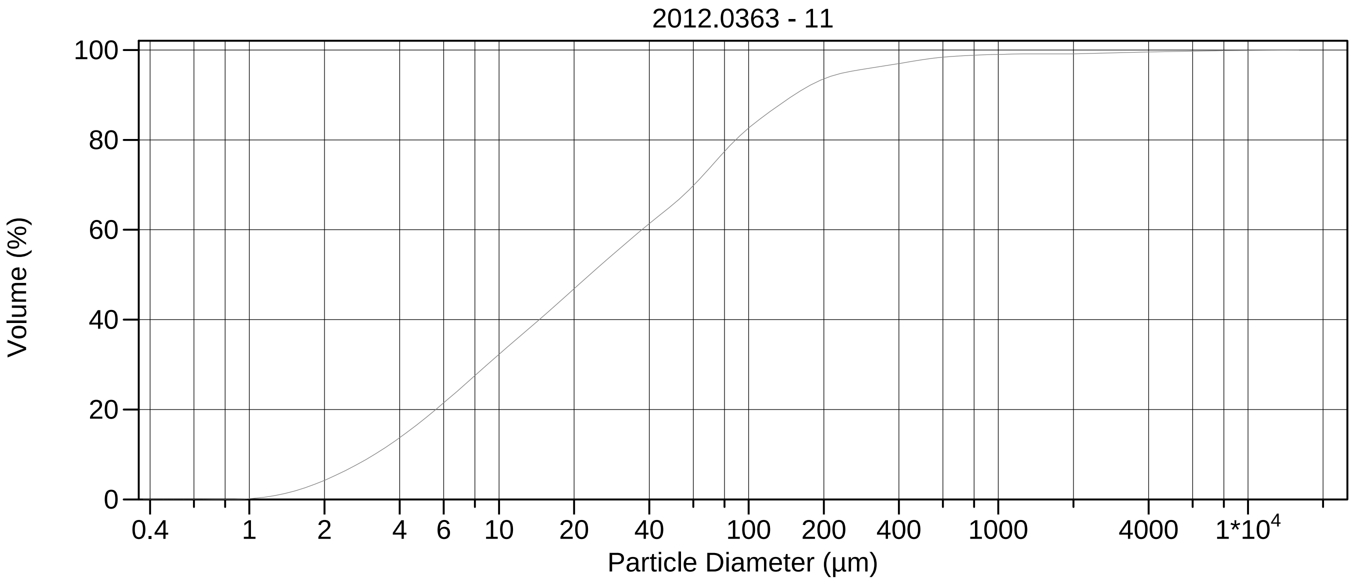
Calculations from 0.375 µm to 2000 µm

Volume	100.0%		
Mean:	83.49 µm	95% Conf. Limits:	0-365.7 µm
Median:	29.96 µm	S.D.:	144.0 µm
D(3,2):	10.10 µm	Variance:	20735 μm^2
Mean/Median Ratio:	2.787	C.V.:	172%
Mode:	66.44 µm	Skewness:	3.690 Right skewed
d_{10}:	3.561 µm	Kurtosis:	17.00 Leptokurtic
d_{50}:	29.96 µm		
d_{90}:	203.4 µm		
Specific Surf. Area	5940 cm^2/ml		

% <	10	25	50	75	90
Size µm	3.561	8.947	29.96	92.93	203.4

10.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	3.85	1000	99.7
5.000	14.9	2000	100
10.00	27.1	4000	100
15.00	35.0	8000	100
20.00	41.1	16000	100
50.00	60.5		
60.00	64.6		
63.00	65.8		
70.00	68.4		
75.00	70.1		
90.00	74.3		
125.0	80.9		
200.0	89.8		
250.0	92.3		
400.0	95.8		
500.0	97.2		



Volume Statistics (Arithmetic) 11a.$02

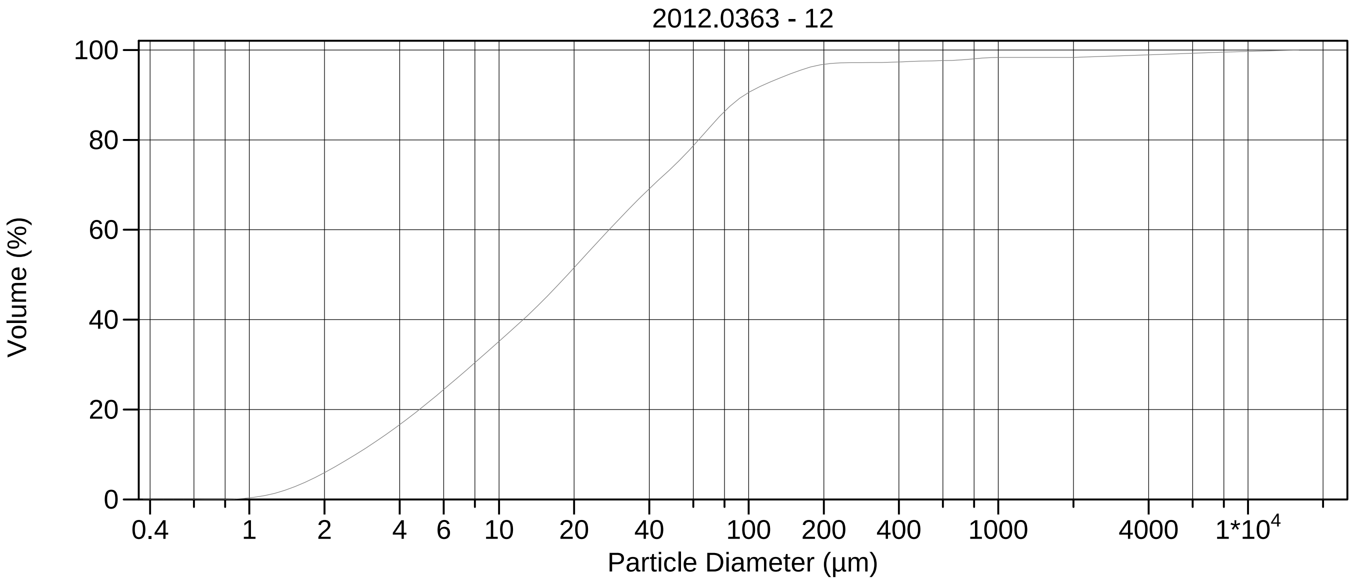
Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	103.4 µm	95% Conf. Limits:	0-1190 µm
Median:	23.11 µm	S.D.:	554.2 µm
D(3,2):	8.929 µm	Variance:	307112 $µm^2$
Mean/Median Ratio:	4.472	C.V.:	536%
Mode:	72.95 µm	Skewness:	14.94 Right skewed
d_{10}:	3.171 µm	Kurtosis:	262.2 Leptokurtic
d_{50}:	23.11 µm		
d_{90}:	152.2 µm		
Specific Surf. Area	6720 cm^2/ml		

% <	10	25	50	75	90
Size µm	3.171	7.110	23.11	73.18	152.2

11a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	4.26	1000	99.0
5.000	17.8	2000	99.2
10.00	32.3	4000	99.6
15.00	40.7	8000	99.9
20.00	46.9	16000	100
50.00	65.7		
60.00	69.8		
63.00	71.0		
70.00	73.8		
75.00	75.7		
90.00	80.3		
125.0	86.7		
200.0	93.6		
250.0	95.1		
400.0	97.0		
500.0	97.9		



Volume Statistics (Arithmetic) 12a.$02

Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	142.7 µm	95% Conf. Limits:	0-1915 µm
Median:	18.83 µm	S.D.:	904.4 µm
D(3,2):	7.633 µm	Variance:	817913 $µm^2$
Mean/Median Ratio:	7.581	C.V.:	634%
Mode:	66.44 µm	Skewness:	10.20 Right skewed
d_{10}:	2.670 µm	Kurtosis:	113.0 Leptokurtic
d_{50}:	18.83 µm		
d_{90}:	96.69 µm		
Specific Surf. Area	7860 cm^2/ml		

% <	10	25	50	75	90
Size µm	2.670	6.170	18.83	51.86	96.69

12a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	5.96	1000	98.3
5.000	20.8	2000	98.3
10.00	35.2	4000	98.9
15.00	44.2	8000	99.5
20.00	51.6	16000	100
50.00	74.1		
60.00	78.7		
63.00	80.0		
70.00	82.9		
75.00	84.7		
90.00	88.8		
125.0	93.1		
200.0	96.8		
250.0	97.2		
400.0	97.3		
500.0	97.5		

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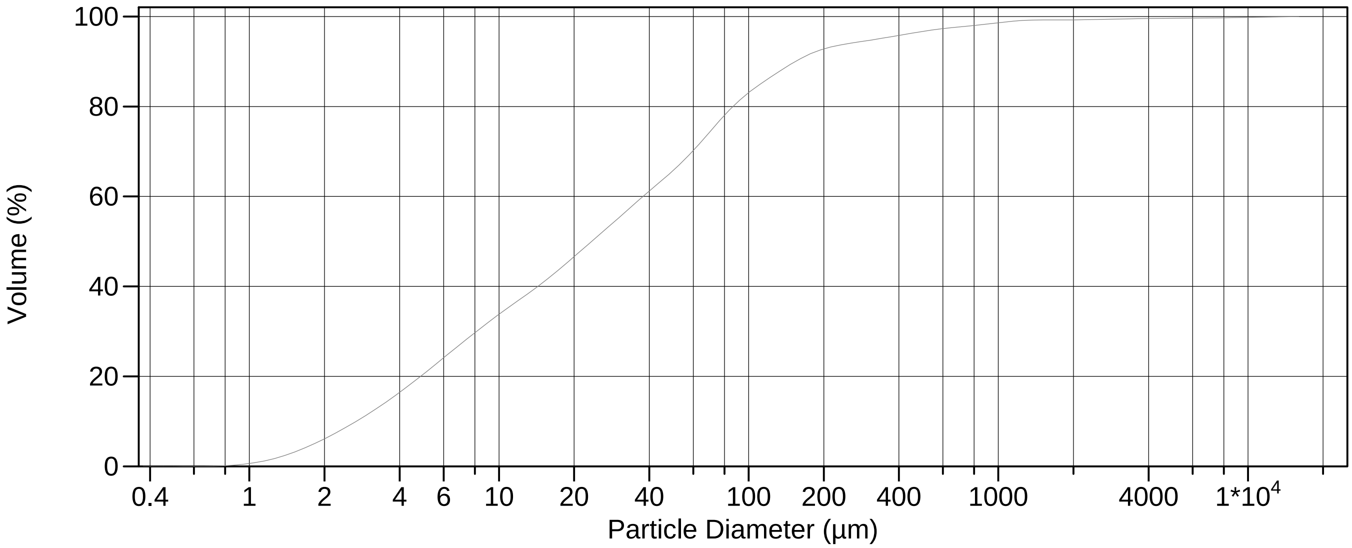

Volume Statistics (Arithmetic) 13a.$02

Calculations from 0.375 µm to 16000 µm

Volume	100.0%		
Mean:	119.8 µm	95% Conf. Limits:	0-1460 µm
Median:	23.52 µm	S.D.:	683.9 µm
D(3,2):	7.816 µm	Variance:	467770 μm^2
Mean/Median Ratio:	5.095	C.V.:	571%
Mode:	66.44 µm	Skewness:	14.17 Right skewed
d_{10}:	2.680 µm	Kurtosis:	219.5 Leptokurtic
d_{50}:	23.52 µm		
d_{90}:	154.2 µm		
Specific Surf. Area	7677 cm^2/ml		

% <	10	25	50	75	90
Size µm	2.680	6.276	23.52	71.58	154.2

13a.$02

Particle Diameter µm	Volume % <	Particle Diameter µm	Volume % <
2.000	6.12	1000	98.6
5.000	20.6	2000	99.3
10.00	33.8	4000	99.6
15.00	40.9	8000	99.7
20.00	46.6	16000	100
50.00	65.8		
60.00	70.2		
63.00	71.5		
70.00	74.4		
75.00	76.3		
90.00	80.9		
125.0	86.9		
200.0	92.8		
250.0	94.0		
400.0	95.8		
500.0	96.7		

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