Sedimentation and Hydrodynamics of Whitianga Estuary

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ABSTRACT:

Whitianga Estuary is a bayhead barrier type estuary located on the east of the Coromandel Peninsula, North Island, New Zealand. The catchment has undergone many land-use changes since pre-European settlement. In some areas of the catchment land-use has changed from native forest to grasslands to forestry and back to pasture. These changes in catchment land-use all contribute to increased sedimentation into the estuary. Development of the estuary itself has also occurred in recent times. Much growth has been focussed around the estuary due to Whitianga town-ship having a large boating community, and includes a 170 berth marina and wharf situated at the tidal inlet entrance to the estuary. These, and the extensive canal development engineering works can have substantial impacts on the sedimentation regime, and may modify tidal circulation, flushing, and sediment deposition within the estuary.

The principle aim of this research is to assess hydrodynamics and sedimentation of the estuary for future management and development purposes, and also to model different scenarios in order to determine the most cost effective, and least obtrusive design for a proposed boat-ramp and approach channel near the marina.

To determine sedimentation rates, sediment cores from four locations were collected to depths of 1 m. Coring locations were chosen based on preliminary model run results, selecting areas that appeared to be long-term sediment sinks of a stable nature. Cores were divided into 10 mm sections and prepared for ^{210}Pb dating and heavy metal analysis, to make an assessment of the vertical sedimentation rates. Recent sedimentation rates were found to be as high as 9 mm/yr post-1950s and past sedimentation rates as high as 30 mm/yr pre-1950s. The use of heavy metal analysis for dating proved difficult as the background levels of the conservative elements used to normalise results varied, making the geochemical analysis approach inappropriate.

As bathymetry is one of the most important aspects of modelling, a large amount of surveying was undertaken for this study. LiDAR, singlebeam data, and recent rectified aerial photographs were interpreted for the creation of a bathymetric grid file to be used for hydrodynamic modelling of the estuary.

The 3DD numerical model was used to determine tidal flows and current velocities. From this initial hydrodynamic model a particle-tracking model was created to determine sediment transport pathways within the estuary. From the initial 20 m model it was then possible to create a number of nested model grids for the purpose of determining the best practice scenario for the creation of a proposed boat ramp and associated approach channel near the harbour entrance. Hydrodynamic results suggest that residual circulation in Whitianga Estuary is nearly in balance, with a low ebb tidal domination present. Particle tracking results suggest that sediment entrained and carried into and within the estuary will accumulate on the intertidal flats. Sediment transport modelling indicates that the impact of a proposed boat-ramp will result in sedimentation of the dredged approach channel due to reductions in residual and tidal velocities.

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CHAPTER ONE: INTRODUCTION

1.0 Nature of the Problem

Anthropogenic activities have induced some remarkable effects on the natural character of Whitianga Estuary. Harbour construction and dredging within the estuary itself, and distant activities such as the deforestation of catchments or damming of rivers are known to alter sediment delivery within estuaries and can have roll-on affects such as changing the water circulation process (Komar, 1997). Therefore, predicting the consequential alterations of processes and sedimentation within an estuary involves research that includes a large effort toward field measurements, and model interpretation (Komar, 1997).

The complex bayhead barrier, lagoon type estuary at Whitianga has a cultural, spiritual, and recreational value to many of the residents who occupy the area. The estuary has undergone many changes in recent years due to development. Much of the development has been focused around the estuary due to this coastal town having a large boating population. Developments include a 170 berth marina and wharf situated at the entrance of the estuary, and an extensive canal development being undertaken by Hopper Developments Ltd which will, when finished, create 1600 new housing sites, most with an associated boat berth. Dredging associated with these developments contributes to the changing character of this estuary. Engineering works such as those occurring in Whitianga can affect the tidal prism and influence channel flow rates. These disturbances can have substantial impacts on the sedimentation regime. Typically such works may modify the tidal current circulation, flushing of the estuary, and sediment deposition within the estuary (Hume, 1991).

The catchment surrounding the Whitianga estuary has undergone many changes since human settlement. In some areas of the catchment land use has changed from native forest to grasslands to forestry and back to pasture. These changes in catchment land-use can contribute to increased sedimentation into the estuary.

The Coromandel Peninsula typically comprises of steep rugged topography containing soft erodable Tertiary sediments and tephras of volcanic origin. High rainfall on steep hillsides results in considerable runoff, which arguably increases the natural rate of sedimentation in the estuary (Hume & Dahm, 1992). Findings from studies undertaken by Environment Waikato suggest that the present rate of infill is ten times higher than that during the early 1950s (Mead & Moore, 2004). However, these values were determined from three random cores taken from the estuary without consideration of the overall estuarine tidal circulation and sediment transport phenomena. Factors such as re-suspension by waves and transportation by tidal currents are likely to transport the sediments to long-term sinks (Hume & Dahm, 1992). Large episodic sediment influx is related to urgent issues surrounding Whitianga inlet. Large sediment inflows and deposition in the upper harbour are thought to be infilling the harbour at a rapid rate, which is contributing to reduction of the tidal prism, which in turn reduces current flows through the entrance. These factors are thought to have contributed to the gradual creation of a "bar" (technically an ebb-tidal delta) outside the Harbour entrance and enhanced shoaling inside the harbour (Steeghs, 2007).

As discussed above, sediment inputs are occurring at a high rate. Therefore, any future development in the estuarine area is going to require knowledge of the hydrodynamics and sedimentation regime in order to assist in planning and design. This research project has come about due to a need to understand the sedimentation processes occurring in the estuary in order to determine if future development potential of this estuary is viable.

1.1 Research Aim & Objectives

The general aim of this thesis is to investigate the hydrodynamics and sedimentation within Whitianga Estuary. The present understanding of circulation within Whitianga Estuary has not been well studied. Previous studies by Hume & Dahm (1992) have reported that sedimentation rates in this estuary could be as high as 12 mm/yr. However, these surveys are now dated and more exotic forest that makes up a large portion of the catchment has been harvested. Therefore, new assessments need to be determined to provide up to date information to assist future management decisions for development that may occur in the estuary.

The specific objectives of this thesis are to:

i. Undertake hydrographic surveys to produce high quality bathymetry and tidal data as a basis for undertaking detailed numerical modelling of the estuarine hydrodynamics.

ii. Undertake an aerial photo analysis to determine changes in estuarine area leading to an assessment of changes to the tidal prism since the 1940's.

iii. Investigate recent sedimentation rates within Whitianga Estuary using ^{210}Pb dating and heavy metal analysis to expand on the current understanding of sedimentation rates.

iv. Make an assessment of the sediment transport pathways and circulation patterns in the estuary using a calibrated hydrodynamic model.

v. Carry out fine scale modelling of the estuary and inlet and assess the feasibility of a proposed new boat-ramp in the vicinity of the present marina.

1.2 Study Area

Whitianga Township, on the east coast of the Coromandel Peninsula, North Island, New Zealand (see Figure 1.1) has the second largest population on the Coromandel Peninsula. In 2001 Whitianga had a usually resident population count of 3078 (Statistics New Zealand, 2007). However, the summer population increases markedly; in the summer of 2003/2004 the population peaked at approximately 17 800 which is over 5 times the usual population (Thames Coromandel District Council, 2007a).

The Coromandel Peninsula is located approximately 80 km east of Auckland city. It forms a large headland separating the sheltered waters of the Firth of Thames and the Hauraki Gulf in the west, from the Pacific Ocean in the east (Carter et al., 1987). The Coromandel ranges (which are orientated with their primary axis to the south and have elevations exceeding 600 m in parts) make up the steep rugged catchments of this area (Figure 1.2) (Hume & Dahm, 1992). Whitianga Estuary has an area of approximately 13.5 km^2, including 5.2 km^2 of mangroves and salt marsh. The catchment that feeds this estuary is the largest catchment in the Coromandel with an area of 441 km^2 (Cooper, 2003).

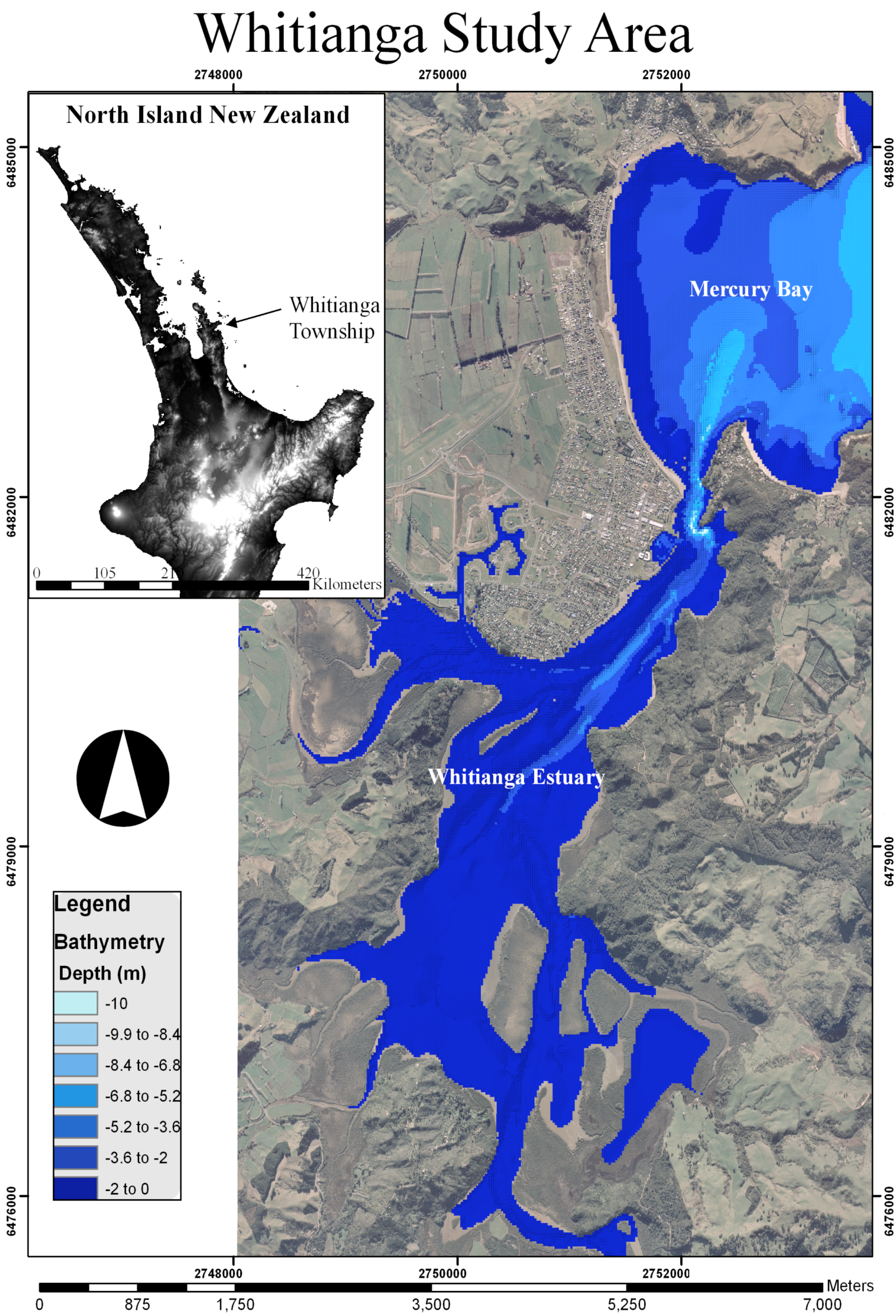

Figure 1.1: Location map showing field study area, Whitianga township, estuary and the surveyed bathymetric data.

Figure 1.2: Whitianga Estuary and surrounding catchment. Illustrating the approximate extent of the study area (denoted by the blue bathymetry). A 3X vertical exaggeration has been applied.

1.3 Thesis Outline

Chapter Two follows the introductory chapter and describes the environmental background of the Whitianga catchment. It portrays the evolution of the area, the tidal processes of the estuary, and the geological and tectonic setting which are all important processes acting on Whitianga Estuary and catchment.

Outlined in **Chapter Three** is an overview of historic land use changes associated with early Polynesian and European settlement in this area. ARC GIS was used to assess historic changes to Whitianga Estuary.

A description of the methods used in the collection of field data and bathymetry, and the processing techniques used to amend errors is presented in **Chapter Four**. The derived bathymetry and field measurements were used in the operation and calibration of the 3DD numerical modelling undertaken in this study.

Chapter Five reports on heavy metal concentrations in sediment cores and the recent sedimentation rates for the upper Whitianga Estuary using ^{210}Pb dating.

Chapter Six provides a description of hydrodynamic model results, illustrating the calibration and validation data of the model. Model outputs for the tidal behavior in the estuary are discussed.

A nested 3DD 10 m model grid was used to simulate a variety of scenarios in the estuary. Hydrodynamic and sediment transport models were used to assess a new boat-ramp and associated approach channel design in the vicinity of the existing marina. The predicted hydrodynamic and sediment transport results from the modelling scenarios are presented and discussed in **Chapter Seven.**

Discussed in **Chapter Eight** is a summary of the key points from the thesis. Also included are suggestions for future work that may be undertaken.

CHAPTER TWO: ENVIRONMENTAL BACKGROUND

2.0 Introduction

The Eastern Coromandel Peninsula has been the centre of interest for many investigations relevant to coastal processes. In particular there are 6 research theses focusing on shelf and coastal processes relative to the Mercury Bay area.

In 1980 D.B. Smith undertook an M.Sc study in Mercury Bay. He examined the individual components that contribute to circulation within the bay, and looked at the interrelationships between bathymetry and bay geometry, sediment distribution, and the hydrodynamics of the embayment. A further study by L. Abrahamson (1987) was to develop an understanding of late Quaternary stratigraphy and evolution of coastal embayments on the east Coromandel Peninsula. B. Bradshaw (1991) undertook an investigation to determine the nearshore and inner shelf sedimentation patterns along the east coast of the Coromandel Peninsula, and the processes (both past and present) that were responsible for these patterns. In 1993 L. Paton made a study of the hydrodynamics and morphodynamics of selected cuspated beaches on the Eastern Coromandel Peninsula, and then in 2003 G. Cooper undertook research with the aim being to identify and characterise the factors contributing to coastal erosion at Buffalo beach, with a specific aim to identify likely sediment pathways. The most recent investigation in the area was undertaken by L. Steeghs (2007). The aim of Steeghs' study was to investigate the sedimentation processes occurring within Buffalo Bay, with the primary goal being to determine the reasons for the shoaling of the tidal inlet and the cause of the shallow area around Pandora rock.

The focus points of the above studies have not however, investigated the evolution of Whitianga Estuary or the physical processes (sedimentation and hydrodynamics) of this estuary that are particular to this thesis.

However, several of the above studies have highlighted the important role that the estuary plays in controlling physical aspects of the surrounding coastal environment. For example:

- Smith (1980) concluded that the hydrodynamic processes that affect Mercury Bay, and the sediment transport occurring within this area are driven by estuarine discharges, oceanic influences, and meteorological forcing.

- Cooper (2003) found that the localised circulation at Buffalo beach can be effected due to the large input of freshwater that the Whitianga estuary releases into Mercury Bay. Freshwater inputs are concentrated and forced to the west of the bay, which causes a density driven circulation cell off Buffalo beach.

- Steeghs (2007) suggests that sediment exported from Whitianga estuary is accumulating in the form of an ebb tidal bar and causing dangerous wave shoaling within Mercury Bay.

This chapter describes the environmental background of the Whitianga catchment. It describes the evolution of the area, the tidal processes of the estuary, and the geological and tectonic setting.

2.1 Evolution of the Area

Whitianga Estuary has evolved through a complicated array of processes. It is in part a barrier spit enclosed estuary created during the Holocene period. In the Holocene marine transgression sea level rose and estuaries on the east coast of the Coromandel Peninsula were formed in drowned river valleys behind marine sand bodies (Bradshaw, 1991). Furthermore, the geology of the ignimbrite cliff faces formed from the flanks of a rhyolite dome that entrap the eastern side of the estuary show great resistance to weathering, and this has resulted in the development of a narrow deep inlet channel into the estuary (Smith, 1980). The classification by topography for Whitianga Estuary is not simple to define as it is not a straight forward barrier enclosed or headland enclosed estuary rather a mix of the two; this estuary is very similar to a bay-head barrier delta formed estuary (Healy, T. 2007, pers. comm.).

The flat, north-western boundary of the estuary on which Whitianga Township is located is an extensive prograding barrier system, which is the largest transgressive barrier system on the east Coromandel coastline (Abrahamson, 1987). To the north of the township lies Buffalo beach. Buffalo beach is located on the seaward edge of over 30 Holocene dunes. The formation of these dunes has created a 5-6 km wide barrier spit that entraps Whitianga (Healy et al., 1981). This prograding barrier spit was deposited during the Holocene period and has developed over the last 6500 years (Bradshaw, 1991).

Headlands and outcrops of erosion resistant rock shape the formation of beaches within Mercury Bay. Paton (1993) put forward that these beaches are principally shaped due to wave refraction patterns. Steeghs (2007) supports this theory by using wave modelling with DHI to show that the nature of the bay and the off-shore islands leads to wave focusing in given areas. Therefore, findings suggest that wave focusing is responsible for localised erosion on Buffalo beach. Furthermore, wave dispersal via diffraction and refraction processes have helped to shape the beaches within the many coastal embayments in this area.

2.2 Tides

Whitianga estuary has a neap tidal range of 1.2 m and a spring tidal range of 1.62 m. Under the classification scheme for estuarine tidal prisms created by Davies (1964) as cited in Schwartz (2004) this estuary can be classified as micro tidal. However, Hume (1991) defines a meso tidal estuary as having tidal prism ranges from about 1.3 x 10^6 to 29 x 10^6 m^3. Given that Whitianga Estuary has a tidal range of over 1.62 m the tidal prism calculated for the spring tidal range from the recently created estuary bathymetry is 14.2 x 10^6 m^3. Tidal prism calculations undertaken by Hume & Herdendorf (1992) using inlet bathymetry from 1979 and aerial photos prior to 1995 for Whitianga have a calculated tidal prism of 12.6 x 10^6 m^3. This suggests that the tidal prism has increased, which may in part be due to the waterway canal development. Further increases in the tidal prism can be expected when the full waterway development is opened. Taking into consideration that Whitianga has a tidal prism similar to that of a meso-tidal estuary, the restricted nature of the inlet channel results in high velocities of the tidal currents, which have been measured with speeds up to 2.5 m/s during peak tidal flows. This ensures that the estuary remains well mixed despite the deep nature of the inlet channel.

The M2 tide (twice daily tide driven by the moon) dominates the tidal constituents at Whitianga and therefore is the predominate forcing for circulation within the estuary. The M2, N2, S2 and K1 tidal constituents as found by Smith (1980) by undertaking a tidal harmonic analysis, make-up the majority of the tidal components found at Whitianga Wharf with the M2 explaining the largest proportion. Further tidal phenomena occurring in Mercury Bay is the seiching due to the resonance of the tide. Smith (1980) found that due to the shape of the bay the tide can cause a long period seiche wave with a period of approximately 40-60 minutes to occur.

Tides are the major hydrodynamic driving force for the circulation in Whitianga Estuary. Whitianga Estuary receives very low wave energy due to the sheltering effect of Whakapenui Point. Although some wave refraction occurs the inlet is sheltered and waves seldom pass the entrance.

2.3 Climate

Due to the steep nature of the Whitianga catchment, much of the climate for this area is localised. Rainfalls and wind conditions at Whitianga are significantly different to those measured at other eastern Coromandel coastal areas during the same period. Whitianga has a moderately temperate climate, which experiences predominantly warm and humid conditions (Maunder, 1974). The average measured rainfall is between 1800 and 2000 mm per year (NIWA, 2008). However, there can be very extreme rainfall events. For example, during a 24-hour period in 1981 rainfall in Whitianga was measured as high as 300 mm (Hume & Dahm, 1992). These high rainfall events provide a means for sediment to be transported from the catchment area into Whitianga Estuary. The associated large precipitation events in the Coromandel catchments create elevated levels of sediment runoff and freshwater input.

Research conducted by Smith (1980) and Abrahamson (1987) using early MetService wind data for the period 1972-1980 demonstrate that the predominant wind direction is from the west, and at times a strong easterly and north-easterly component arises. This indicates that wind direction and wind speed for Buffalo Bay are significantly controlled by the topography of the area. However, work carried out by Wilkins & Davies (1986) and Cooper (2003) (where in both examples the deployment of an Automatic Weather Station to record wind data occurred), found the prevailing wind direction was from the west to southwest (270-225 degrees) with fastest recorded velocities of ~12 m/s and average speeds of 2.5 m/s. Much of the variation between findings can be attributed to the localised wind and climate that occurs in Whitianga. At present, MetService wind data is collected from the Slipper Island, which is located offshore from Mercury Bay.

2.4 Geology and Tectonics

The geology of a catchment plays an important role in the supply of sediment into an estuary. The geology surrounding Whitianga estuary is dominated by the Whitianga and Coromandel groups (Skinner, 1976; Adams et al., 1994). Areas with steep topography, shallow soils, or unsustainable land use practices following native de-forestation such as those found on the Coromandel Peninsula, will often lead to increased rates of geomorphic action including landslides, soil erosion, and fluvial activity (Knies et al., 2007).

2.4.1 Geology

The Coromandel Range consists of basement rock of Mesozoic greywacke overlain by andesitic rocks of Miocene age (Figure 2.1). These are in turn overlain by younger Pliocene rhyolitic rocks (Hume & Dahm, 1992). Furthermore, on a local scale some areas have been intruded by plutonic igneous rocks (Hume & Dahm, 1992). Throughout the Coromandel there are signs of hydrothermal modification due to plutonic volcanic activity (Hume & Dahm, 1992). A quantity of the volcanic activity that occurs along the axis of the Coromandel Peninsula is associated with the Coromandel Volcanic Zone (CVZ).

2.4.2 Tectonic setting

The igneous rocks found around the Coromandel have been produced by intrusion and volcanic activity that occurred in the north–northwest trending continental margin forearc basin which was active from the Miocene period (20 million years ago) through to the Pleistocene period (less than 2.5 million years ago) (Carter et al., 1987). This activity is responsible for the volcanic intrusions and volcanic activity associated with the region (Carter et al., 1987).

The rugged ranges of the Coromandel Peninsula run through the centre of the Coromandel volcanic zone (Figure 2.2) which lies on top of three spatially and temporally individual volcanic arcs: Northland – Three Kings – Coromandel arc, the Colville – Lau arc, and the White Island – Taupo volcanic zone – Kermadec arc (Malengreau et al., 2000). To the west of the Coromandel range is the Hauraki depression, which consists of a down faulted graben (Thompson, 1966; Steeghs, 2007). Active plate margins of the Australian and Pacific tectonic plates result in an uplifted horst block that is down tilted to the east of the Peninsula (Cooper, 2003). Furthermore, from Whitianga to Whangamata are located several Miocene calderas. These calderas include the Aldermen Islands and the Mercury Islands (Malengreau et al., 2000). The active plate margins of the many volcanic arcs that intersect this area have caused faulting on the Coromandel Peninsula, consequentially resulting in the downwarping of some coastal zones and formation of deep basins where shelf and coastal sedimentation can accumulate (Bradshaw, 1991).

The hydrothermally altered volcanic zones that make up the Whitianga catchment rocks, and the steep faulted horst and graben geology of the Coromandel area result in unstable soils. Healy & Dell (1987) report that many of the harbours in the eastern Coromandel have rapidly infilled. The high sediment inputs that are contributing to this infilling can be attributed to the highly erosive properties of the catchment.

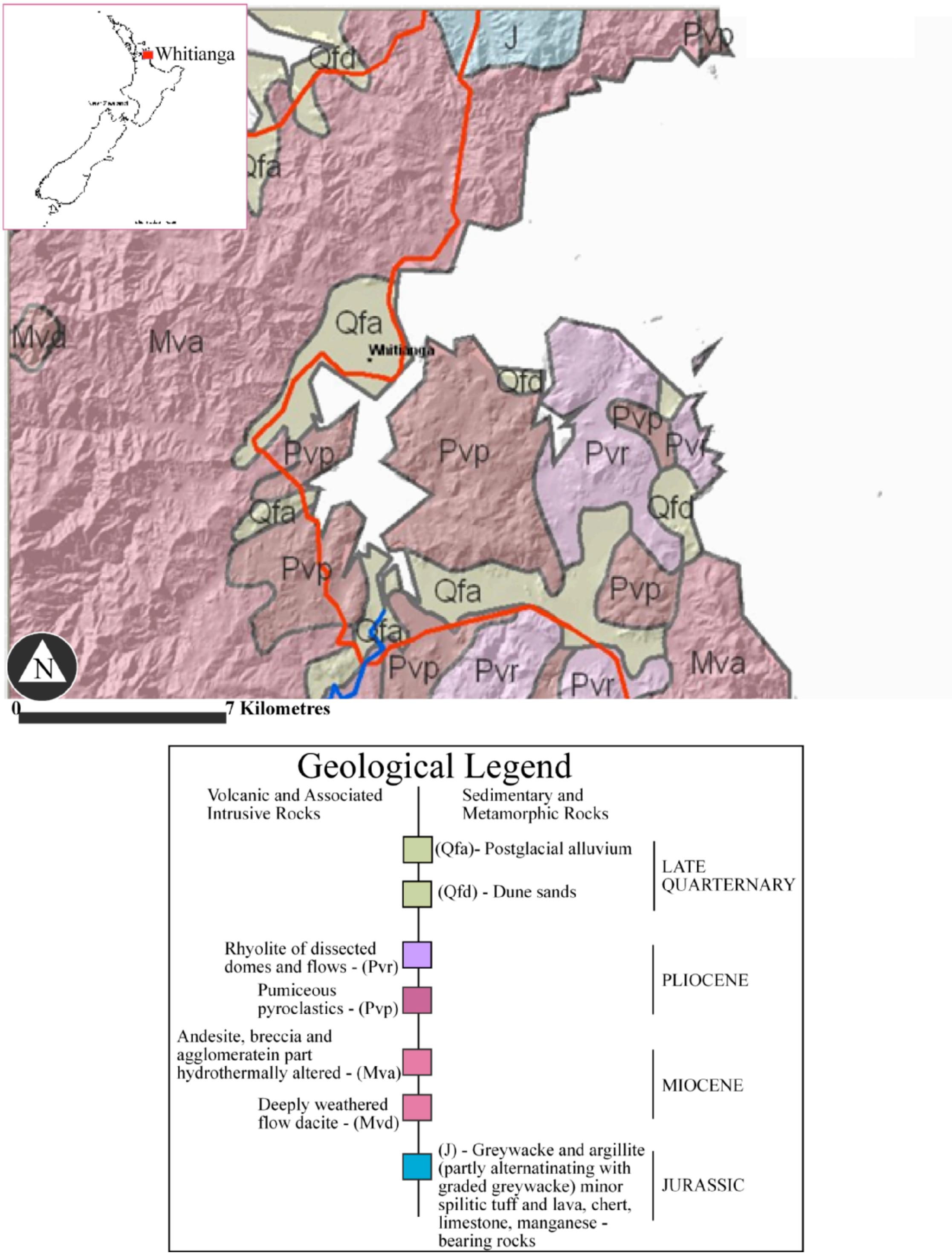

Figure 2.1: Geological map of Whitianga catchment showing geology of the surrounding area. Adapted from GNS geology map (Skinner, 1995).

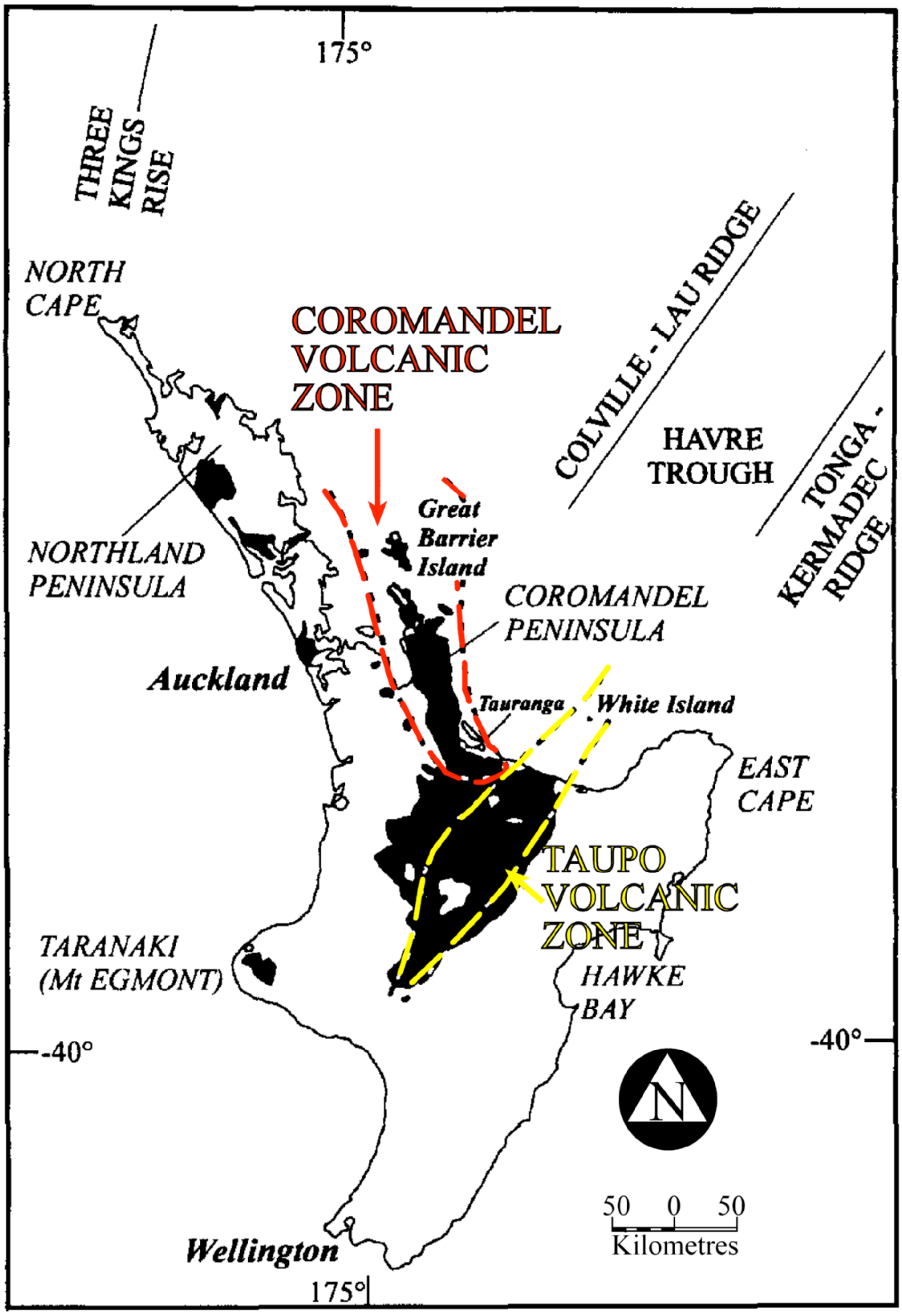

Figure 2.2: Map of the North Island showing the volcanic regions of the TVZ and CVZ also illustrating the locations of the three volcanic arcs that the CVZ lays on top of, producing the tectonic setting of the area. (Adapted from Malengreau et al., 2000).

2.5 Conclusion

The prevailing wind at Whitianga is derived from a west to southwest direction, and has an average velocity of 2.5 m/s. Due to the sheltered nature of the estuary, and the relatively short fetch in relation to the prevailing wind, the effect of wind and swell waves are not thought to be major factors in the forcing of estuarine hydrodynamics. Therefore, the predominant hydrodynamic forcing occurring within the estuary is that of the M2 tidal constituent.

The regional geology of the Whitianga catchment is dominated by the Whitianga group, which consists of soft erodable tertiary sediments and tephras. The erodable nature of the catchment, in conjunction with steep topography, and a localised temperate climate in which high rainfall events are common (as great as 300 mm in a 24 hour period), results in considerable sediment inputs into the estuary.

As will be discussed in the following chapters a combination of sediment input and the hydrodynamics of Whitianga Estuary lead to a number of problems associated with maintenance of the estuary.

CHAPTER THREE: HISTORICAL LAND-USE OF THE WHITIANGA CATCHMENT

3.0 Introduction

Changing land-use patterns in the Whitianga catchment have led to increased sedimentation in the Whitianga Estuary. Whitianga catchment has been subjected to much change since human settlement, with most of the land-use changes occurring since early European settlement.

This chapter examines the historical land-use of the Whitianga catchment. It looks at land-use activities and coverage during Polynesian and early European settlement, and the changes in estuarine area of time. It also looks at mangrove coverage of the estuary, and discusses possible reasons for the increase of mangroves in the area.

3.1 Polynesian Settlement

The Coromandel catchment has undergone much change since the area was first settled (Hume & Dahm, 1992). At the time of early occupation by Maori the Mercury Bay area was heavily wooded, and the flat land surrounding Whitianga estuary was covered with thick flax (Riddle, 1996). Analysis of pollen samples in sediment cores taken from estuaries within the Coromandel region have found that in pre-polynesian times the area was covered in dense forest, and typically there was an increase in bracken during the times of Polynesian settlement (~700-110 yr BP) which is related to small scale burn-off of forested areas for the purpose of horticulture (Hume & Dahm, 1992).

3.2 European Settlement

Significant catchment changes mainly occurred during the early European colonisation of the area when forested areas were disrupted with large unsustainable burn-offs and deforestation associated with Kauri logging, gum digging, and gold mining activities (Sale, 1978; Hume & Dahm, 1992). Furthermore, land use activities including dairying during the 20th century may also have increased sedimentation rates into the estuary.

When Captain James Cook arrived in Mercury Bay on 3 November 1769 the mountainous country of the Coromandel Peninsula was covered in tawa, rimu, and kauri trees, and shrub, fern and coastal vegetation. Raupo, flax, and rushes grew in wetland areas, and mangroves grew in the tidal estuaries (Salmond, 1991). Cook was impressed with the forest cover of the region and a proposal was made to the British Government to use the timber available in New Zealand (Harrison, 1988). Mercury Bay became the first centre of Kauri milling in the Coromandel and according to historic records, the first sawmill in New Zealand was established there in 1838 (Sale, 1978). Given that the estuary and surrounding area was a hive of sawmill activity for nearly 90 years (Sale, 1978), there is a strong likelihood that sediments within Whitianga estuary will contain a layer of sawdust and wood chips from this activity. The presence of such deposits can create a known unconformity within the geological record. This unconformity can then be used to support dating methods ^{210}Pb dating to determine recent sedimentation rates this methodology has been applied by Hume (1991).

Commercial production of Kauri gum began in the 1840s and by 1845 it made up half of the exports from Auckland. Burning of scrub was a common practise for locating the gum (Harrison, 1988), and this also contributed to land clearance and possibly associated sedimentation in the Whitianga catchment. Gold mining became popular in the Coromandel region following discovery of gold at Coromandel in the 1850s (Harrison, 1988). One of the major impacts of gold mining was the clearance of all large stands of timber for the purpose of lining mine shafts and tunnels, and also for use as fuel (Harrison, 1988). Along with timber milling, gum digging, and gold mining activities, flax milling also occurred in the catchment. Flax was grown for both domestic and commercial purposes by local tribes (Harrison, 1988), and the first flax mill was established in the Mercury Bay region in 1866 (Riddle, 1996).

Farming became fully established as a catchment land-use activity in the 1920s when both the gold mining and timber industries had been exhausted. By the 1950s farming activity had greatly increased, with dairy farming occurring in the lower catchment area and sheep farming developing in the hill country (Wilkins & Davies Group, 1986).

Land clearance associated with Polynesian and early European settlement of the Whitianga region has most likely led to an increase in sedimentation rates occurring in the estuary. Pollen analysis of two sediment cores undertaken by McGlone (1988) within the estuary was used to obtain records of changes in the catchment vegetation and their evolutionary development throughout recent history. Dating and changes in pollen horizons were used to establish sedimentation rates, and it was found that during the Polynesian era (prior to mass land clearing and deforestation) sedimentation rates ranged from 0.6 to 1.1 mm/yr. However, during the period of 1970-1988 the estimated sedimentation rates ranged between 4 and 9 mm/yr within the Whitianga Estuary, suggesting sedimentation rates remained high after kauri logging ceased (McGlone, 1988).

3.3 Changes in Estuarine Area

A reduction in the estuarine intertidal area over time is clearly evident from the digitisation of aerial photos created using ARC GIS (Figure 3.1). Using ARC GIS to calculate estaurine area, changes over time were assessed. There has been significant reclamation of land around the outer estuary. As can be seen in Figure 3.1, the greatest period of land reclamation occurred between 1966 and 1984. This can be attributed with the reclamation of dryed up salt marsh which can be associated with the end of the Kauri deforestation period and the start of the land development for agriculture in this area.

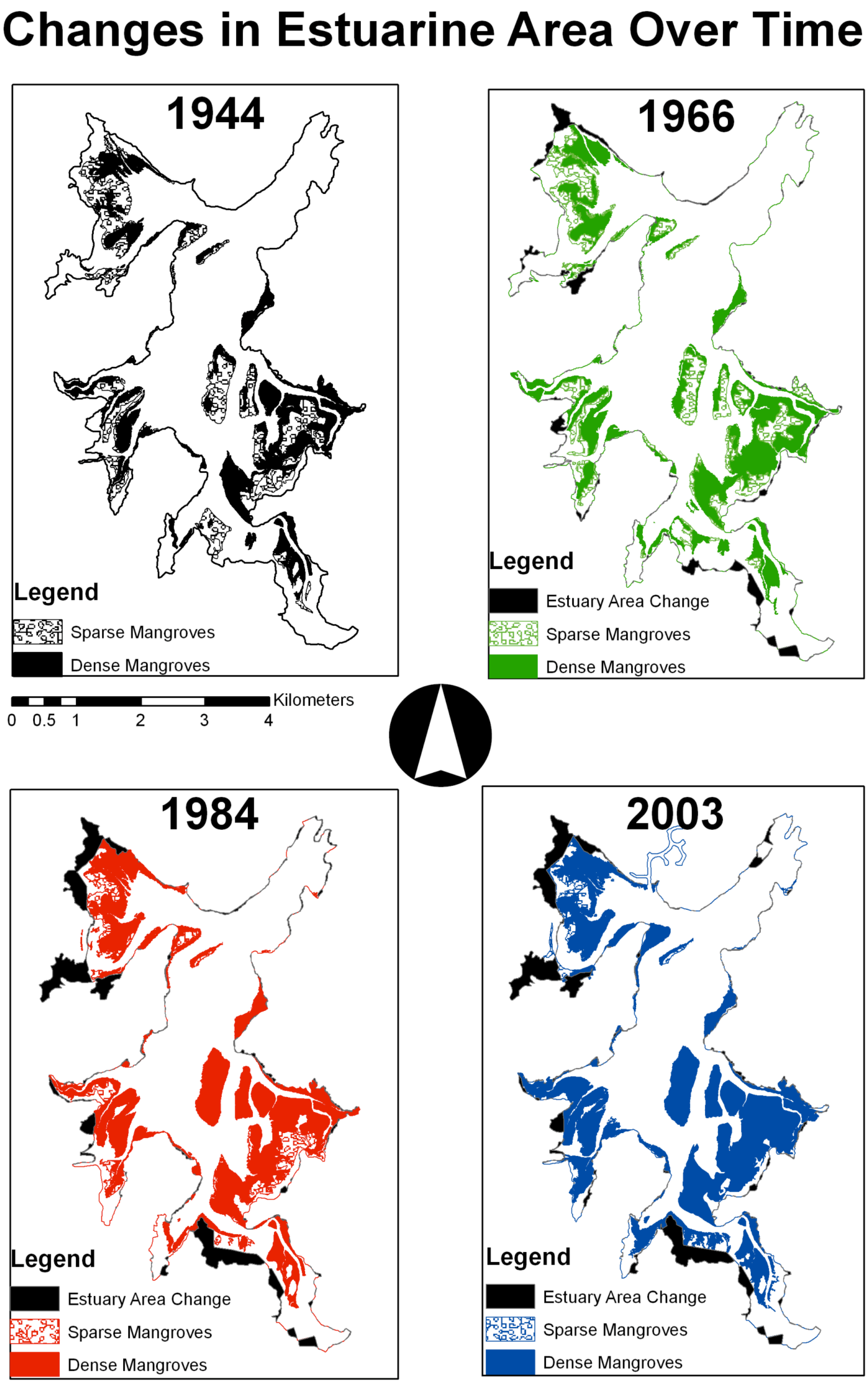

Figure 3.1: Digitised images showing change in estuarine area between 1944 and 2003. Reduction in estuarine area denoted as the black area.

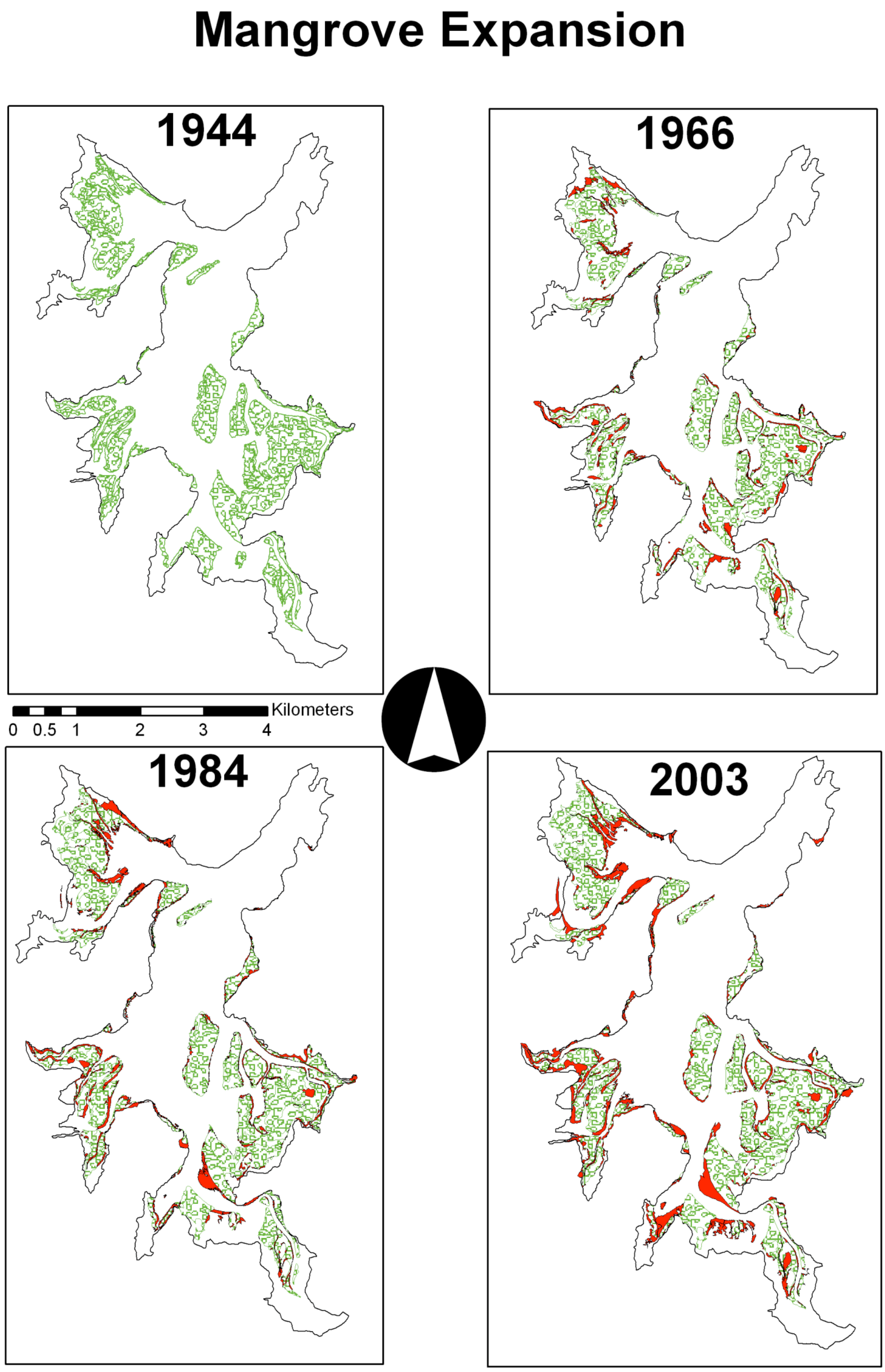

Figure 3.2: Digitised images of mangrove expansion in Whitianga Estuary (shown in red) between the period of 1944 and 2003.

It is also noteable that the mangrove forests have become much denser over time (Figure 3.2). Table 3.1 shows that mangroves are now twice as dense as they in 1944. As can be seen in Table 3.1, expansion of the mangrove forests covering the tidal flats of Whitianga Estuary has been occurring since 1944. Most of the mangrove expansion can be seen to have occurred between 1988 and 2003 (Figure 3.2).

Mangroves have long been established in the Whitianga Estuary. When Captain Cook arrived in the region in 1769 he described the head of the river as branching into channels and forming a '*number of very low flat Islands all cover'd with a sort of Mangrove trees and several places of the shores of both sides of the River were cover'd with the same sort of wood…*' (Beaglehole, as referenced in Riddle, 1996). Figure 3.3 shows Cooks chart of Mercury Bay, indicating the area where mangroves were present. Note the naming the river 'Mangrove River'.

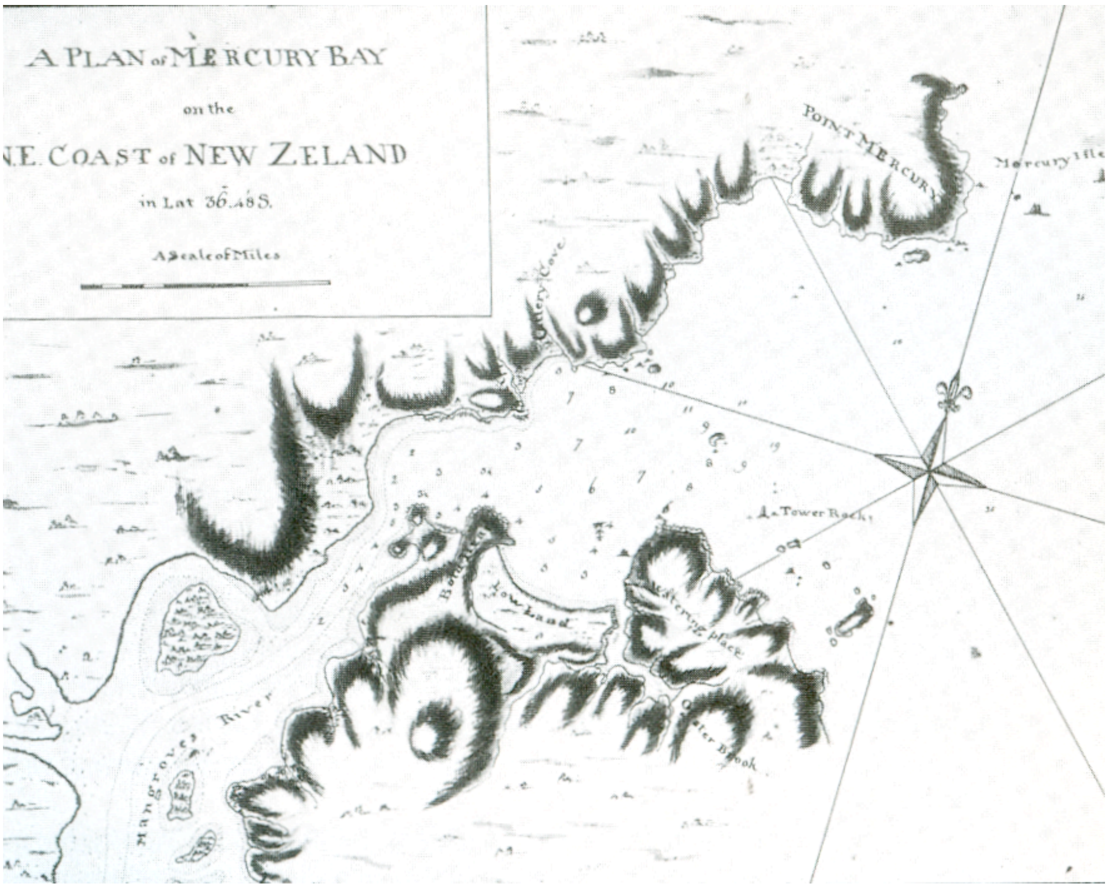

Figure 3.3: Cooks chart of Mercury Bay. Note: he has named the river (bottom left of image) 'Mangrove River'. (Source: Riddle, 1996 p 33).

Table 3.1: Digitised area calculations undertaken using ARC GIS of Estuarine and mangrove changes from 1944 to the most recent aerial photos collected in 2003. Note: 2003 is the estuary area when recent waterway development has been removed from the area.**

Year	Estuary area (Km^2)	Dense mangrove coverage (Km^2)	Sparse mangrove coverage (Km^2)	Total mangrove coverage (Km^2)
1944	16.4261	2.5130	2.1436	4.6562
1966	15.9760	3.2123	1.5950	4.8072
1988	15.3028	4.1029	0.7700	4.8729
2003	15.3025	5.1041	0.2864	5.3905
2003**	15.1764	5.1041	0.2864	5.3905

It can be argued that mangrove expansion occurs in areas of high sediment loads associated with catchment deforestation. However, mangrove-habitat expansion has been observed to be occurring decades after deforestation of the surrounding catchment, and therefore other alternative explanations for this increase in mangroves can be attributed to climate change, and an increase in nutrients associated with agricultural activities in the catchment (Swales et al., 2007). Much of the decrease in estuarine area occurred during the period of 1966 to 1984, when there was a push for agricultural land. This decrease in estuarine area can clearly be seen to be associated with land development and the reclamation of salt marsh areas.

From aerial photo analysis it is evident that much of the reclaimed land was salt marsh that had silted and become dry. Therefore, if the assumption is made that reduction in estuarine area is in part related to siltation that has occurred, some conclusion could also be drawn about a reduction to the tidal prism. Given that the tidal prism of an estuary is regulated by the area and tidal range of the estuary, and by the tidal wave amplitude and phase (Hicks & Hume, 1991), the reduction in estuarine area that has occurred in Whitianga can be associated to a reduction in the tidal prism. However, recent developments in Whitianga of a waterway canal have increased the estuarine area to an area similar to that prior to 1988, indicating that an increase in tidal prism of the estuary must have occurred. Since 1944, yet prior to significant estuarine development (i.e.

the Whitianga waterways canal development), it can be seen that due to reclamation and sedimentation a 7 % decrease in estuarine area has occurred. Dredging of the area for the construction of the waterways canal development has since led to a 0.7 % increase in area, with the full waterway development still to be completed. The increase in estuarine area is related to an increased volume of water in the estuary, which will in turn lead to an increased flow during the latter part of the tides. The implications of this are that the inlet gorge may deepen due to increased erosion as the velocities through the entrance increase. Such conditions are expected to result in an increased import and/or export of sediment, therefore the ebb tidal delta and/or flood tidal delta will become more prominent (Davis & FitzGerald, 2004; Kraus, 2006).

3.4 Conclusions

Whitianga Estuary and the surrounding catchment have undergone many changes since human settlement. During early occupation by Maori the Mercury Bay area was heavily wooded, and underwent periods of small scale burning. Following early european settlement of the area there was a significant shift in catchment land-use, resulting in large scale land clearances.

Much of the decrease in estuarine area occurred during the period of 1966 to 1984. This period is associated with an increase in agriculture in the area, and much of the changes to the estuarine area occurred due to reclamation of land for agricultural purposes. Further changes that have occurred more recently (1984 to present) are the development of a marina, and the creation of a large waterway canal.

An interesting finding is that mangrove expansion within Whitianga Estaury cannot be attributed to a period of increased sedimentation rates associated with early land clearances. Expansion of mangroves was observed to be occurring decades after deforestation of the surrounding catchment. The largest period of mangrove expansion appears to be during the 1984 – 2004 period. Therefore, other alternative explanations for this increase in mangroves are attributed to climate change, and to an increase in nutrients associated with agricultural activities in the catchment.

All these changes result in disturbances to the estuarine tidal prism and hence changes to sediment transport pathways within the estuary. Much of the past disturbance to the estuarine area can be associated to loss of area and a reduction in tidal prism. Recent development can be seen to have resulted in an increase to the tidal prism through an increase in estuarine area and volume due to the waterway canal development.

CHAPTER FOUR: FIELD DATA & BATHYMETRY

4.0 Introduction

The primary aim of the field deployments and surveying was to obtain high quality bathymetry, current velocity, and water level data to run, calibrate, and verify the 3DD hydrodynamic numerical model.

This chapter describes the methodology used to obtain bathymetry, current velocity, and water level data from Whitianga Estuary, for the purpose of model calibration and validation. It also discusses the techniques used to create a high resolution XYZ bathymetric data set, while reducing many errors that occurred due to high levels of suspended sediments and shallow water reflection effects that were present in portions of the collected single-beam data.

4.1 Methodology

Collection of bathymetry is very costly; therefore initial bathymetry was digitised using hydrographic fair sheets from hydrographic surveys undertaken by the Royal New Zealand Navy and reproduced by Land Information New Zealand (LINZ). The Whitianga Naval Fair sheet of the soundings used to create the local chart was imported into ARC GIS and geo-referenced to aerial photos of the area. Depths were inferred from 2006 ortho-rectified aerial photos in zones where the hydrographic chart data were not available. These depths were then spot-checked using a boat-mounted depth sounder that was corrected for tide using tide board readings at Whitianga wharf. Results from the initial bathymetry showed that most of the checked chart readings for the outer most harbour were within 0.5 m of the charts. However, over the bar outside the harbour and within the estuary itself, differences were very significant. These findings promoted the need for more comprehensive surveying of the estuary to be undertaken. As the main area of interest for this thesis was the lower estuary, a large effort was put into single–beam and later multi–beam surveys.

4.1.1 Bathymetry

For the purpose of hydrodynamic modelling, precise bathymetry measurements are essential for the accurate resolution of numerical modelling outputs (Mourre et al., 2004). Therefore, the collection of high-resolution bathymetric data is the first and one of the most important aspects of numerical modelling to be undertaken. Lack of good bathymetric data will result in poor calibration and inaccurate resolution of results.

To collect accurate high resolution bathymetry for Whitianga Estuary a comprehensive survey was undertaken. Several methods were used to collect data. Collection techniques and data sources included a single-beam data survey, a walking Real Time Kinetic (RTK) survey, LiDar data, spot-depths, and a multi-beam survey. All data were inputted into ARC GIS. To increase resolution, data were also interpolated and contour lines were created based on 2003 rectified and geo-referenced aerial photos.

Using ARC GIS a 5 m resolution raster surface was created and exported as XYZ ascii files. These files were then grided using Golden Software SURFER™. SURFER™ was chosen over griding in MATLAB and ARC GIS as it enables for the establishment of blanking cells at the land boundary. Furthermore, SURFER™ proved to produce the best interpolated bathymetry. Bathymetry produced in ARC induced sharp peaks and edges that were unrealistic (Figure 4.1). The kriging method of interpolation was chosen with a search radius of 200 m to grid initial 5 m resolution estuarine bathymetry. Further grid resolutions were made at 10 m and 20 m. The 20 m grid was used for the large-scale model and applied to the whole estuary area and inner Mercury Bay.

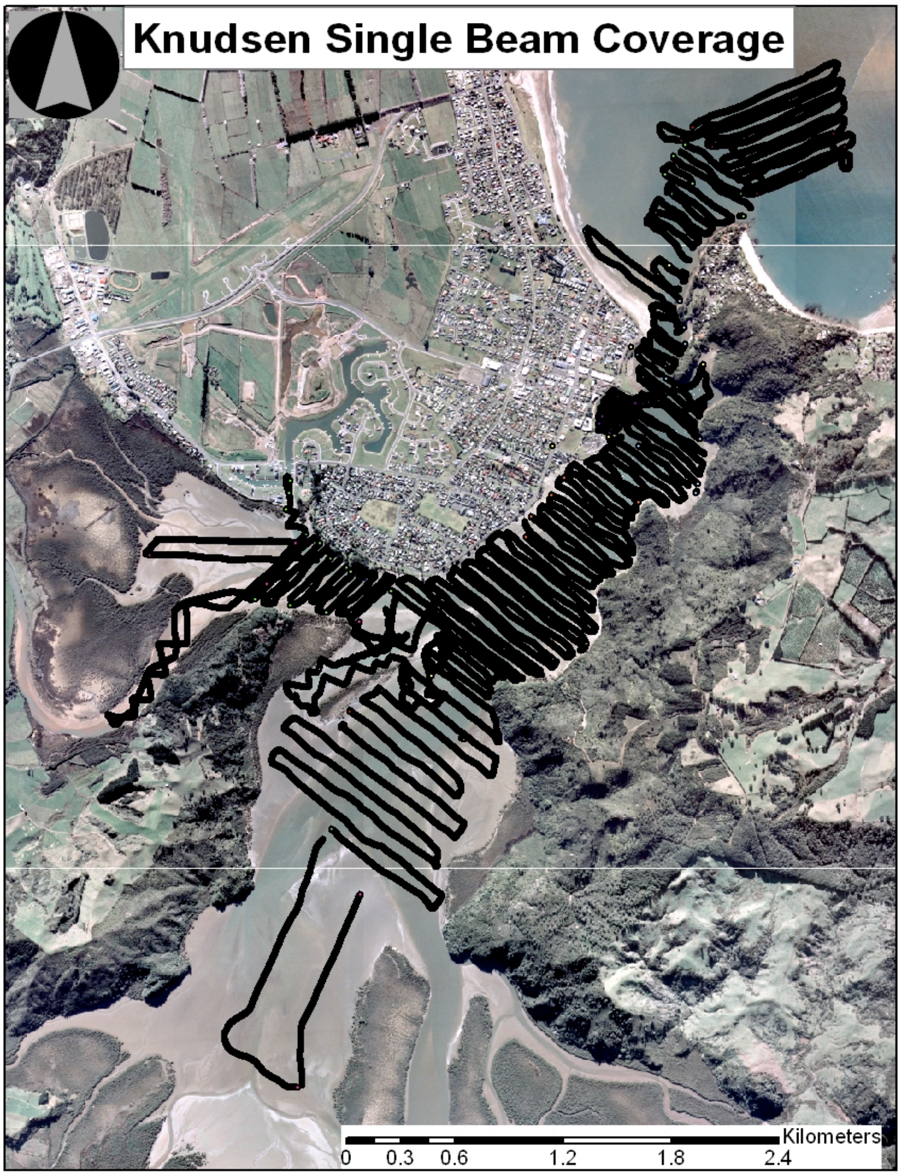

Figure 4.1: Knudsen single beam echo sounder coverage. Data were collected during a 4-day boat survey 17-20 April 2007 using the Waikato University boat "Taitimu".

Surveying the entire upper estuary using single-beam or RTK would have required weeks of work and was beyond the scope of this research. Therefore, to create the best bathymetry using the time available single-beam and RTK surveys focused on key areas of interest: (a) the ebb tidal bar which has formed over recent years; (b) the main inlet channel; and (c) the channel located around the entrance of the western basin that was created by the waterways project.

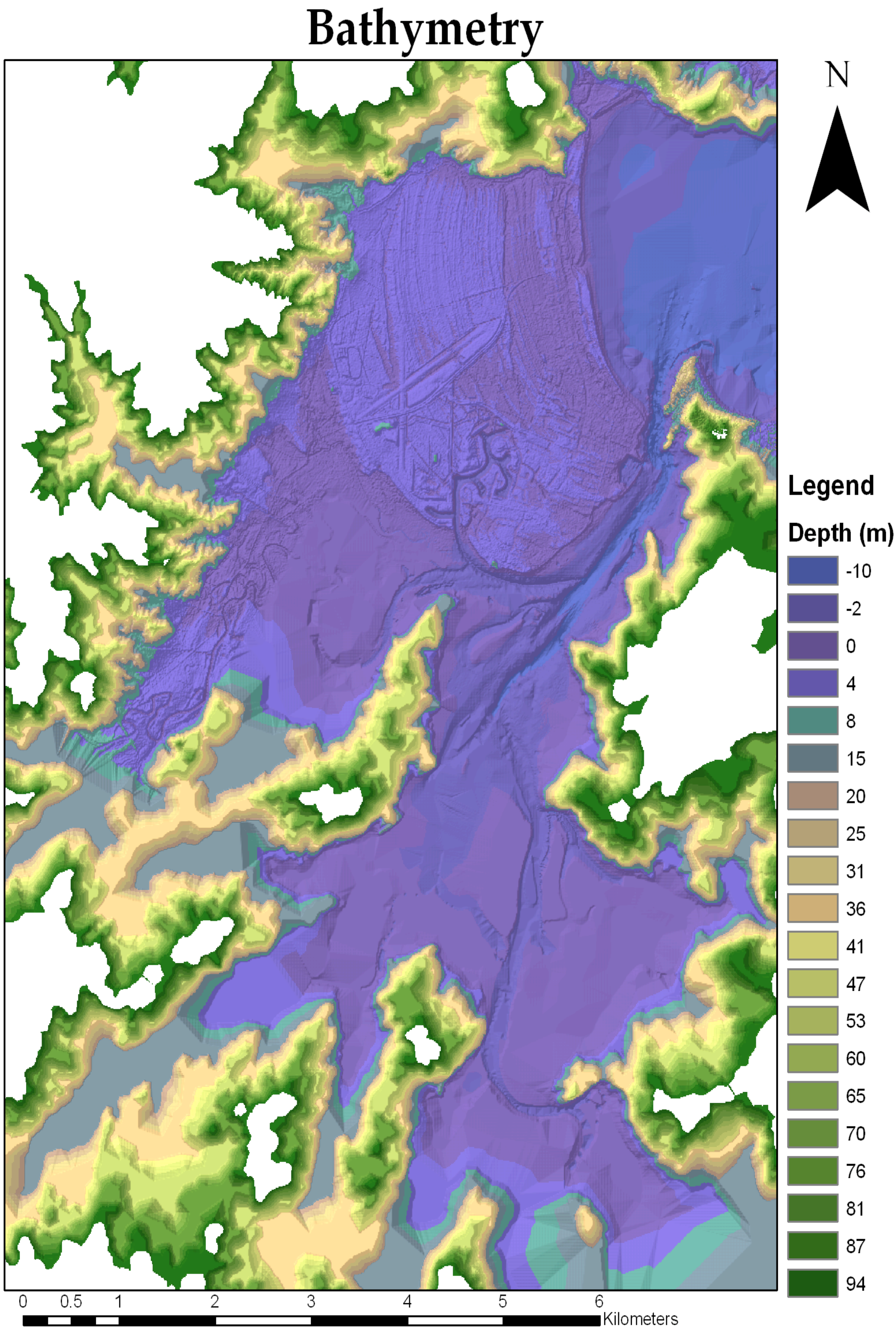

Figure 4.2: Bathymetry produced using ARC GIS. Note the sharp edges produced using the griding function. All data was exported as a raster surface to SURFER™ for griding to reduce this error.

4.1.2 Bathymetry Errors

HYDROpro comes with a very simple depth and spike filter, which has two filtering options (set ranges and spike detection). However, neither of these methods were efficient in filtering out low frequency noise produced by the single beam sonar in shallow water. Figure 4.3 is screen shot from HYDROpro. Note the reverberation created in shallow water. This is most clearly seen in the light blue trace of the reduced depth line. This section presents a method for reducing errors from single beam data using a low pass filter, to produce an accurate bathymetric model of single beam soundings for Whitianga Estuary.

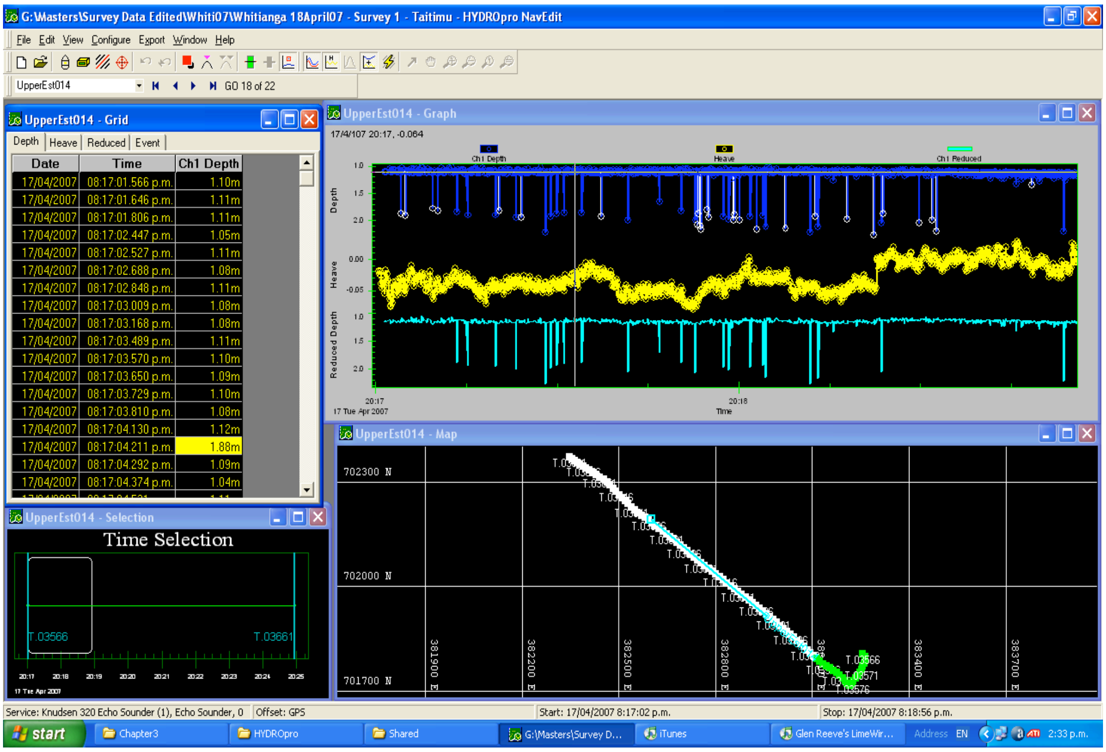

Figure 4.3: Screen shot collected from the processing software HYDROpro. Note the reduced depth on the lower screen portion. It is clearly evident that some errors present in the data. Errors can be seen as spikes descending from the actual bathymetry.

Much of the noise seen can only be processed out using a manual data entry method. For large surveys this can result in time consuming loss of efficiency. Therefore, an improved methodology was created to reduce the errors that were induced. Much of these errors were thought to be from sediments in the water column and shallow water reflection errors. The method used to resolve this problem was to export data into MATLAB and undertake different low pass filtering techniques. The key to the processing was to smooth out unnatural errors without smoothing out natural oscillations in the bathymetry.

Figure 4.4: MATLAB figure showing the different levels of filtering applied to the raw data to filter out errors. Note the smoothed values are the number of values that the low pass filter uses to smooth the data.

The basic MATLAB code is a medium filter applied to a set number of "pings" via a set filtering window size. Figure 4.4 shows different filtering levels applied to the raw data to remove errors that were present. A filtering level of 7 was selected as it smoothed out errors but not the natural fluctuations present in the data.

The average spacing between single-beam points is between 20-80 mm. Taking this into consideration it is simple to determine a reasonable slope for bedforms that are detected by the single-beam. Knowing wet sand with excessive water (such as that found in the survey area) has an angle of response of no greater than 12° (Webster, 1919), then using simple geometry it is clear that many of the spikes detected in the single-beam data are errors. Calculations by Webster (1919) and measurements collected from a normalised dredged harbour entrance (Tauranga Harbour), which had a maximum steepness of 12.5°, indicate that this is a fair assumption to make for a sandy bottomed area.

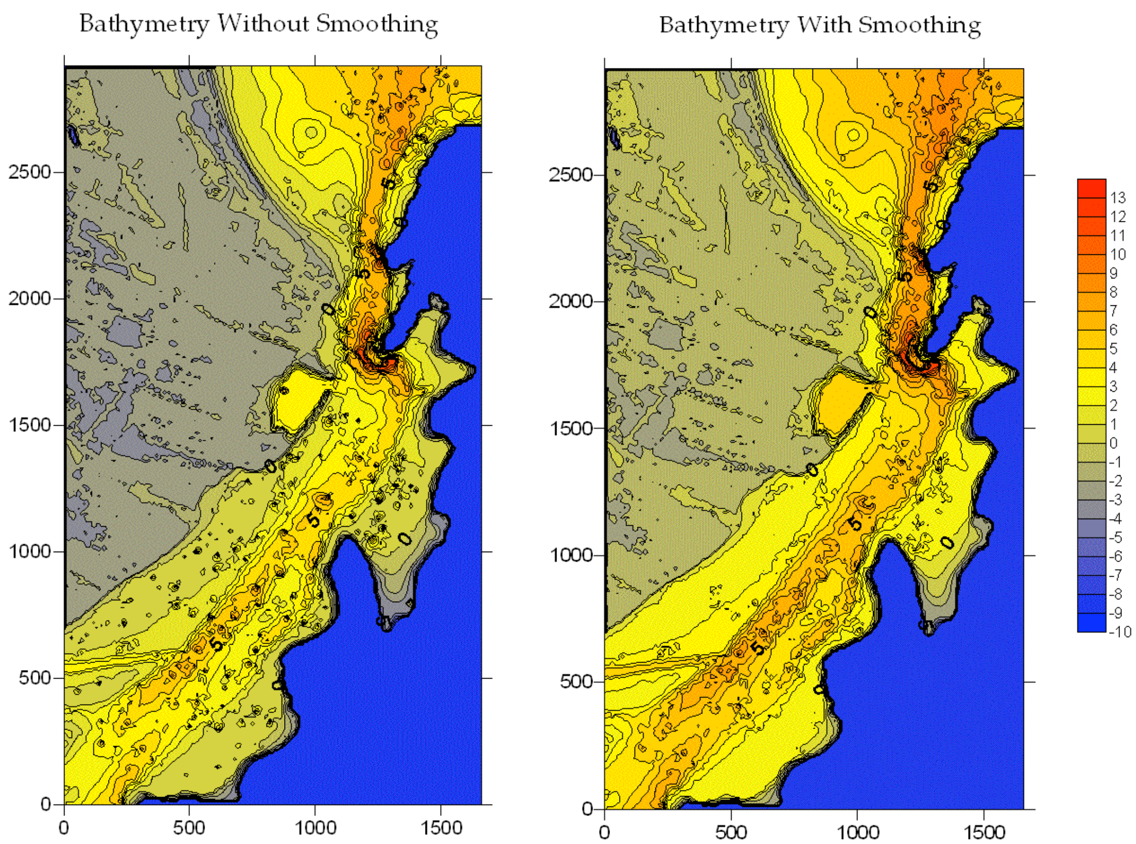

Figure 4.5: The effect of applying the low pass filter to the data. Note the pot marks on the intertidal flats, which are related to errors in the bathymetry.

4.1.3 RTK Errors

Real Time Kinetic (RTK) is a Global Positioning System (GPS) land survey based system that allows for very accurate horizontal and vertical measurements to be acquired. RTK corrections are based on a differential use of carrier phase measurements of the GPS, Glonass, and/or Galileo signals where a single reference station provides the real-time corrections to a centimetre level of accuracy. This is achieved by using a base-station of a known location, which transmits a radio frequency to the GPS system. Known locations allows for the correction of atmosphere errors induced by normal GPS (Scarfe, 2002).

Both the single-beam survey and the walking survey employ the same GPS system. This is the Trimble MS750™ system. The Trimble system provides for dynamic positioning by providing 20 mm + 2 ppm horizontal accuracies and 30 mm + 2 ppm vertical accuracies when using the low latency positioning mode (Trimble, 1999).

4.1.4 Field Deployment

Instrument deployment consisted of four *InterOcean* S4ADW electromagnetic current meters and two FSI 3D-ACM (Falmouth Scientific Inc) acoustic current meters being deployed (Figure 4.6). The S4 current meters were mounted on stainless steel frame 1 m off the seabed. Each S4 location was recorded using boat mounted GPS for retrieval purposes. Further fieldwork was undertaken with C.T.D (Conductivity, Temperature and Density) casts and ADCP (Acoustic Doppler Current Profiler) surveys. These surveys were conducted through the entrance during ebb, slack and floodwater tidal conditions. C.T.D casts were undertaken to determine whether Whitianga Estuary was well mixed so as to determine whether modelling could be carried out in two dimensions or if three-dimensional modelling would be required.

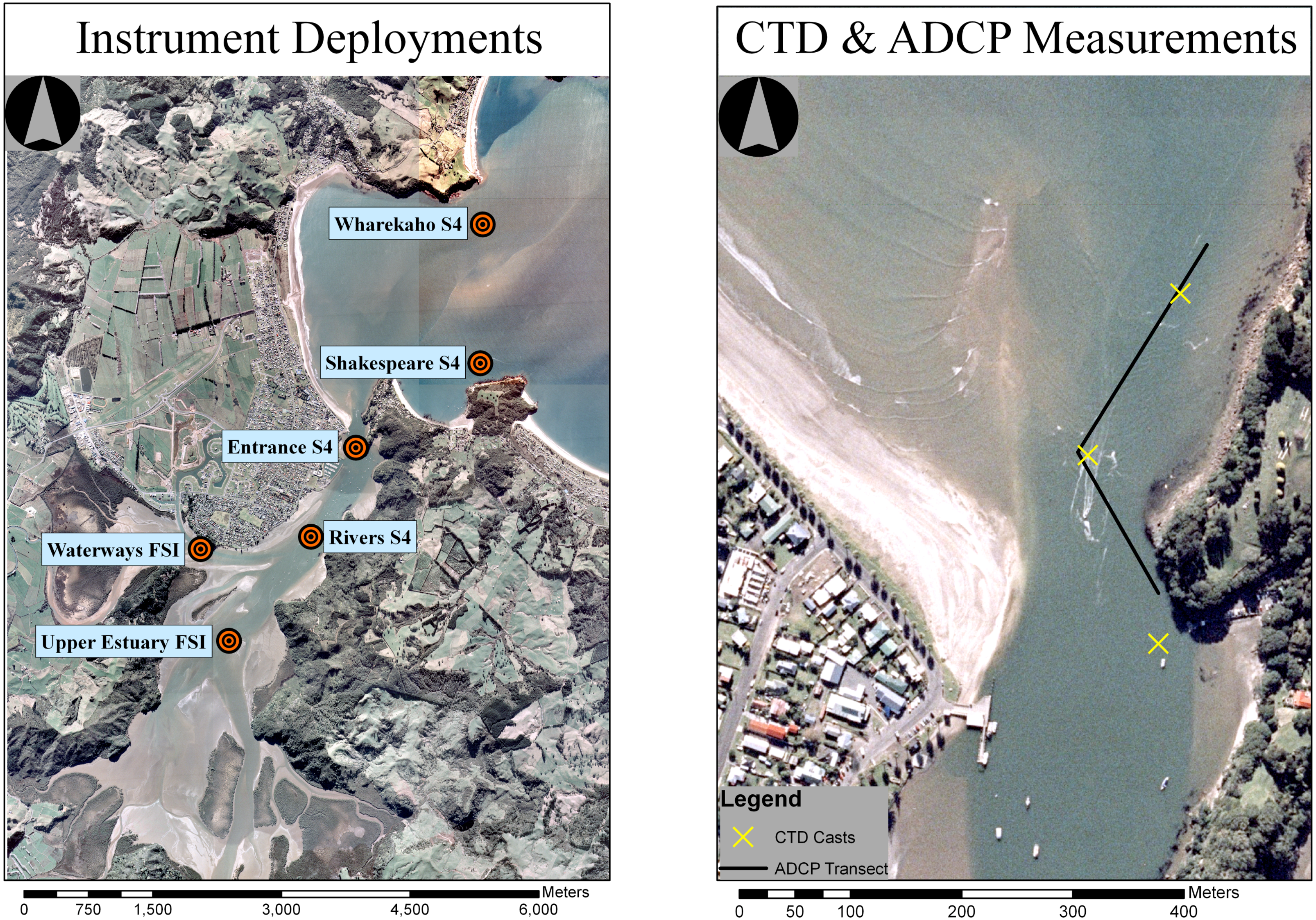

Figure 4.6: Locations of instruments deployed for the model validation and calibration (left), and CTD cast and ADCP transect (right).

The locations of instrument deployment, and the relative depth at which the instruments were deployed at can be seen in Table 4.1.

Table 4.1: Location of instrument deployments and relative depths.

Location	Instrument	North	East	Depth
Shakepeares Cliff	S4	5921048.85	1843115.91	7m
Wharekaho	S4	5922667.45	1843143.05	6.8m
Entrance	S4	5920063.83	1841663.95	9.8m
Rivers	S4	5919026.09	1841139.27	4.1m
Waterways	FSI	5918883.06	1839853.61	2.5m
Mussel Farm	FSI	5917812.82	1840183.61	1.5m

InterOcean Software Version 4.1.1 was used to undertake initial data processing from current meters, which converts the raw pressure data to depth and into measured current direction and velocities. The S4 current meters were set to record bursting for 18 minutes ever hour at 1 Hz. Data was exported from the InterOcean software as a 1 hour time averaged text file. MATLAB was used to undertake harmonic analysis using the MATLAB Tidal Analysis Toolbox.

Wave analysis was not undertaken with the current meters, as the focus of this study is estuarine hydrodynamics. Therefore, tidal analysis was the main focus. Furthermore, the steep cliffed catchments and restricted entrance of this estuary do not promote the development of significant waves, hence making conditions ideal for boat moorings.

FSI analysis requires the conversion of pressure as recorded by the FSI to depth. There is a relationship between depth, pressure and velocity given by the Bernoulli Equation:

$$pgh + p + \frac{\rho u^2}{2} = constant \qquad \text{(Equation 4.1)}$$

Where p represents pressure, g gravitational acceleration, h water depth, ρ fluid density, and u fluid velocity.

Due to a large flood event that occurred on the 30 March 2007, the upper estuary FSI (located at the mussel farm) was buried by the shifting of a sand bed. Therefore, much of the record for that current meter could not be used as there was not enough data to undertake a tidal analysis.

4.2 CTD Cast

CTD casts were undertaken through the inlet of the harbour using an SBE 19 (Sea-Bird Electronics Inc.) plus SEACAT profiler (jointly called a CTD) as shown in Figure 4.6. These were undertaken to determine whether a two or three-dimensional model would need to be applied to the estuary. CTD casts were undertaken during incoming, outgoing, and slack tides. Three casts at each location were done over a period of one hour leading up to and during these events. Results were then averaged for each hour and plotted and graphed using Ocean Data viewer software (Figures 4.7, 4.8, and 4.9).

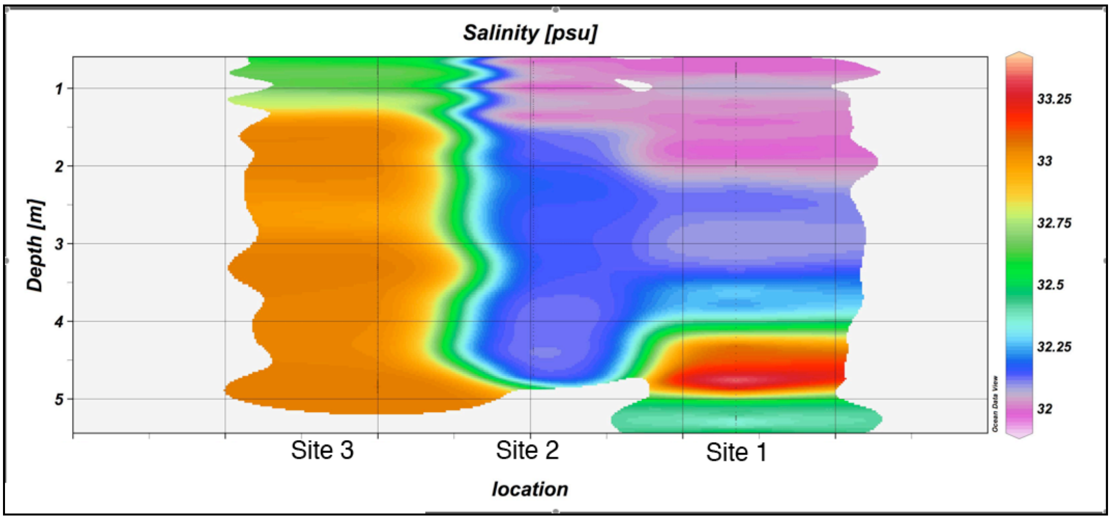

Figure 4.7: Salinity measurement collected during peak flood tide using a CTD on 19 April 2007. Site 1 represents the inner estuary, Site 2 is in the entrance channel, and Site 3 is located outside the entrance in Mercury Bay.

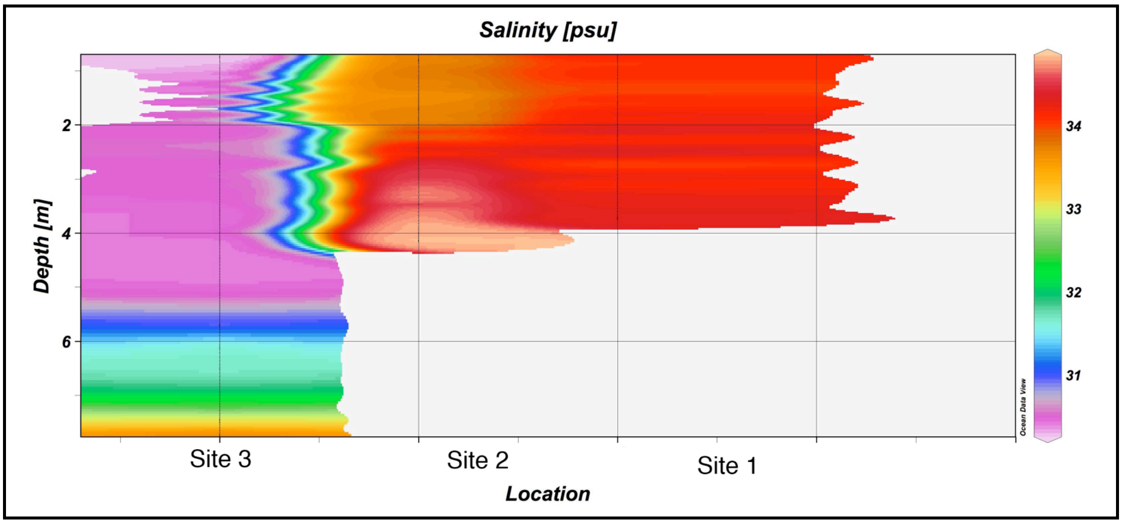

Figure 4.8: Salinity measurement collected during low water slack tide using a CTD on 19 April 2007. Site 1 represents the inner estuary, Site 2 is in the entrance channel, and Site 3 is located outside the entrance in Mercury Bay.

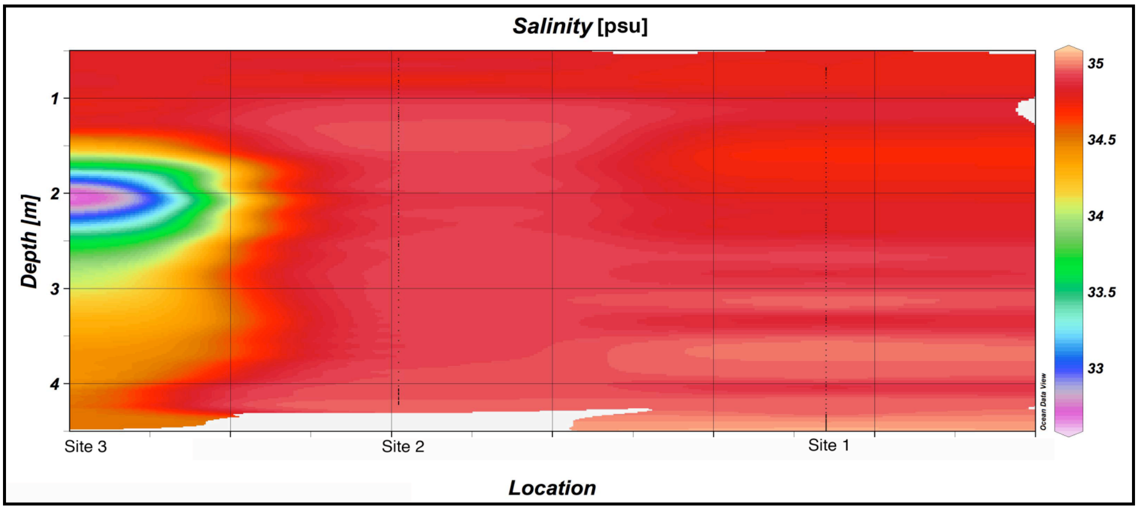

Figure 4.9: Salinity measurement collected during ebb tide using a CTD on 19 April 2007. Site 1 represents the inner estuary, Site 2 is in the entrance channel, and Site 3 is located outside the entrance in Mercury Bay.

Results show that the high current speeds and turbulence created in the constrained entrance of Whitianga Estuary result in complete mixing of the water column within the estuary. This means that there are no density fronts present, and therefore, it is reasonable to run the model in two-dimensions rather than three-dimensions. However, density differences can be seen to occur about the location of site 3 (the outer CTD cast location). This means that for certain applications (such as oil spill) modelling of Mercury Bay would require a three-dimensional model. However, as the focus of this thesis was the inner harbour and the estuary, a two-dimensional model was adequate for the purpose of hydrodynamic modelling of circulation patterns for the understanding of sediment transport pathways.

4.3 Conclusion

The high-resolution bathymetry data presented in this chapter are critical for determining the accuracy and reliability of the numerical modelling undertaken in this study. A range of techniques were undertaken to create and correct the bathymetric data that was grided for the Whitianga Estuary model. The final bathymetric output file is of high resolution with minimal errors. Possible bathymetric errors for the areas covered by the single-beam survey have accuracies of 20 mm + 2 ppm horizontal accuracies and 30 mm + 2 ppm vertical accuracies. However, as single-beam does not give full coverage some interpretation is done during the griding process. Therefore, it is expected that errors may increase by a factor of 10 %.

CTD casts collected in the entrance show that a density front occurs at the outer entrance sampling location. However, as this is beyond the entrance, and the fact that Whitianga Estuary can be assumed to be well mixed, three-dimensional modelling was not required, and therefore a two-dimensional modelling approach was undertaken.

CHAPTER FIVE: SEDIMENTATION WITHIN WHITIANGA ESTUARY

5.0 Introduction

Estuaries naturally tend to accumulate sediments (Komar, 1997). However, it has been demonstrated that the estuaries that encompass the Coromandel coastline have a higher sedimentation rate than what would be considered a natural infilling rate (Hume & Dahm, 1992; Sheffield et al., 1995; Mead & Moore, 2005). The main process of infilling has been found to be due to the accumulation of fine sediments from river-borne sediment being trapped by the deepened water and the induced circulation that reduces the delivery of at least the coarser grain-size fractions to the ocean (Komar, 1997).

In recent decades, there has been a considerable focus upon recent human impacts in estuaries and their catchments (Hume & Dahm, 1992; Sheffield et al., 1995; Mead & Moore, 2005). Many of these studies have demonstrated the effects that human impacts have on estuarine systems and provide invaluable information for the understanding and management of human impact on the physical environment (Swales et al., 2005). Such studies use methods including heavy metal analysis and lead-210 dating to measure and assess the impact that human occupation has had on estuarine sediments and sedimentation rates (Hume & Dahm, 1992; Sheffield et al., 1995; Mead & Moore, 2005; Swales et al., 2005).

Heavy metal distribution in marine sediments provides an opportunity for researchers to investigate anthropogenic impacts on coastal ecosystems (Vaalgamaa & Conley, 2008). Evidence produced by the inputs of heavy metals from sewage, industry inputs, mining activities, and atmospheric fallout can provide baseline data for dating deposits associated with human occupation (de Groot et al., 1976; Forstner & Wittman, 1981; Loring & Rantala, 1992). Spatial patterns in heavy metals found at depth and within the surface sediments of cores taken from different locations provide evidence of current contaminant levels and what changes have occurred over time (Hakanson, 1988). Historical patterns can also result from analysing the seaward progradation of tidal flat deposits (Gorenc et al., 2004). This enables an opportunity to assess the relative contributions into the two upper sub estuaries from the surrounding catchments and inflowing river systems.

This chapter discusses the findings of a sedimentation investigation from four cores collected in the upper Whitianga Estuary for the purpose of determining estuarine sedimentation and to assess whether the estuary is infilling at an accelerated rate.

5.1 Limitations of Present Knowledge

A number of studies focusing on estuarine sedimentation have been conducted within the estuaries of the Coromandel Peninsula (McGlone, 1988; Hume & Dahm, 1992; Sheffield et al., 1995; Mead & Moore, 2005). The most comprehensive study of sedimentology within the Whitianga Estuary was conducted by McGlone (1988) and used by Hume & Dahm (1992). In this study pollen analysis was conducted on two sediment cores for the purpose of determining sedimentation rates.

Limitations of present knowledge of sedimentation processes in Whitianga Estuary relate to how sediment accumulation rates have changed over the last 150 years as a result of human activities within the estuary, in particular the effects of past deforestation, conversion to pastoral land, and the establishment of exotic forest.

5.2 Dating of Recent Sediments

This section of the thesis discusses the theory behind ^{210}Pb dating, heavy metal analysis, and geochemical normalisation for the purpose of determining sediment accumulation rates.

5.2.1 Summary

It is possible to use radioisotopes such as lead-210 (^{210}Pb) and caesium-137 (^{137}Cs) to reconstruct the sedimentation history of an estuary. Heavy metal analysis (i.e. analysis of Pb, Zn, and Cu profiles in estuarine sediments) is also useful for providing information on the effects of human development (Swales et al., 2005).

5.2.2 ^{210}Pb Dating

Lead-210 (^{210}Pb) is a radioactive form of lead, which has the atomic weight of 210. It is one of the last elements created by the radioactive decay of the isotope uranium-238 (^{238}U) (USGS, 2003). ^{210}Pb forms naturally in sediments and rocks that contain ^{238}U, as well as in the atmosphere as a by-product of radon gas. Within 10 days of its creation from radon, ^{210}Pb falls out of the atmosphere. It accumulates on the surface of the earth where it is stored in soils, lake and ocean sediments, and glacial ice. The ^{210}Pb eventually decays into a non-radioactive form of lead. Radioisotopes such as that of ^{210}Pb (^{210}Pb has a half life of 22.3 years) and caesium-137 (^{137}Cs half-life of 30 years) can be used to reconstruct the sedimentation history within an estuary (Swales et al., 2005). Assuming that the sediment layers remain undisturbed, then as the sediment ages it slowly loses its radioactivity (Appleby, 1993). This enables a potentially reliable and precise method to determine how old a sediment layer is, by how much ^{210}Pb it contains. It takes about 7 half-lives, or 150 years for the ^{210}Pb in a sample to reach near-zero radioactivity (USGS, 2003), which makes it ideal for dating recently deposited sediments.

The quantity of ^{210}Pb found in estuarine sediments is supplied from the insitu decay of ^{238}U in catchment soils, which are eroded and accumulated in estuaries and some atmospheric deposits in the form of rainfall. This means that there are both direct and indirect inputs into the estuarine receiving environment. This is termed unsupported ^{210}Pb.

5.2.3 Sediment Accumulation Rates (SAR)

In order to determine changes in estuarine morphology it is necessary to calculate sediment accumulation rates within the estuarine system. Rates of sediment accumulation can be calculated by measuring the thickness of sediment between dated layers within sediment cores. The layers are dated using radioisotope techniques. The sediment accumulation rates are the long-term sedimentation rates obtained from cores, the cumulative result of sediment deposition and erosion. However, the best results are achieved from the least disrupted environments where mixing and resuspending actions are limited. This results in clear sediment profiles. A combination of clear sediment profiles, and low bioturbation produce higher dating resolution (Swales et al., 2005).

5.2.4 SAR from ^{210}Pb dating

Two possible models can be applied to date ^{210}Pb profiles under changing sediment accumulation rates (SAR). These are (i) constant rate of supply (CRS), and (ii) constant initial concentration (CIC) (Appleby, 1993). These models have both been applied successfully for estuarine sediment dating (Swales et al., 2005). The validity of modelled ^{210}Pb results is a factor of how well the predicted model results explain the transport process of sediment to the estuary (Swales et al., 2005).

For the purpose of calculating the SAR for this study, accumulation is based on an exponential ^{210}Pb concentration decrease at a rate that is inversely proportional to the sedimentation rate (Appleby, 1993). This produces a net SAR. If the assumptions are made that there is a finite period and sedimentation (*S*) is constant then an exponential decay model (CIC model) can be solved (Ruiz-Fernandez et al., 2004). Given an initial unsupported ^{210}Pb concentration (C_0), the value of C (Bq kg^{-2}) will decline exponentially over time (*t*) (Swales et al., 2002).

$$C_t = C_0 e^{-kt} \qquad \text{(Equation 5.1)}$$

Where the radioactive decay constant for ^{210}Pb (k) is 0.03114 and C_0 is the unsupported ^{210}Pb concentration (Bq kg^{-2}) at time zero. Swales et al. (2005) suggest that the CIC model is feasible when the main source of unsupported ^{210}Pb is in the form of eroded catchment soils and hence is ideal for such sites as Whitianga where catchment erosion is high.

The CIC model; age of sediment at depth x is given by:

$$t = \frac{1}{k}\ln\frac{C_0}{C} \qquad \text{(Equation 5.2)}$$

The exponential decay model (CIC) means that a depth profile of the natural log C should yield a straight line of the slope $b = -k/S$. Therefore, a simple transformation of the data means that a regression fit can be carried out to calculate the concentration of ^{210}Pb. Consequently, a sedimentation rate over the depth of the fitted data is given by:

$$S = -(k)/b \qquad \text{(Equation 5.3)}$$

This is advantageous as it fits a regression line for the entire depth of measurement, resulting in a more accurate net accumulation rate rather than dating of single layers.

5.2.5 Heavy Metals

Heavy metal analysis provides valuable information about development within the catchment and surrounding estuarine area (Thorne & Nickless, 1981; Vaalgamaa & Conley, 2008). A large portion of anthropogenic discharge of heavy metals accumulates in estuarine sediments because coastal sediments act as a sink for heavy metal deposits (Vaalgamaa & Conley, 2008). Assuming that heavy metal levels within the sediment remain the same (as there are no other inputs apart from nature), then if there is a period of increasing heavy metals that can be identified this can be associated with anthropogenic (generally industrial) inputs.

5.2.6 Geochemical Normalisation

Geochemical normalisation is often required to remove the effect of grain-size from estuarine sediments when undertaking heavy metal analysis. de Groot et al. (1982) define three methods of normalisation which can be undertaken to determine the relationship between heavy metal concentration and grain size. These methods are: (a) the separation of a grain size fraction; (b) extrapolation from regression curves; and (c) comparison with conservative elements (geochemical normalisation). Geochemical normalisation is required to standardise heavy metal samples so that comparisons between sites can be ascertained.

5.3 Methods

This section describes the core locations and the methods used to analysis four cores collected from Whitianga Estuary. Methods include core collection techniques, radioisotope dating using ^{210}Pb, heavy metal analysis, and geochemical normalisation.

5.3.1 Sediment Cores

Core locations were selected at sites that appeared to be stable long-term sediment sinks. Five locations were chosen (Figure 5.1): three from the larger southern estuarine basin (shown as locations A, C, and D), and two from the smaller western basin (locations B and E). Core B was collected from a location in the western basin but was not sampled. This core was taken in order to investigate if there was a common stratigraphic layer that could be used. It was vibrated to a depth of 1.5 m, which caused considerable compaction. However, no layers were found. Consequently, this core was disregarded because the compaction caused by hard/coarse sand layers hit at just over 1 m was too severe to be used for ^{210}Pb dating.

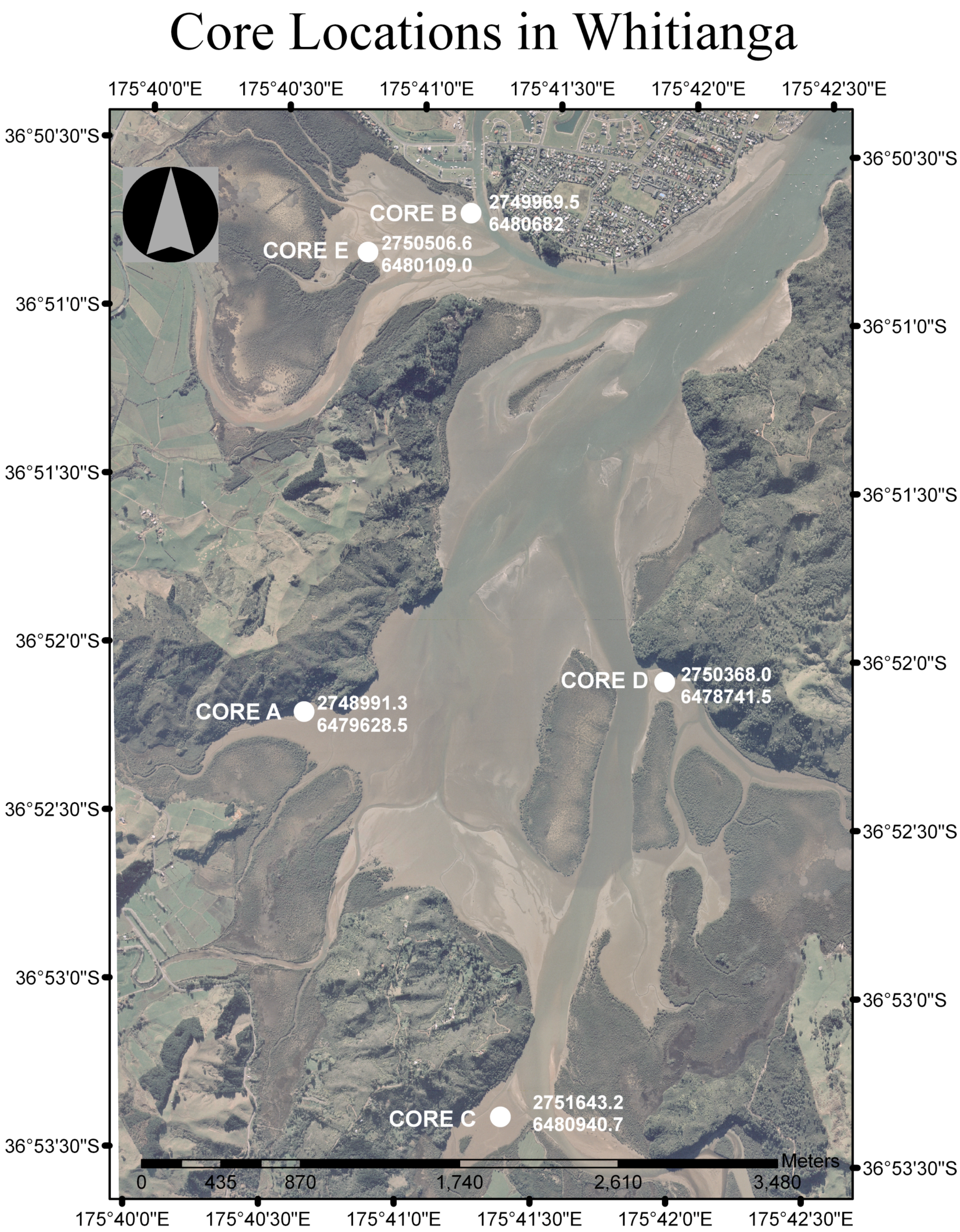

Figure 5.1: Location of sites in Whitianga Estuary that illustrate zones of accretion. These sites were used for the collection of sediment cores for heavy metal analysis and ^{210}Pb dating.

Five cores of just over 1 m in length were collected using vibra-coring. Several methods of core collection were tried including short cores of 30 cm, which proved to be too inaccurate to date as the top 30 cm of sediment is often turned over biologically or through erosion and sedimentation processes. Furthermore, more confidence can be placed in the dating through the use of the location of the ^{137}Cs layer. The ^{137}Cs layer is a deposit that can be found in sediments as a result of over 400 nuclear weapons tests that were conducted between 1945 and 1980 (Pfitzner et al., 2004). Therefore, deeper sediment cores were required as this layer was not present in the short 30 cm cores. Other tried methods included the collection of 1 m long cores by driving plastic tubes into the sediment then sealing the ends and pulling them out. Compaction was excessive in this technique and therefore samples were unacceptable for ^{210}Pb dating. Vibra-coring proved to be the best method with compaction at most sites being negligible.

Cores were vibrated and sunk to depths until resistance was felt, or until the required depth (1 m) was achieved. Resistance was generally created by coarse sand layers, which would cause the aluminium tubes to resonate and compact any unconsolidated mud layers above. This made applying compaction factors difficult due to the assumption that there is a linear compaction throughout the core. Therefore, any compaction can be accounted for and applied to the dating results. However, when coarse sand beds cause excessive compaction through resonation, a linear compaction assumption cannot be applied. This is because compaction occurs above the coarse bed layer where vibration is at a maximum, and not evenly throughout the core.

Core samples of up to 1.5 m in length were collected from most sites and stored in sealed 70 mm diameter aluminium tubes. In the laboratory the tubes were cut down either side using an adapted concrete cutting saw and cradle (see Figure 5.2). Each core was then split into two equal portions using cutting wire. Photographs were taken of each core (for the purpose of creating stratigraphic columns) and one half of each core was sealed and refrigerated. The other half became the working half.

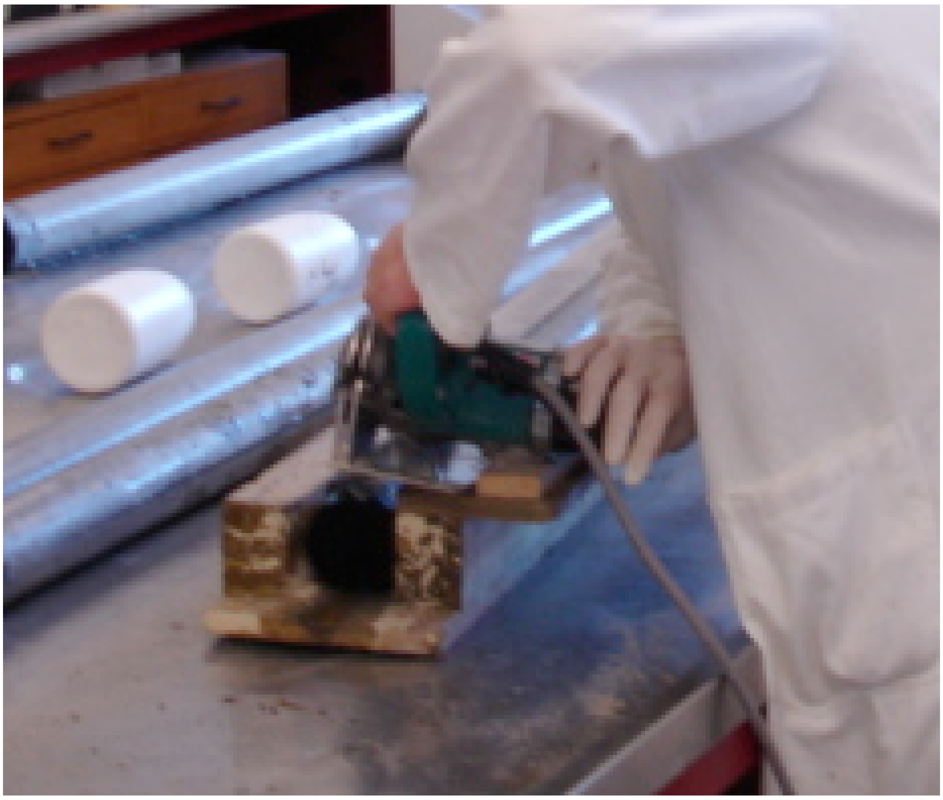

Figure 5.2: Cradle and saw adapted to section aluminium coring tube without penetrating into the core and therefore not disturbing the structural composition of the sediment.

Each core was divided into 10 mm increments, and each 10 mm sample was the weighed, dried for a period of 24 hours at 50°C, and ground with a pestle and mortar before being passed through a 500 μm sieve to remove excessive coarse material.

5.3.2 ^{210}Pb Dating

For each 10 mm interval of sediment core (over the entire length of each core) 20 g of air-dried sample was bagged and sent to the Department of Coastal Ocean Science, Nanjing University China for ^{210}Pb dating. The standard procedure for ^{210}Pb analysis was carried out to determine concentrations of radioisotopes using alpha ray spectrometry.

5.3.3 Heavy Metals

Reverse *aqua regia* (3 HNO_3:1 HCl) was used to digest the sediment in order to release the heavy metal elements present in the sample. One gram of dried sample was weighed into a 50 ml centrifuge tube, and 15 ml HNO_3 and 5 ml HCl reverse *aqua regia* was added. Samples were left to pre-digest over two nights with the lids loosely attached. The samples were then placed on a heated digestion block (50°C) for 3 hours. Samples were then cooled before being centrifuged for 15 minutes at 4000 rpm. For analysis by the Inductively Coupled Plasma – Mass Spectrometer (ICP-MS), a 0.5 ml sample was then pipetted into a 15 ml tube and diluted with 10 ml of deionised (type one) water.

Heavy metal concentrations of elements from the ICP-MS analysis had to be calculated from the amount of material that was digested and the dilution that was used for the preparation of the samples. The concentration of a given heavy metal element (C_{HM}) is equal to the ICP-MS measured result (M_{IPC}) (ug/ml) multiplied by the volume of solution prepared ($VS_{(total)}$) (ml) multiplied with the volume of *aqua regia* acid used for digestion ($AR_{(aqua\ regia)}$) (ml), divided by the portion of a solution used for acid digestion (V_A) (ml) divided by the unit weight of dried sediment (D_s) (g).

$$C_{HM} = M_{ICP} \times VS_{total} \times AR_{aqua-regia} / V_A / D_s \qquad \text{(Equation 5.4)}$$

Although over 40 heavy metals were analysed only the concentrations of Phosphorous, Lead, Iron, Copper, Zinc, Magnesium, Manganese and Cadmium were considered significant enough to have statistical analysis carried out. Statistical analysis (correspondence analysis) was conducted on heavy metal concentrations to determine whether normalisation was required.

5.3.4 Geochemical Normalisation

A combination of extrapolation and geochemical normalisation was chosen as the preferred methodology for normalisation of data to remove the effect of the grain size from skewing the results. The reason these methods were selected instead of the method of grain size fraction was because large samples are required for the separation of grain size methods, due to the need to save as much sample as possible for ^{210}Pb dating.

Extrapolation was conducted to determine the best conservative element for geochemical analysis. Extrapolation requires that a grain size percentage (in this instance the less than <53 μm) be calculated. Any grain size fraction associated with mud could be selected. Sub-samples were prepared for laser sizing to establish grain size variability. Sample preparation required the removal by digestion of all organic content from the sediment using hydrogen peroxide. Hydrogen peroxide was added in 10 ml increments daily, over a period of approximately one week, until reactive activity decreased. Samples were heated to 50°C on a hot plate (heating to increase the digestion process until chemical reactions ceased) which is the standard operating procedure carried out for marine sediment samples. Calgon was then added to each sample to prevent flocculation, and the samples were processed with the Waikato University Malvine laser sizer (see Appendix I for laser sizing results).

5.4 Results

This section presents the results for core stratigraphy, ^{210}Pb dating, heavy metal concentrations and statistical analysis, and geochemical normalisation.

5.4.1 Core Stratigraphy

Cores from sites A, C, D and E are dominated by fine sand. Unlike sites A, C and E, sites B and D are midstream and are subject to changing higher tidal flow velocities. Site B is further subjected to disturbances associated with the development of the Whitianga waterways canal. Hence, site B is subject to considerable re-suspension, resulting in much coarser sediment material than at sites A, C and E.

The A-site core became finer in the lower portion of the logged core and at 550 mm is banded with a coarser sand layer (Figure 5.3). The core collected from site C has a band of burnt wood found between 200 and 250 mm depth (Figure 5.4). At a depth of 500 mm a layer was located which contained traces of Kauri gum. Further down the core the sediment grain-size becomes coarser sand. Core D (Figure 5.5) contains a surface layer of brown sand and becomes finer at depth. This may indicate that this sediment has been deposited very quickly in an oxidising environment, indicating that Core D has a very high sedimentation rate owing to an influx of sediment from the catchment (i.e. flood deposit). However, considering the lack of organic matter present in this core, it may also indicate that the main channel has simply moved at this location (the core location is situated between two channels), resulting in redepositing of sediments. Sheffield et al. (1995) discuss a similar finding at Whangamata Harbour, and channel movement is given as the likely explanation. Below a depth of 700 mm this core becomes highly calcareous due to the large amount of broken shell debris. Core E (Figure 5.6) has a band of coarser sand between 400 and 600 mm. This layer also contains a layer of wood debris, indicating a large deposition event relating to a time of high catchment erosion. Bioturbation was not evident in any of the cores. Although not logged (as only 1 m of core was logged and examined), most cores showed a trend (such as that seen in Core D) where the lowest portion of the core became coarser and contained broken shell fragments. This layer varied in depth between sites.

All cores contain relic shell layers of the common cockle *Astrovenus stutchburyi*. This indicates that there have been periodic high sedimentation events where surface suspension feeders have been smothered. The relative consistence between cores of this shell bed being situated between 500 mm and 700 mm further supports this theory. One such explanation for this layer could relate to the 1960 tsunami generated in Chile, as it has been suggested that this event deposited large quantities of sediments at some locations within the estuary (Riddle, 1996).

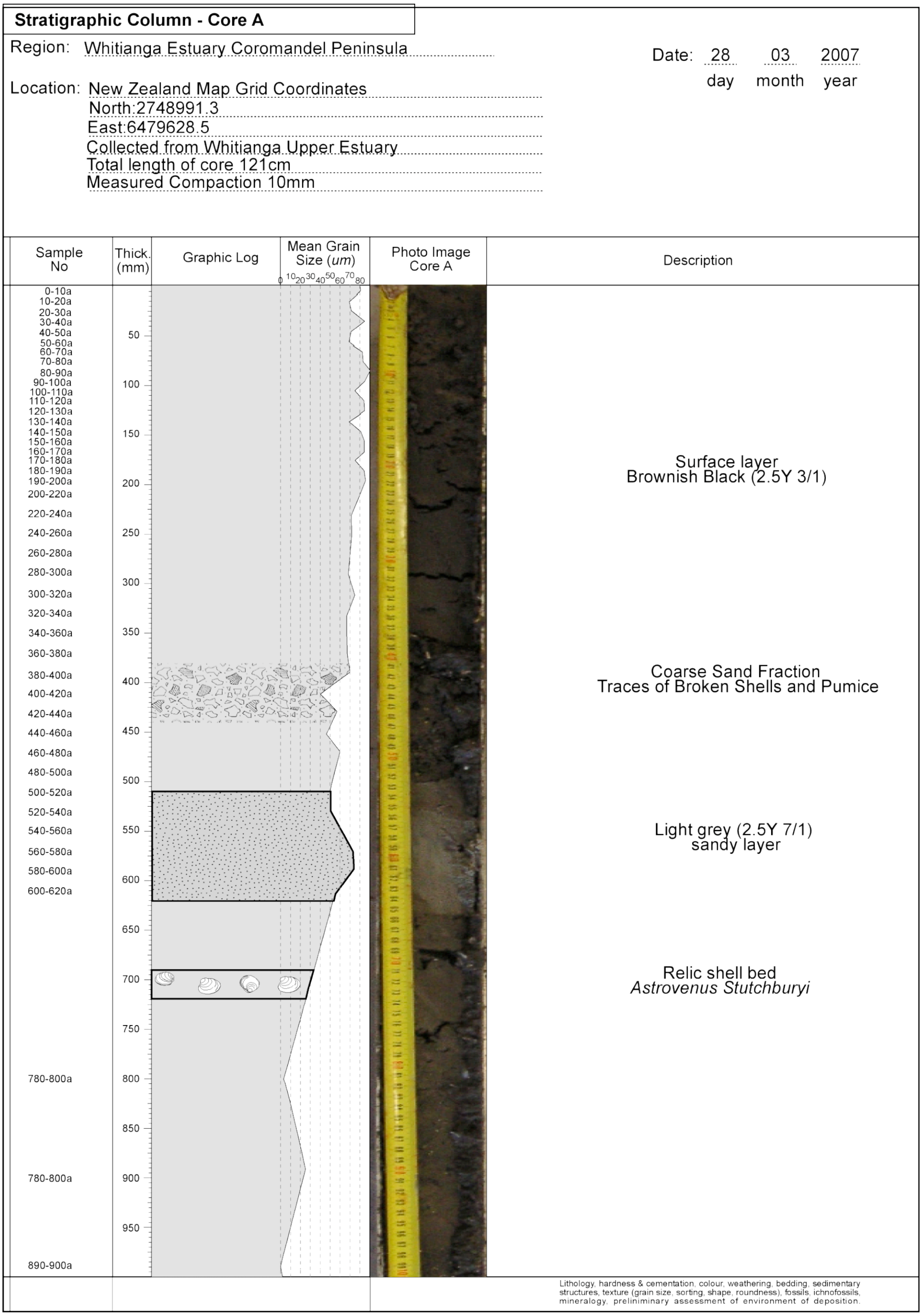

Figure 5.3: Stratigraphic column for Core A.

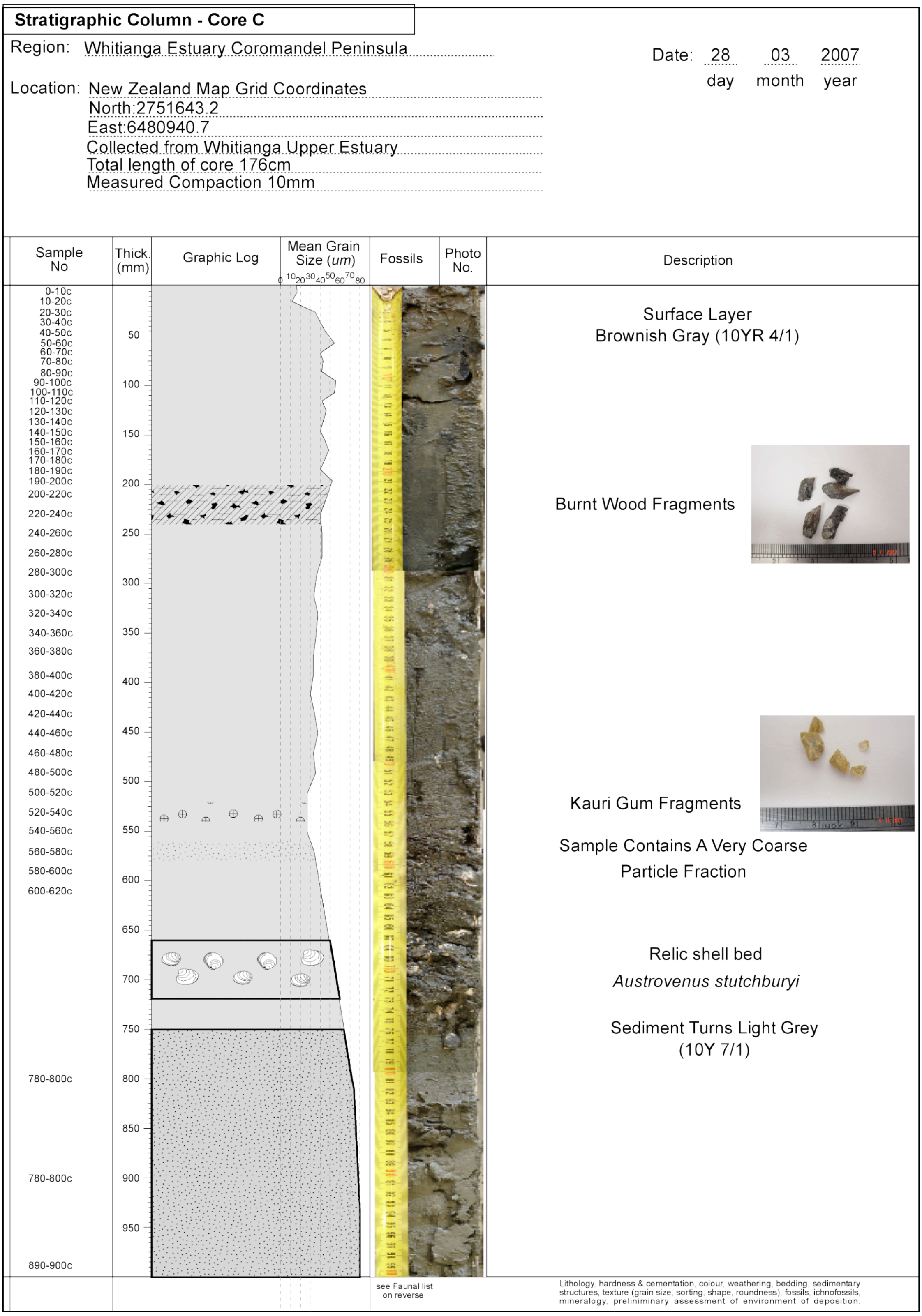

Figure 5.4: Stratigraphic column for Core C.

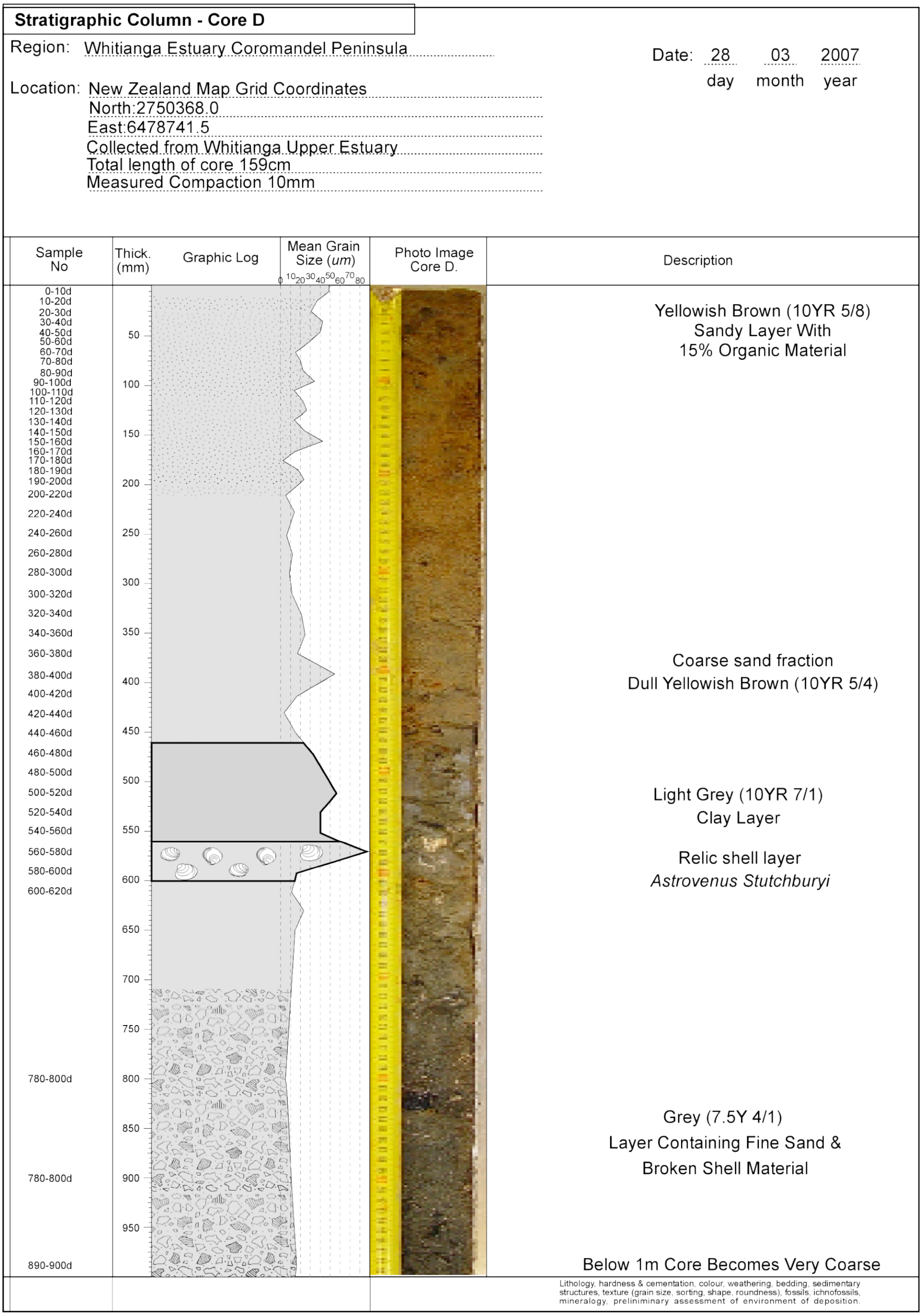

Figure 5.5: Stratigraphic column for Core D.

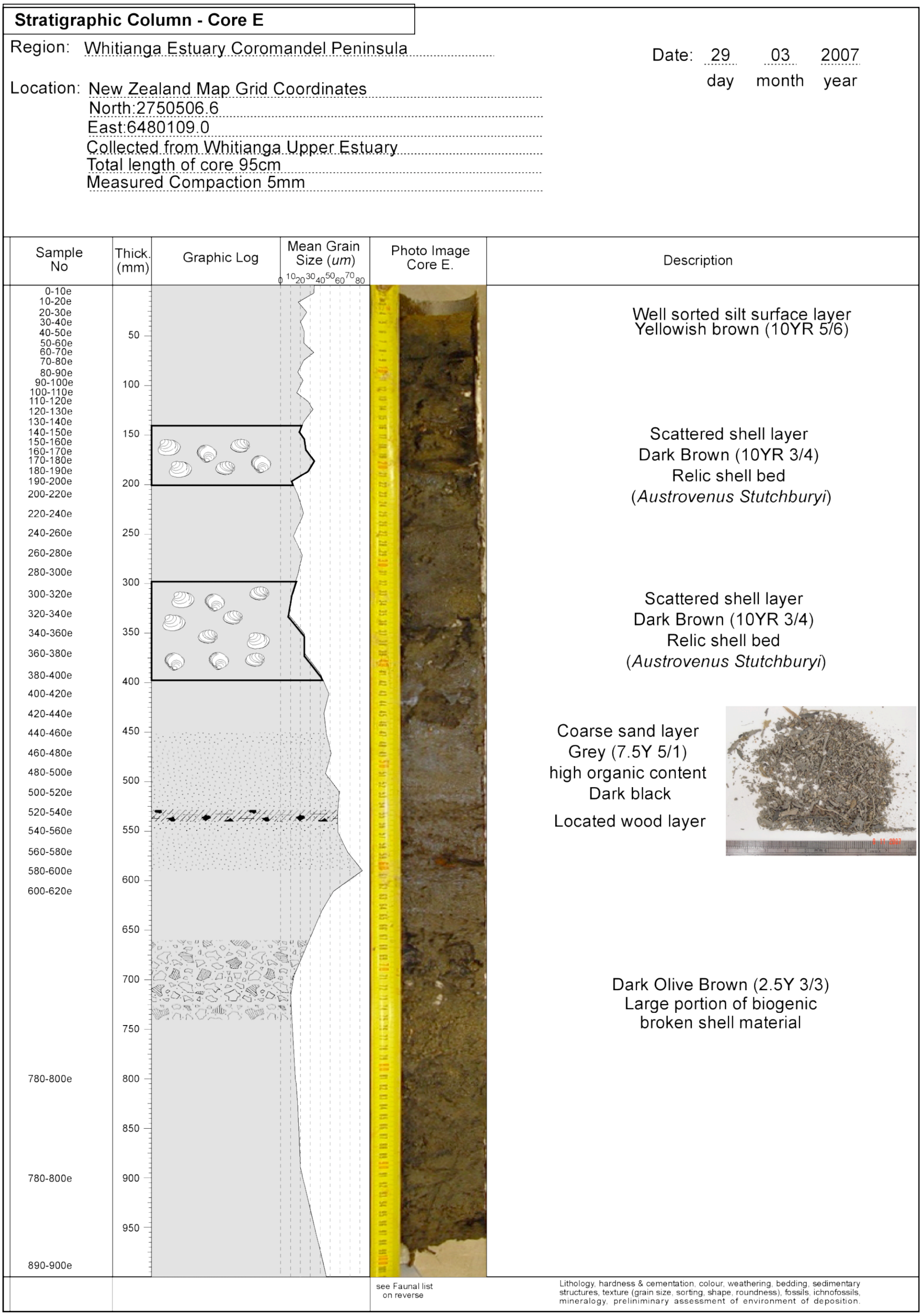

Figure 5.6: Stratigraphic column for Core E.

5.4.2 ^{210}Pb Dating

For sediment dating, ^{210}Pb concentrations are interpolated over 10 mm depth increments. Therefore, the calculated SAR can be made from a linear regression fit to the ^{210}Pb data. It can be seen that the accumulation rate for Core A is well described by the regression equation (r^2 = 0.82), showing that the recent upper SAR is 4.9±0.1 mm/yr (Figure 5.7). For the lower core section it can be seen that SARs are much higher with rates of 31 mm/yr being calculated (Figure 5.8). Core C has a recent sedimentation rate of 4.9 mm/yr (Figure 5.9). Unfortunately for this core there is not enough data for the lower section to determine a sedimentation rate. Sedimentation for Core D shows that the upper core rate is 8.2±01 mm/yr (Figure 5.10), while the lower core regression fit produces a sedimentation rate of 21.6 mm/yr (Figure 5.11). The upper sedimentation rate for Core E is 9.6±0.1 mm/yr (Figure 5.12), and the lower section can be seen to be 30.3 mm/yr (Figure 5.13). Overall, regression analysis for the ^{210}Pb is good with all r^2 values being very high (range = 0.72 to 0.96). Furthermore, the consistency in sedimentation rates between sites indicates that high confidence can be placed in the findings.

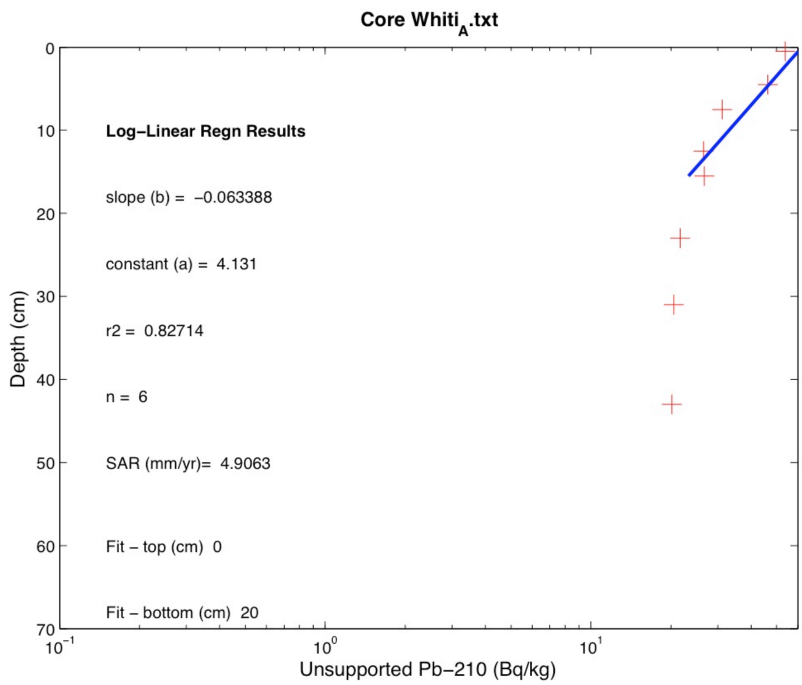

Figure 5.7: Plot of unsupported ^{210}Pb log linear regression fit (r^2=0.83) of sedimentation rates for the upper 20 cm of sediment at Core A.

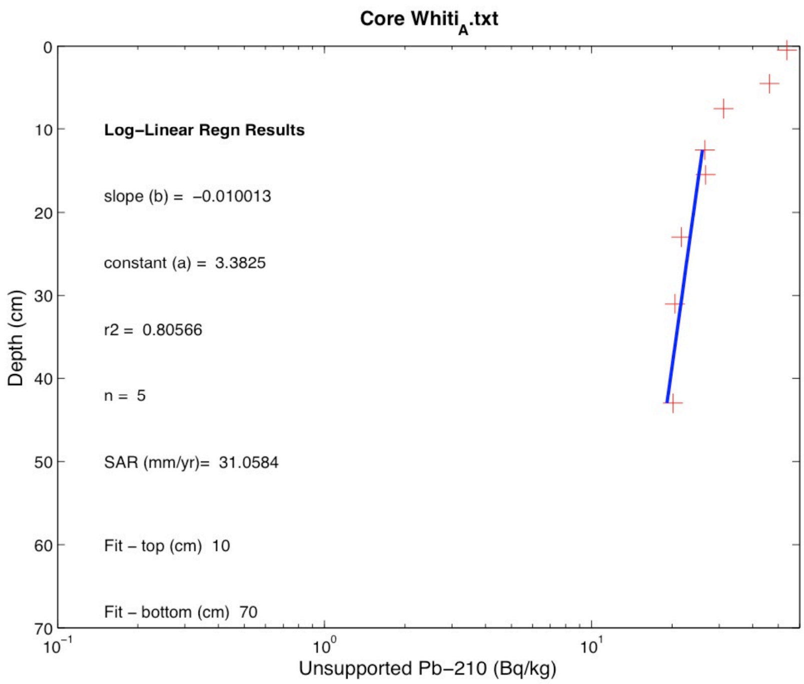

Figure 5.8: Plot of unsupported ^{210}Pb with a log linear regression fit of (r^2=0.81) for the lower section of Core A.

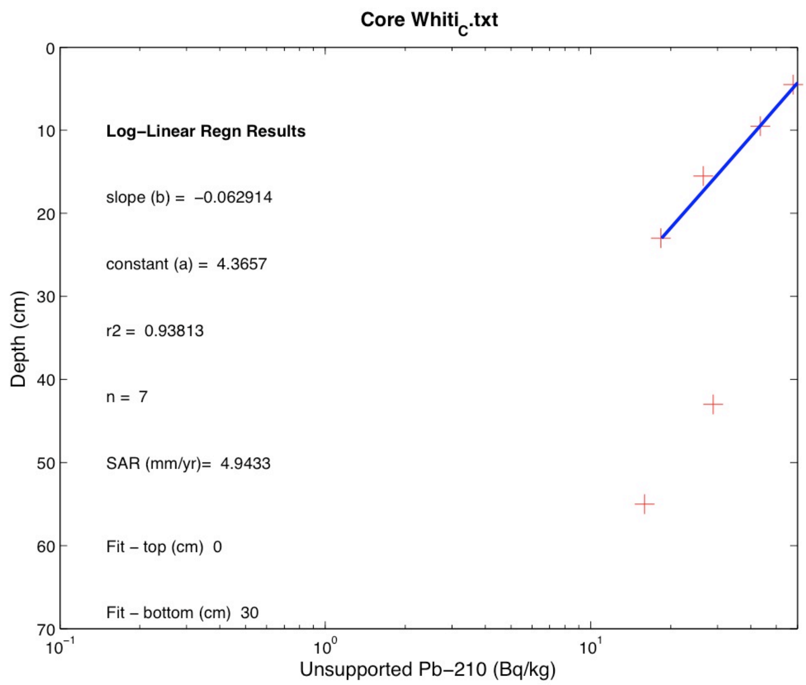

Figure 5.9: Plot of unsupported ^{210}Pb log linear regression fit (r^2=0.94) of sedimentation rates for the upper 20 cm of sediment at Core C.

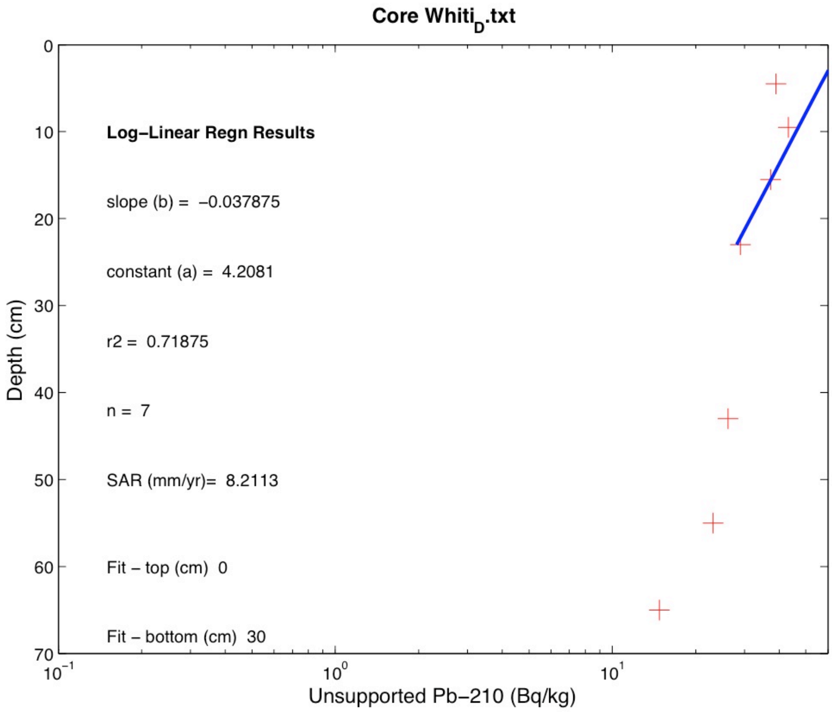

Figure 5.10: Plot of unsupported ^{210}Pb log linear regression fit (r^2=0.72) of sedimentation rates for the upper 20 cm of sediment at Core D.

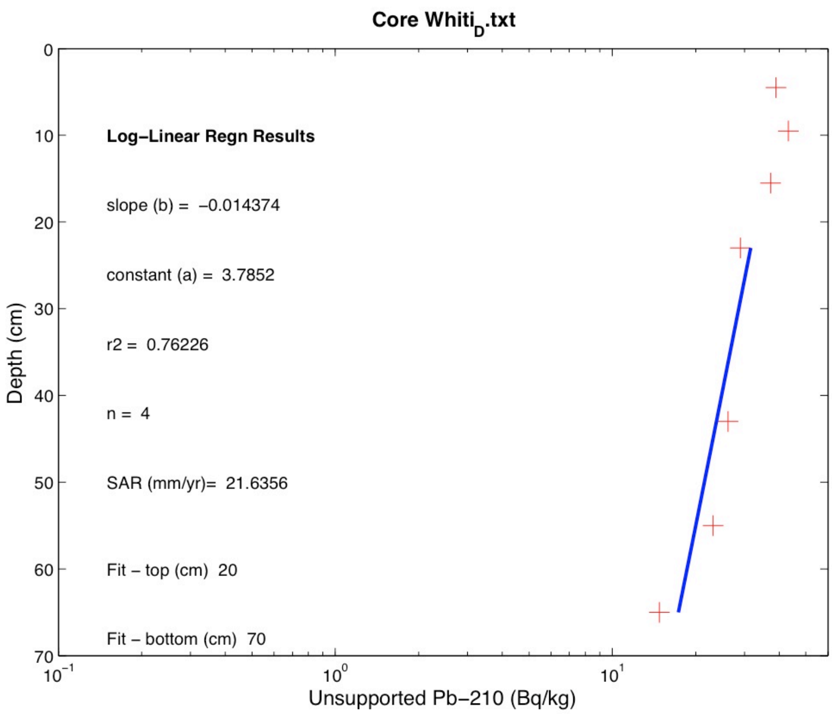

Figure 5.11: Figure 5.21: Plot of unsupported ^{210}Pb with a log linear regression fit of (r^2=0.76) for the lower section of Core D.

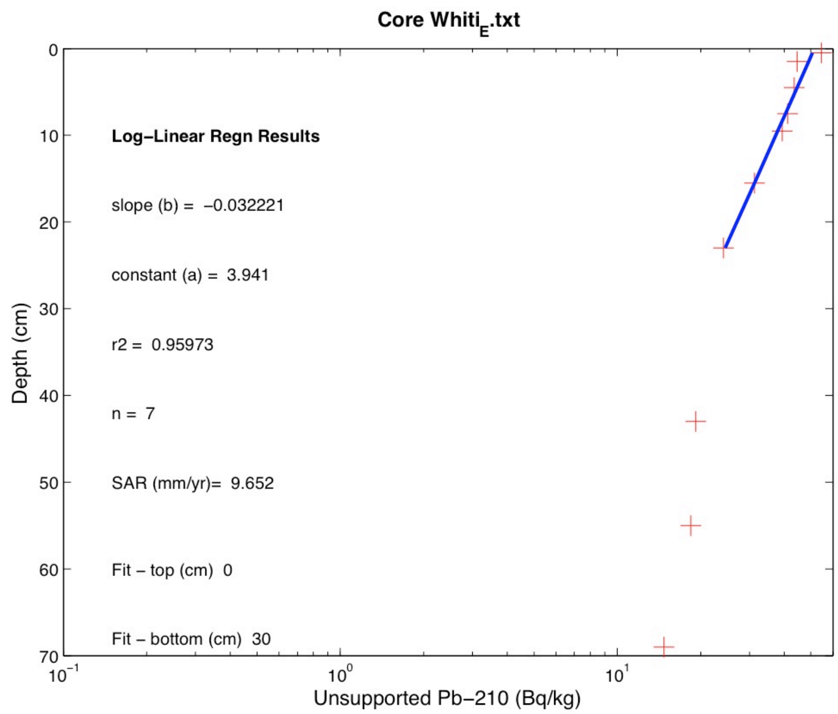

Figure 5.12: Plot of unsupported ^{210}Pb log linear regression fit (r^2=0.96) of sedimentation rates for the upper 20 cm of sediment at Core E.

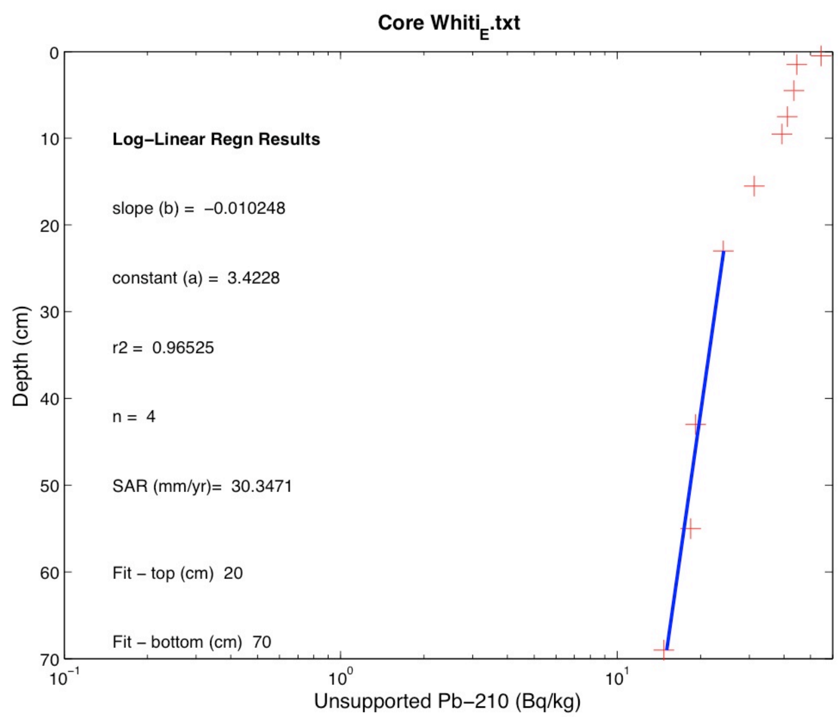

Figure 5.13: Plot of unsupported ^{210}Pb with a log linear regression fit of (r^2=0.96) for the lower section of Core E.

The results from the CIC model show that the recent sedimentation rates (top 20 cm) within Whitianga Estuary are calculated as high as 9.6 ± 0.2 mm/yr for the upper estuary (see Table 5.1).

Table 5.1 Results for accumulative sedimentation rates for all four cores collected.

Core	Sedimentation Rate (mm/yr)	Error ± (mm/yr)
Core A upper	4.9	0.21
Core C upper	4.9	0.1
Core D upper	8.2	0.11
Core E upper	9.6	0.12
Core A lower	31	0.21
Core C lower	N/A	N/A
Core D lower	21.6	0.08
Core E lower	30.3	0.11

5.4.3 Heavy Metals

Several methods of analysis were undertaken on the four selected sediment cores (Cores A, C, D, and E). Initially heavy metal concentrations were plotted against sediment grain size to determine whether grain size was promoting large variability in the heavy metal concentration (see Figures 5.14, 5.15, 5.16, 5.17; further graphs in Appendix II). The understanding for this section is that heavy metal concentration is correlated to grain size. It is well know that fine-grained sediments (such as clays and silt) tend to accumulate higher concentrations of heavy metals. However, the significance of this correlation is unknown for Whitianga sediments.

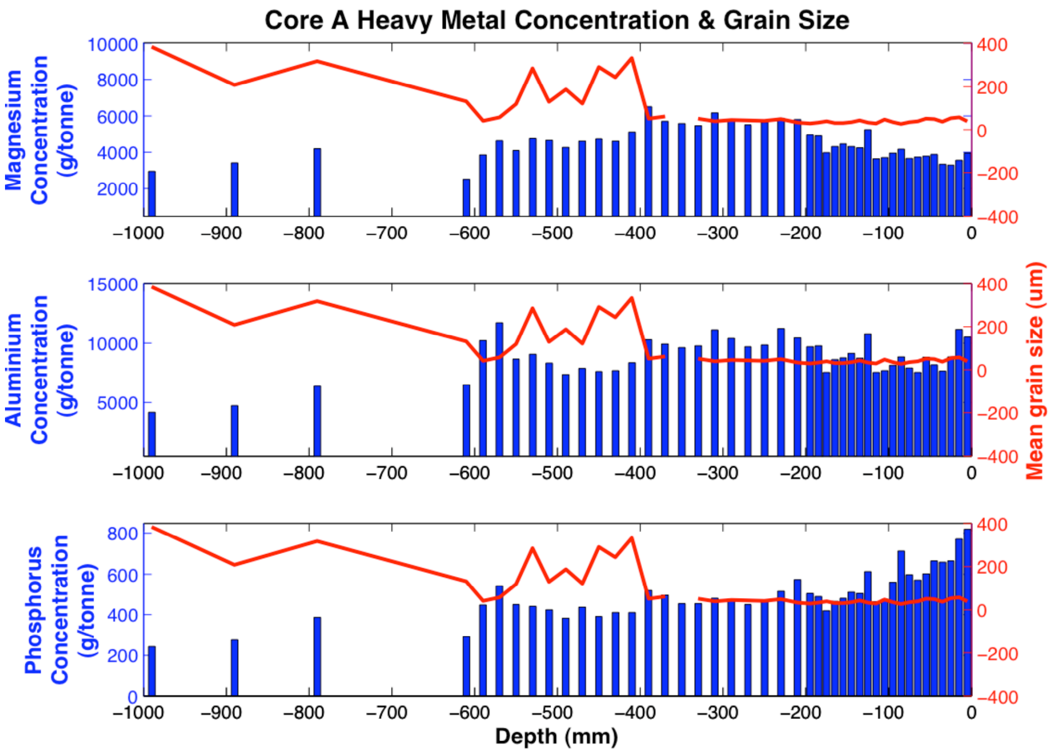

Figure 5.14: Example of heavy metal concentrations and grain size found at core site A. Graph shows the concentration of Magnesium, Aluminium and Phosphorus.

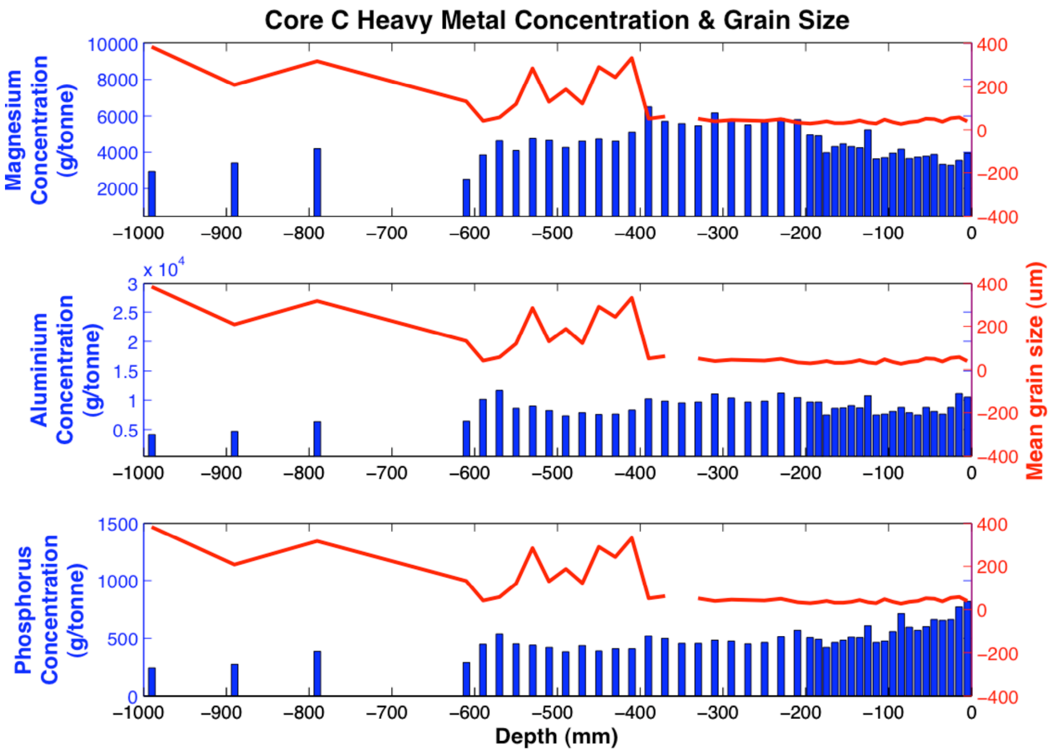

Figure 5.15: Example of heavy metal concentrations and grain size found at core site C. Graph shows the concentration of Magnesium, Aluminium and Phosphorus.

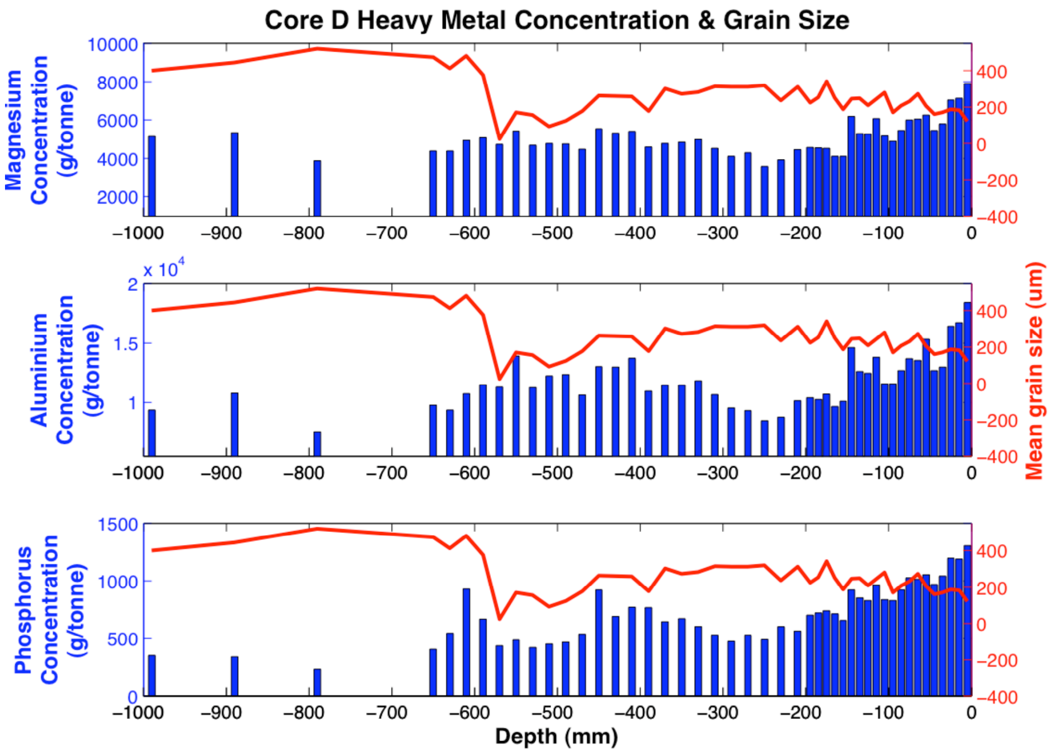

Figure 5.16: Example of heavy metal concentrations and grain size found at core site D. Graph shows the concentration of Magnesium, Aluminium and Phosphorus.

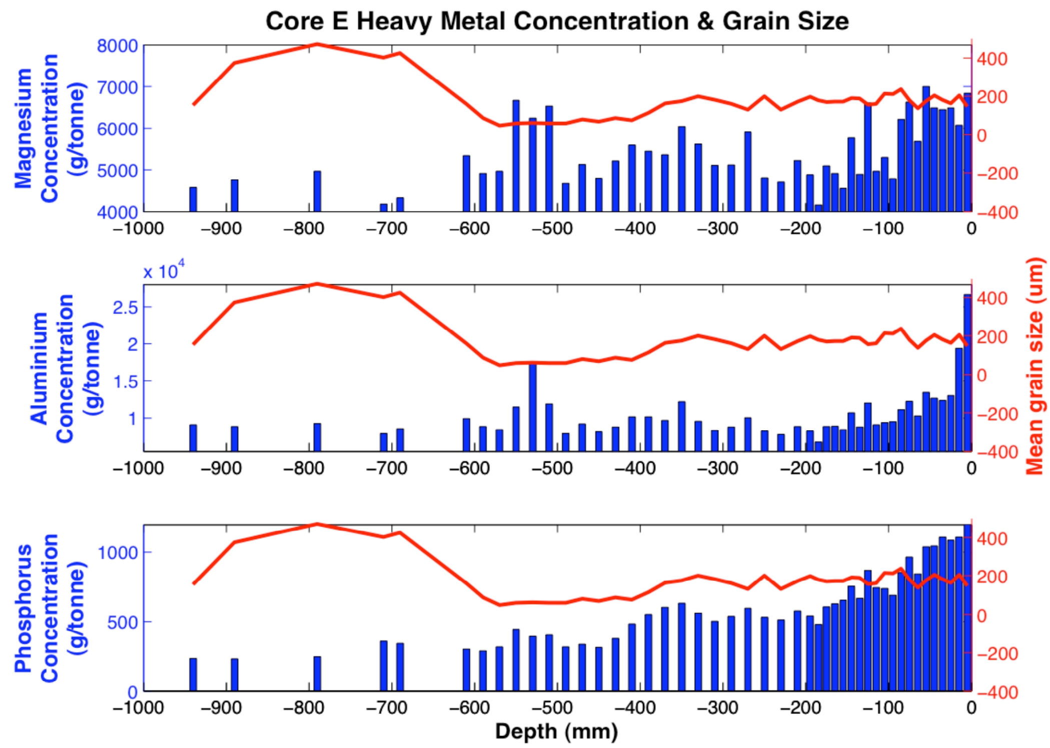

Figure 5.17: Example of heavy metal concentrations and grain size found at core site E. Graph shows the concentration of Magnesium, Aluminium and Phosphorus.

The above figures show that there appears to be some correlation between heavy metal and grain-size (as is expected because as grain size increases, heavy metal concentration decreases). Therefore, statistical analysis was required to determine to what extent grain size was having an effect. It is noteworthy that for all sites there is an increase in Phosphorus as depth decreases. This increase is clearly evident and is not an artefact of grain size.

5.4.3.1 Statistical Analysis

To determine the significance of correlation between grain size and heavy metals (also some organics), Correspondence Analysis (CA) (which is basically an analysis of covariance) was undertaken using the statistical software package XLSTAT (Townend, 2002). Due to the large amount of data collected from the cores, CA enabled vertical and spatial variation of heavy metal distributions to be evaluated.

Results shown in Figures 5.18 and 5.19 demonstrate a negative correlation between grain size and heavy metal concentration. Therefore, grain-size is a significant contributor to the variation seen in concentration within all cores sampled for heavy metal elements (see Table 5.2). This confirms the need to undertake normalisation. Tested was the null hypothesis that heavy metal concentrations are independent from grain sizes. Therefore, the alternative hypothesis is that there is a link between heavy metal concentrations and grain sizes. As the computed p-value is lower than the significance level (0.05) 95 %, one should reject the null hypothesis and accept the alternative (see Table 5.2).

Table 5.2: Test of independence between grain size and the heavy metal concentration.

Chi-square (Observed value)	474983.433
Chi-square (Critical value)	1838.156
DF	1740
p-value	< 0.0001
Alpha	0.05

Due to the variability in grain size from the four sampling locations, the resulting heavy metal data needed to be normalised for the grain size so that comparisons between sites could be made (Miserocchi et al., 2000). Grain sizes from different origins will vary in chemical concentration (Klamer et al., 1990). Therefore, sediment contaminant levels of different origins can only be compared when the data have been corrected for grain size effect (Klamer et al., 1990).

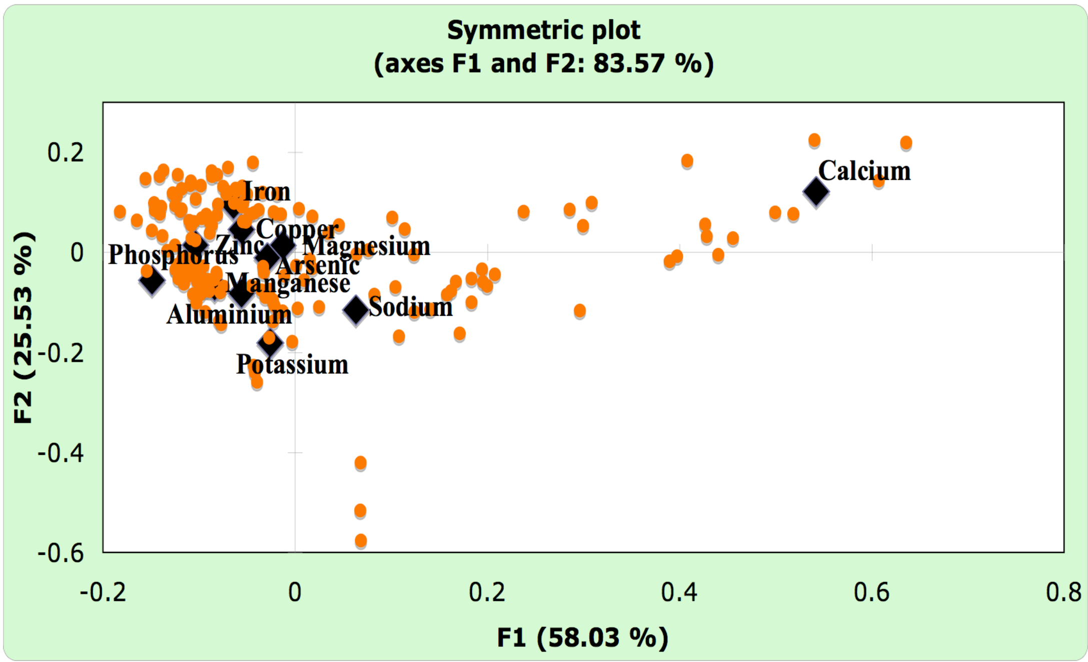

Figure 5.18: Symmetric Correspondence Analysis plot. Note that the clustered grain size concentration to the left of the F1 axis shows that there is a negative correlation between grain size and heavy metals. This concurs with most findings that as grain size decreases there is an increase in heavy metal concerntration. 58 % of the variation seen in the plot can be explained by the F1 axis. However, one exception to the rule is calcium which is correlated to larger grain sizes. This is to be expected as the larger grain size fractions are probably associated to broken shell fragments and therefore higher concentrations of calcium.

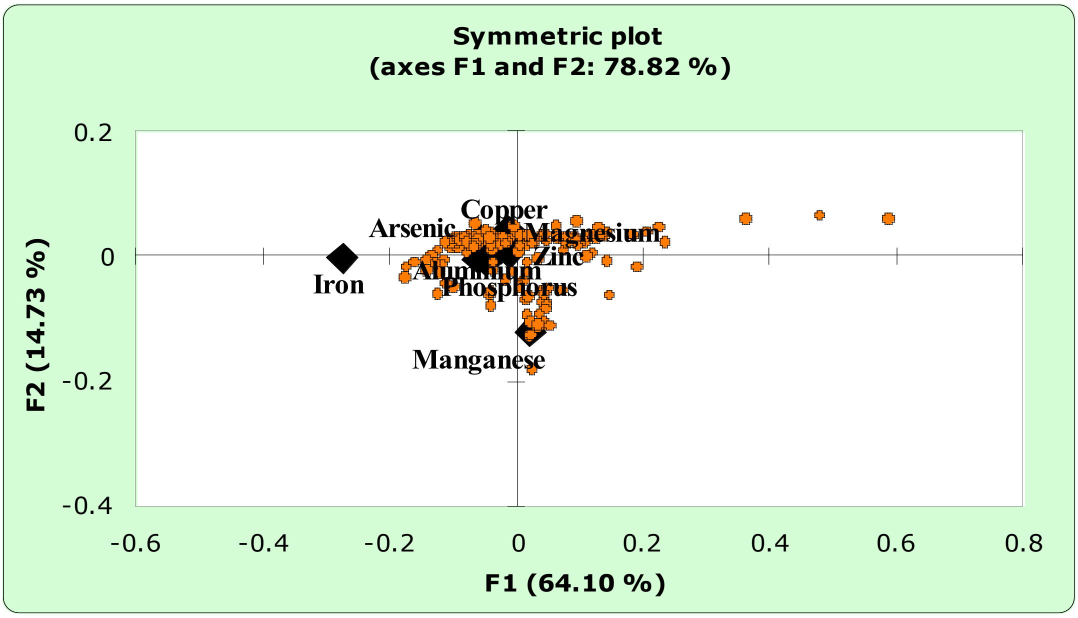

Figure 5.19: Symmetric Correspondence Analysis plot with calcium and sodium removed to make sure the results were not being skewed. Results are still good quality and there is still a negative relationship between grain size and heavy metal concentration.

The scree plot produced by XLSTAT (Figure 5.20) shows the quality of statistical analysis. F1 and F2 total 83.56 %. This indicates that the analysis is good quality.

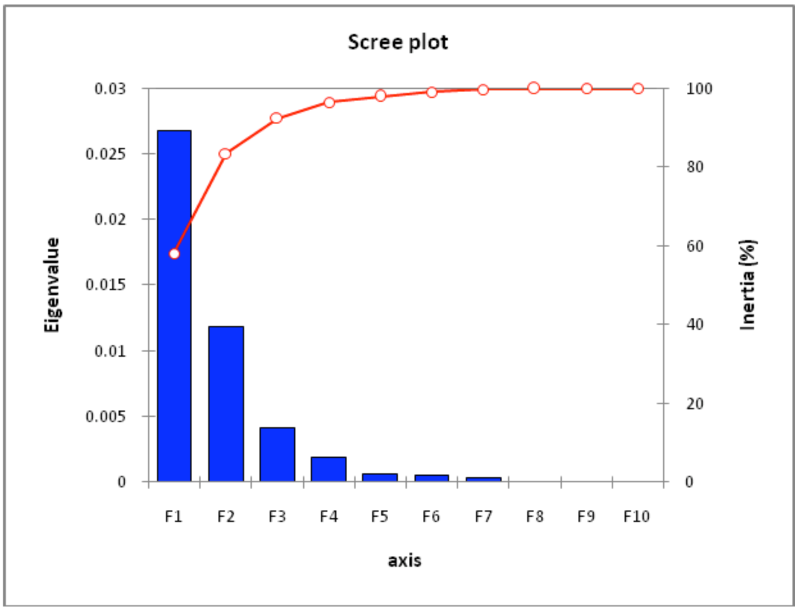

Figure 5.20: Scree plot showing the quality of analysis. Evaluation of the scree plot shows that the sum of the first two eigenvalues adds up to 83.566 % of the total. This indicates that the analysis is good quality.

5.4.3.2 Geochemical Normalisation

Lithium (Li) has the best regression fit, over Fe (iron), and Al (aluminium) when extrapolation to grain size fractions is undertaken (Figures 5.21, 5.22 & 5.23). The magnitude of the residual variances could be compared and the most effective normaliser (i.e. that which results in the lowest residual variance) selected. Regression fits shown by Fe or Al were not as good a fit as those shown by Li. Therefore, these were not used as conservative components (co-factor) for normalisation. Furthermore, Li was also a better proxy as it explained the coarse fraction better than the alternatives. Lithium was also found to be the best co-factor for geochemical normalisation by Loring (1991) and Kersten & Smedes (2002).

Although the calculated r^2 value for lithium was low which indicates that lithium did not explain all the variation in the data, high r^2 values were not expected as factors such as organic matter and mineralogy are not accounted for by the regression solution (Loring, 1991).

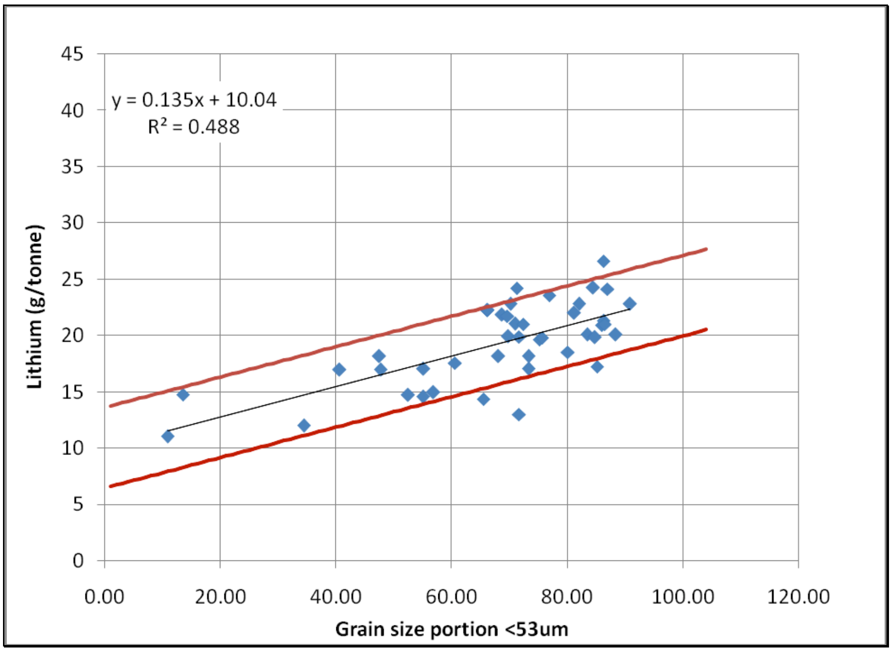

Figure 5.21: Grain size concentration less than <53 μm versus lithium for Core A. Although the r^2 value is only 0.488 when 95 % confidence intervals are added (as shown in red), much of the data is explained.

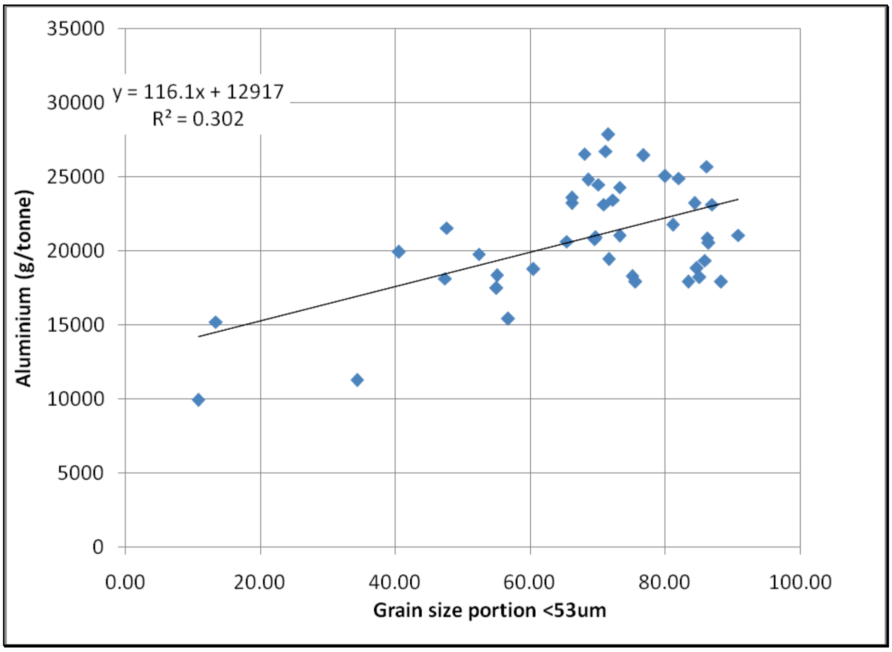

Figure 5.22: Concentration of Aluminium plotted against the fine fraction grain size portion <53 μm (fine silt to clay fraction of the sample collected).

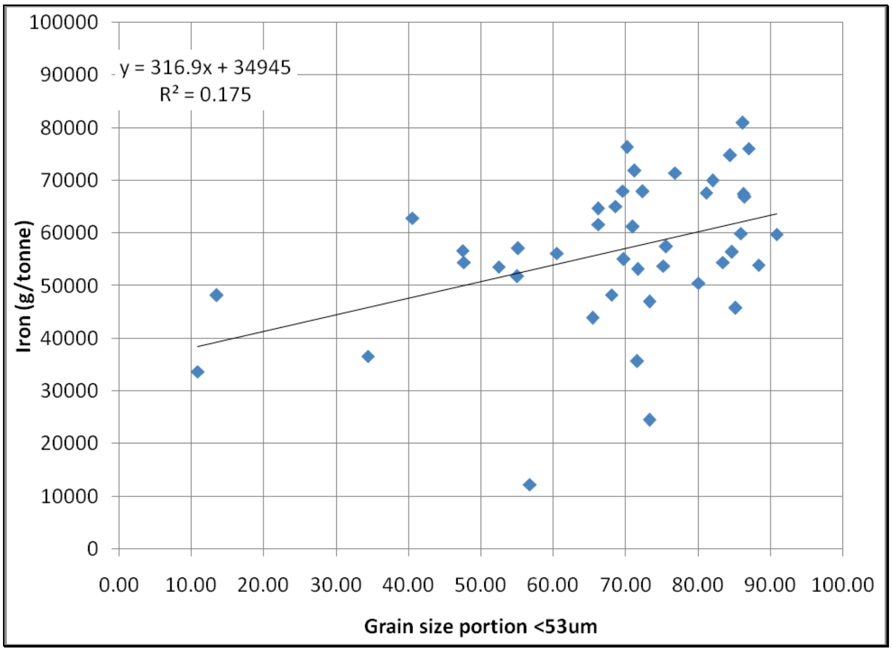

Figure 5.23: Concentration of Iron plotted against the fine fraction grain size portion <53 μm (fine silt to clay fraction of the sample collected).

As indicated above, the purpose of normalisation is to reduce the overall variance of a data set about any fitted trend, thereby increasing the statistical power of the analysis. To select the most appropriate normaliser for any series of temporal trend data for important elements Cd, Co, K or Pb, the concentrations of the contaminants of interest should be expressed as ratios to the concentrations of the co-factors (lithium). This should enable the comparison of sites by removing the associated heavy-metal effects.

When carrying out this analysis it became evident that the selected method of geochemical analysis did not work well for Whitianga. With the regression fits being so weak, no confidence could be placed in the results (see Figures 5.24 and 5.25). Furthermore, sites that clearly had the highest concentrations of heavy metals did not have the steepest regression lines as would be expected. Bearing this in mind, geochemical analysis methodology does not enable a way to compare heavy metal concentrations between sites. One interesting finding from this analysis is the fact that this methodology cannot be applied. The two possible reasons for the non-result are (i) complete digestion of sediment did not occur during the preparation of samples which resulted in not all of the heavy metals being released from the mineral lattice of the sediment; or (ii) the hydrothermally altered catchment rocks of the Coromandel have varying basement levels of the conservative elements.

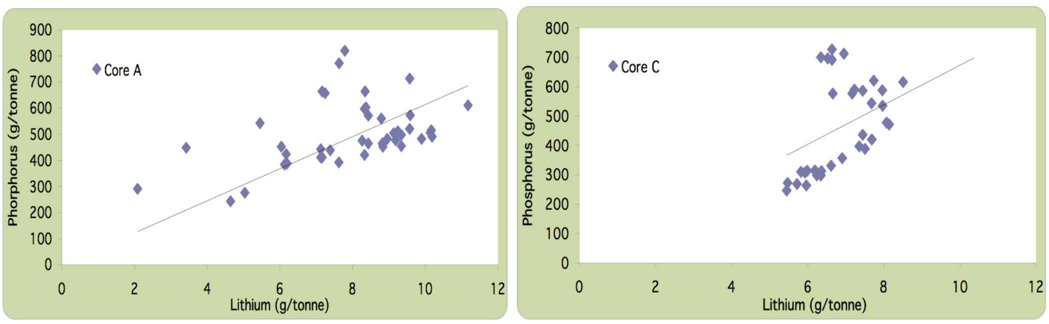

Figure 5.24: Geochemical analysis of Phosphorus for Core A and Core C. Note the weak regression fit.

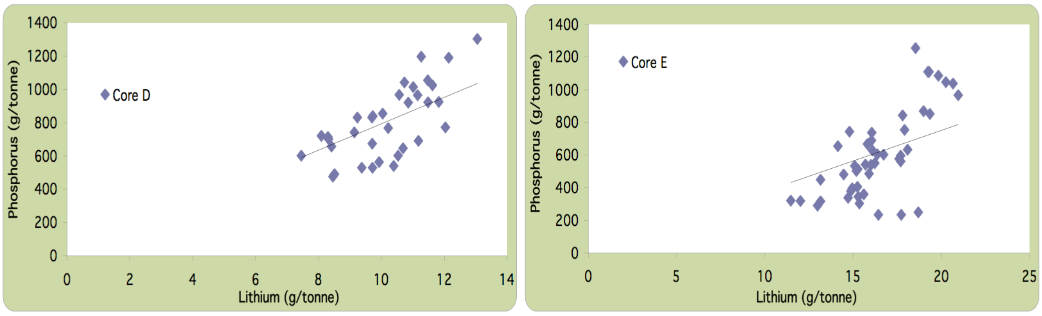

Figure 5.25: Geochemical analysis of Phosphorus for Core D and Core E. Note the weak regression fit.

5.4.4 Non Normalised Data Interpretation

By undertaking analysis of the initial ICP-MS heavy metal data (see Figure 5.26) some conclusions can be drawn. Due to the data not being normalised, comparisons between sites are not clear. Nevertheless, there is evidence to draw some conclusions and trends from the raw data.

Figure 5.26 shows that there is a strong relationship between Al, Fe and Mg. Cores A and C show no real changes in heavy metal concentrations. Therefore, it is safe to say that there are no real anthropogenic inputs effecting sediments in the upper estuary core locations. However, Figure 5.26 does show that concentrations of all measured heavy metals in cores D and E have increased. Given that grain size for the upper portions of cores D and E stay relatively regular it would be a safe assumption to make that there has been an increase in heavy metals for these sites. The close location of these cores to the Whitianga township means that one could assume these heavy metal inputs are storm-water and sewage inputs from the town. Figure 5.26 shows clear trends of increasing inorganic phosphorus in the sediment. However, in order to determine how much these heavy metal concentrations have increased over time, a measurement for background level is needed, and without normalisation this cannot be achieved. The consequence of this is that contamination levels are only qualitative and cannot be quantified.

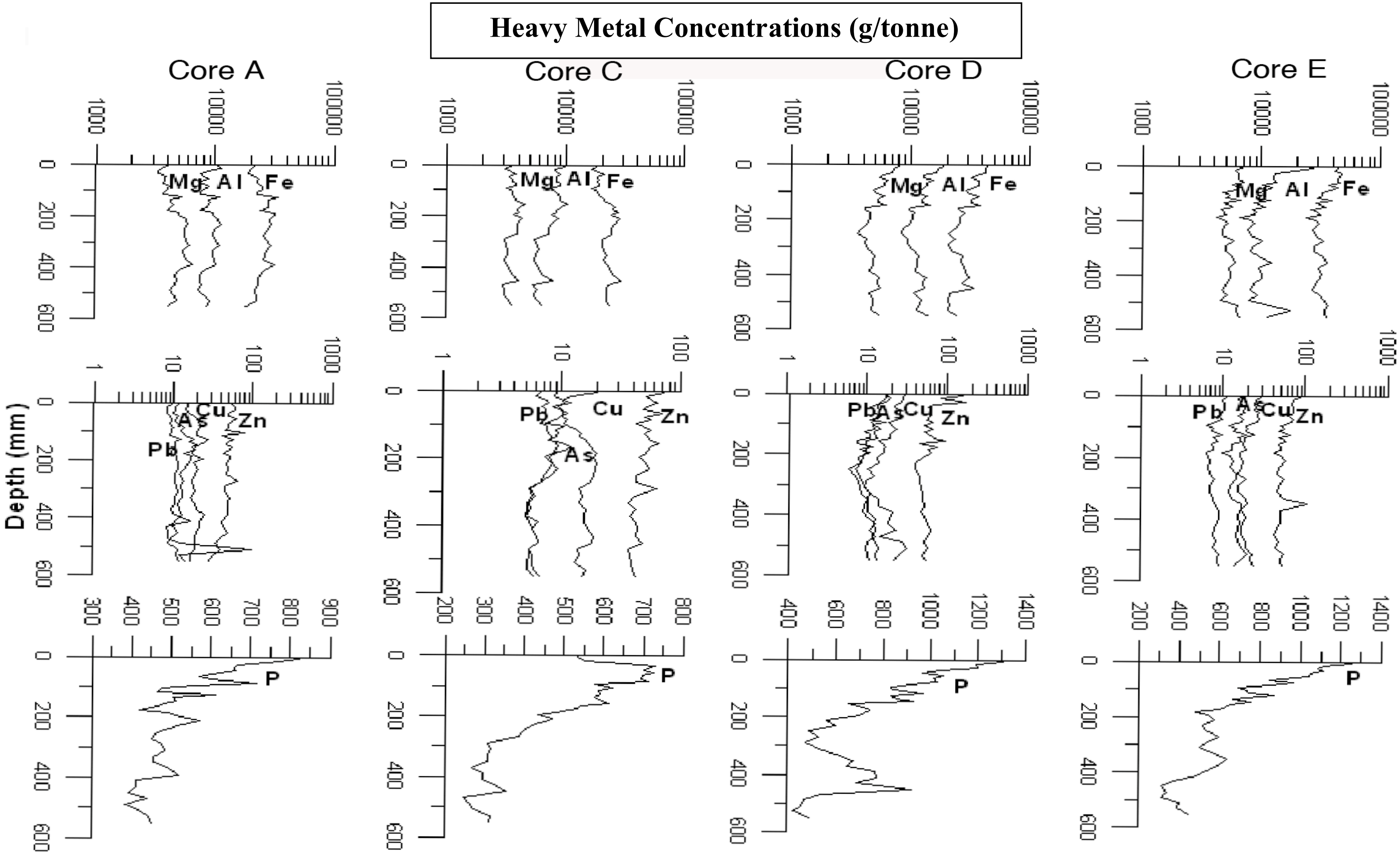

Figure 5.26: Vertical distributions of Heavy Metal concentrations. Note that Pb, As, Cu, Zn, Al, Fe, Mg are plotted on logarithmic axis. Fe, Al and Mg can be seen to have a correlated relationship.

The heavy metal concentrations shown in Figure 5.26 for sites D and E show an increase from 30 cm depth. This indicates 30 cm of sediment deposition has occurred since significant development commenced in Whitianga in the late 1930s (Sale, 1978).

If the assumption is made that sedimentation has been constant, an approximate accumulation rate can be calculated. This gives a sedimentation rate of 4.5 mm/yr (based on a late 1930s peak development). However, no key heavy metal concentrations (such as peaks in lead concentration) are evident so dating is only an approximate measure, meaning the confidence in results significantly reduces.

5.5 Discussion

One of the key impacts on the estuary morphologic evolution is the rate of sedimentation and infilling. This creates ongoing impacts to development including problems relating to navigation within the estuary.

At Whitianga there have been several periods of large-scale land cover changes (as discussed in chapter 3) that have resulted in substantial sedimentation rates. Findings by (McGlone, 1988) using pollen analysis put the sedimentation rate in Whitianga Estuary at 1 mm/yr up until the 1950s. However, after this period the sedimentation rate is suspected to be more likely 10 times this level due to the large-scale changes in land use activities. McGlone (1988) explains that the abrupt changes in pollen horizons enable relatively accurate dating. However, after the 1950s this dating became difficult and dating could be only estimated, due to pollen horizons becoming unclear due to mixed pollen inputs.

Unfortunately, ^{137}Cs was not detected in Whitianga Estuary. Therefore, it was not possible to use ^{137}Cs to support the findings from the ^{210}Pb dating results. Pfitzner et al. (2004) suggest that due to there being a much smaller quantity of ^{137}Cs deposited in the southern hemisphere (121 PBq (petabecquerels) up until 2002) compared to that of the northern hemisphere (393 PBq up until 2002), and the lack of an easily distinguishable peak that corresponds to the atmospheric testing undertaken in the 1960s, the use of ^{137}Cs as a sedimentary marker is limited.

The sedimentation rate is calculated by applying the CIC regression model to ^{210}Pb dating results (Benoit et al., 1999). Findings show sedimentation rates within Whitianga advocate that the current change in recent land use changes to exotic forest (from pasture) has reduced sedimentation rates to around 5 - 9 mm/yr. However, past deforestation effects are clearly evident with very high sedimentation rates being calculated for the lower core sections (between 21 - 30 mm/yr). Due to lack of data to support and constrain CIC regression model, such as ^{137}Cs or an alternative dating method, depth age curves could not be calculated for the sediment profiles. However, it can be seen that there has been a reduction in sedimentation rates at 20 - 25 cm depth in all of the profiles. These date to approximately the 1950s - 60s. Therefore, it can be said that the high sedimentation rates of 21 - 30 mm/yr are pre 1960. This fits well with deforestation occurring in the catchment up until the mid 20th century.

Although there has been a significant reduction in sedimentation, the current finding of between 5 and 9 mm/yr is still a high infilling rate, compared to the average infilling rates of 2 - 4 mm/yr post 1990 for North Island estuaries (Swales et al., 2005). Results show that the past assessment for sedimentation rates (of 1 mm/yr) by McGlone (1988) may have underestimated sedimentation rates. However, it is worth noting that McGlone (1988) suggested that rates after the 1950s could be as much as 10 times his initial findings. ^{210}Pb results for the lower core indicate rates as high as 21 - 30 mm/yr may have occurred in the past. Confidence can be placed due to the agreement between sites with SAR being consistent, (Swales, pers comm. 2007). Furthermore, the non-normalised heavy metal concentrations imply that sedimentation rates are around 4.5 mm/yr, which compares well with ^{210}Pb dating results. However, some study limitations should be considered, as there is some uncertainty in calculating SAR from sediment cores. For example, processes such as wave-driven sediment transport and bioturbation can resuspend sediments and deposit them in different locations which can result in the over estimation of SAR (Swales et al., 2005).

Sedimentation rates calculated for Whitianga Estuary agree well with findings from other Coromandel estuaries such as those recorded by Hume & Gibb (1987) for Tairua Estuary, Hume & Dahm (1992) for Coromandel Harbour, and Sheffield et al. (1995) for Whangamata Harbour. Recorded sedimentation rates for Whangamata show considerable variation for the different environments within the estuary. Sheffield recorded maximum results of 19.8 mm/yr. These findings are thought to be an overestimate due to channel migration (Sheffield et al., 1995). However, if these overestimated results are disregarded and other core results are used for this estuary, then findings of SAR are 6.6 – 11 mm/yr at Whangamata (Sheffield et al., 1995). Previous SAR findings of 6 mm/yr at Tairua (Hume & Gibb, 1987), 0.3 - 11 mm/yr at Coromandel Harbour (Hume & Dahm, 1992), and 6.6 - 11 mm/yr at Whangamata (Sheffield et al., 1995), can be seen to compare well to findings of the present study of 5 - 9 mm/yr at Whitianga Estuary (Table 5.3).

Table 5.3. Estuarine sedimentation rates in an assortment of North Island estuaries. Source: Hume & Gibb (1987); Hume & Dahm (1992); Sheffield et al. (1995); Mead & Moores (2005); and Swales et al. (2005).

Location	Type of analysis	Time Interval	Sedimentation Rates (mm/yr)
Whitianga	^{210}Pb, Heavy Metals	1950-2007	5 - 9
Manukau	Carbon, ^{210}Pb, Pollen	110BP-1988	0.4 – 5.7
Tairua	Wood layer	1933-1984	6
Whangamata Harbour	Pollen, Carbon	1940-1990	6.6 – 11 (19.8 max)
Firth of Thames	Carbon, ^{210}Pb, Pollen	1840-1984	0.5 – 1.5
Whangapoua Harbour	Carbon, ^{210}Pb, Pollen	?	0.9 – 1.3
Coromandel Harbour	Carbon, ^{210}Pb, Pollen	?	0.3 – 11.7
Whaingaroa (Raglan) Harbour	Carbon, ^{210}Pb, Pollen	post-1990	2.5 – 8

Grain size has a significant effect on the concentration of trace metals found in sediments at Whitianga. Heavy metal dating methods proved inconclusive and geochemical analysis proved to be ineffective in Coromandel sediments. It is unclear why geochemical normalisation would not work with Whitianga sediments. The two most likely reasons for this methodology failing to achieve a usable outcome are (i) complete digestion of sediment did not occur; or (ii) there are varying background levels of the conservative elements. Research undertaken by Mangan (2007), investigated which minerals within Rotorua lake sediments are responsible for the retention of phosphorus. As part of this work, extractions using different reagents were undertaken to determine the effectiveness of these reagents in getting total digestion. It was found that Aqua Regia was very efficient in extracting all aspects of chemicals bound to the mineral lattice that make up the clay particles found in Lake Rotorua. Therefore, it is more feasible that the reason the geochemical normalisation methodology did not work is because of a variability of heavy metal elements in the catchment rocks of the Coromandel.

Heavy metal results do show that there has been an increase in heavy metal concentrations in the sediments at sites D and E. This corresponds to the areas closest to development. The highest trace metal concentrations were found in surficial sediments collected near polluting sources. Zn is the most concentrated anthropogenic metal found at each site and is considered as a tracer of the dispersion of waste effluents (Bellucci et al., 2005). This is most likely due to the occasional release of treated sewage. The Whitianga wastewater plant is located on Moewai Road to the west of Whitianga Township. The treatment process consists of an aerated pond followed by a retention/maturation pond. Treated wastewater is disposed of via two consented methods. Part of the treated effluent is disposed via spray irrigation to a block of eucalyptus trees, while the remainder is discharged to the Ngarahutunoa Stream. However, during peak summer loads the Whitianga plant (which requires upgrading) reaches capacity for the increasing residential and holiday population (Thames District Council, 2007b). Therefore, a large portion of wastewater is released into the smaller sub estuary in the north. This is likely to be a major factor contributing to the high levels of heavy metals found in the sediment cores.

5.6 Conclusion

Key findings of the present study show evidence of significant sediment accumulation in the upper estuary of Whitianga for at least the last 150 years. This time period coincides with European settlement of the area and past large-scale environmental changes to the estuary and surrounding catchment. It has been shown in many studies of North Island estuaries that catchment deforestation is responsible for substantially increased sediment loads and infilling (Hume & McGlone, 1986; Hume & Gibb, 1987; Hume & Dahm, 1992; Sheffield et al., 1995; Mead & Moore, 2005; Swales et al., 2005).

Unsupported ^{210}Pb concentrations show good consistencies between sites and high regression relationships (range = 0.72 to 0.96). Therefore, confidence in results is high. ^{210}Pb results indicate that sedimentation rates for the uppermost sediment layers (200 – 300 mm) have an SAR of 5 – 9 mm/yr. This can be attributed to post 1950 activities occurring within the catchment. Below 300 mm, SARs were calculated to between 21 – 30 mm/yr suggesting that pre 1950s catchment activities resulted in significant sediment inputs to the estuary.

Heavy metal findings show that concentrations can be seen to have increased from a depth of approximately 250 – 300 mm, which relates to a period of development in the area. Heavy metal results suggest that cores closest to Whitianga Township have sedimentation rates of 4.5 mm/yr. This provides some evidence to support ^{210}Pb results for the upper portion of the core.

CHAPTER SIX: NUMERICAL MODELLING

6.0 Introduction

The ability to numerically simulate estuarine hydrodynamics has large economic and ecological importance for the management and development of estuaries (Whitehouse et al, 2000). Suspended sediment supplied to an estuary enters an astonishingly complicated environment, where a complete understanding is still far from being understood (Nichols, 1984). At present numerical simulations do not allow a complete understanding of the processes that are occurring. However, to date numerical simulation has proven to be the best method for understanding sediment transport and hydrodynamics over large spatial areas. The interaction of many processes within estuaries can result in features such as density currents, turbidity maxima, lutoclines and many others (Toorman, 2001). Although it is nearly impossible to reproduce the complicated array of processes that develop in an estuary because such phenomena result from the fluxes and forces that occur in estuaries (Toorman, 2001), models are invaluable in management applications, as they can be simplified to visually show answers to socio-economic objectives (Williams, 2006).

This chapter presents the large-scale hydrodynamic modelling of Whitianga Estuary including model calibration results, and assesses sediment transport pathways and circulation patterns obtained from the calibrated hydrodynamic model.

6.1 3DD Numerical Simulations

The 3DD model uses an explicit, finite difference scheme to solve the momentum and continuity equations (Black, 1995). The model has the ability to be able to be either a two or three-dimensional Cartesian grid format. However, three-dimensional grids are only necessary where there is a need to resolve in the third dimension for factors such as a thermocline, density differences, or salinity changes. Celerity temperature density (CTD) meter casts undertaken within the estuary show that the shallow nature of the upper estuary results in complete mixing. Also the high current velocities and the constrained nature of the inlet create turbulence, which results in no stratification within Whitianga Estuary. The salinity front occurs in Mercury Bay (refer to Chapter 4). Therefore, a two-dimensional grid is used for modelling Whitianga Estuary.

The 3DD model was set up to solve the two-dimensional hydrodynamic equations for nearly horizontal flow. All hydrodynamic models solve some form of the Navier-Stokes equations, or more accurately the Reynolds-average equations (Williams, 2006).

Black (1983) found that an explicit solving scheme formulation for the algorithms behind the model proved to be ideal for shallow water and tidal inlets, hence ideal for the conditions within Whitianga Estuary. Explicit schemes such as that of 3DD basically solve the algorithms one at a time. A value for a certain grid point is calculated only from a known value at another point. Therefore, it only treats one equation at a time. This increases computational time but also increases accuracy. Furthermore, implicit schemes can prove to be unstable if the stability criteria are not met. Implicit solving schemes work by solving a set of simultaneous equations. Therefore, often the values inputted can be unknown. The benefits of implicit models are that the computational times are greatly reduced. However, there is a trade-off for accuracy (Ramming & Kowalik, 1980).

6.2 Boundary Conditions

Four boundary conditions were required to force the coarse scale bathymetric 20 m model grid. These boundaries consisted of three major river discharges (inputted as perpendicular flow) and a water level elevation for the outer harbour boundary.

Open tidally forced boundary conditions were determined using a time series of water level elevations recorded at the boundary by an S4 current meter **(A)** (Figure 6.1). Inflow boundary conditions included the input of the three major rivers entering the upper estuary. These rivers are the Whangamomo **(B)**, Whenakite **(C)**, and Waiwawa **(D)** (Figure 6.1). Inputs for these rivers were calculated from measurements collected by Environment Waikato from tributaries of the catchment. Using correlation from flow data at sites and comparable catchment sizes, a time series could then be calculated (Brown, pers comm. 2007).

Initial model results showed relatively poor calibration at the outer forcing boundary, and root mean square error measurements showed large errors. This is due to there being a significant phase difference in the tide. Cooper (2003) found the tide to rotate around Mercury Bay in a clockwise direction with tide entering to the east and exiting in the north-east. This caused a phase difference at the boundary. Tidal phase analysis was carried out to determine the propagation time for the tide in Mercury Bay, to create a phase varying boundary for the purpose of forcing the model. The two S4 current meters located off Shakepeare Cliff and Wharekaho beach were used to calculate a phase difference for Boundary **A** (Figure 6.1). Once the phase was calculated an interpolated boundary file was created for the 3DD model suite.

$$Pd = \frac{(phase1 - phase2)}{360}T \qquad \text{(Equation 6.1)}$$

Equation 6.1 shows the calculation, where Phase 1 is the phase of the predominant tidal constituent/s at location 1, Phase 2 is the phase at location 2, and T is the dominant tidal period/s. As a result a 2-minute phase lag between the sites is calculated. Taking this into consideration using the DHI (Mike 21) software, an interpretation across the boundary was undertaken, creating a forcing file for each individual boundary cell in 3DD. This allows for the model to better predict circulation that occurs in Mercury Bay.

20 m Bathymetric Model Grid & Model Forcing Boundaries

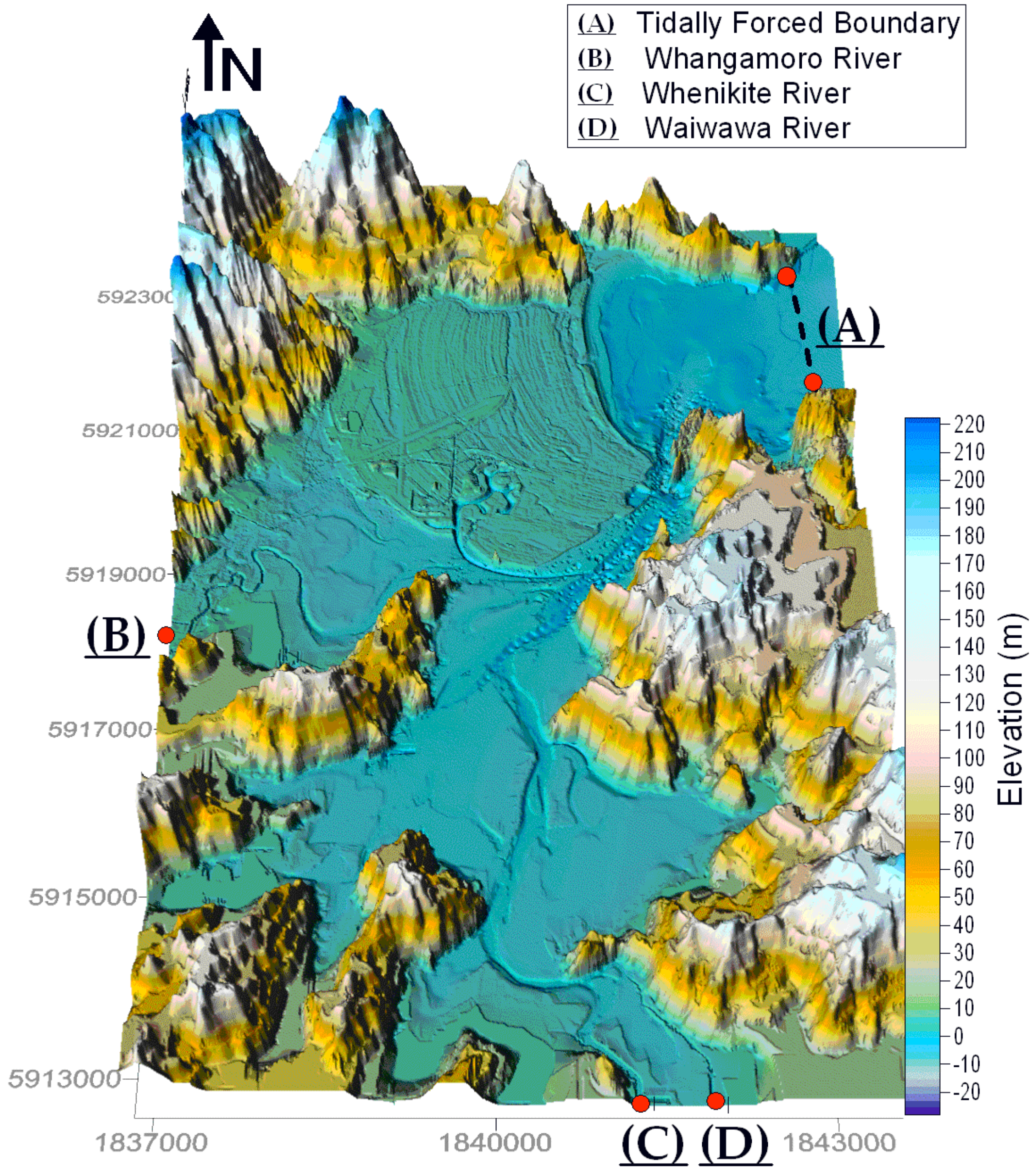

Figure 6.1: Digital terrain model of the 20 m bathymetric grid. The forcing boundaries that were used for the 3DD model application are illustrated as (A), (B), (C) and (D). Note: image has a vertical exaggeration of 5X.

6.3 Meteorological Data

Meteorological data such as rainfall, wind speed and direction, and air pressure are variables that can be inputted into the 3DD model for accurate resolving of model results. Air pressure and rainfall data were retrieved from the Whitianga Airstrip monitoring station and inputted in the model. However, wind speed and direction data are only collected from Slipper Island, which is located several miles from Whitianga. Due to the sheltered nature of this estuary this data did not seem appropriate to apply to the forcing conditions of the model, and therefore was not used. Reports published by Wilkins & Davies Group (1986) for the establishment of Whitianga Marina show that the predominant wind direction that could enter the estuary is from the northeast and southwest (0-30 degrees and 150-200 degrees). However, they do state that the calculated wind velocities measured offshore for their study would be significantly higher than those measured at the shore. Furthermore, Wilkins & Davies Group (1986) established that the effective fetch for wave generation within the estuary is approximately 400 m, which results in small wind chop waves.

6.4 Model Resolution

A number of different grid sizes were experimented with to establish the optimum size for this study. The final resolution is a compromise between accurate model results and acceptable computational size. As a rule, a large reduction in grid size will result in increased computational time. One way to speed up the model is to increase the grid size. However, increasing grid size is not always possible. Within Whitianga Estuary there are features (such as the dredged waterways canal) that have significant bathymetric details that will affect the hydrodynamics. Also, the constrained nature of the tidal inlet and river systems means that specifying a large grid cell (>20 m) can cause the model to become constricted around the entrance, resulting in loss of detail. Clearly, fine resolution is best in order to distinguish small-scale processes and features such as eddies and circulation that occur in the 3 km entrance (Chau, 2003). The optimal grid size that retains a high enough model resolution and low adequate model computational time was 20 m.

Model fundamentals:

Model Grid

20 m Y

20 m X

Grid Size

I max	338
J max	559

Distance X	6780 m
Distance Y	11180 m

X origin	1836141
Y origin	5912618

Orientation (rotation) 0 (no rotation)

Max Depth 16 m

Horizontal Eddy Viscosity 1 m^2/s

Bed Roughness	Friction file created (rough.frc)
Effective Depth	0.3 m
Drying Height	0.05 m
Coastal Slip	98 % for land sea boundaries

6.5 Model Calibration

In order to calibrate and validate the 3DD hydrodynamic model, the model simulation periods were compared to measured data. Due to all model simulations beginning from a cold start (i.e. flat water, no currents and no circulation), a period of four complete tidal cycles (2 days) was allowed to 'warm up' the model, before any results were extracted. Initial calibration was conducted on model runs of eight days.

The accuracy of the predicted current speed and direction is very important as these parameters will greatly influence the residual circulation and simulation of the sediment transport. The key assumption made is that there is a stable flow through the water column. Therefore, a logarithmic velocity profile (Rouse profile) can be assumed in order to correct for depth. However, in reality there is more of a non steady state (Oscillatory flow), rather than the steady state defined by the Rouse profile. The Rouse profile is the assumption that most models use to calculate velocity profiles for depth averaged model results. Current speeds in two-dimensional models such as 3DD and Mike 21 HD output velocities as depth averaged. Therefore, the resulting velocities are similar to those that make up the majority of the water column. Due to the friction created by the bed, velocities will decrease in the lower portion of the water column. Bearing this in mind, the measured velocities collected by the S4 current meter are collected 1 m above the bed. Therefore, the measured velocities will require depth averaging in order to calibrate and compare velocities accurately. Converting the velocities to depth averaged is undertaken using the equation:

$$u_0 = u^* \Big/ k \times \left(1n \frac{depth \times 0.4}{z_0} \right) \qquad \text{(Equation 6.2)}$$

Where k is von Karmens constant of 0.41, depth is the time series of measured depth and z_o is the bed roughness 0.0001 m for planar beds (Black et al., 1989) such as the Buffalo Bay site, and 0.001 m for estuarine beds (Black et al., 1989) such as the wharf site. u^* is calculated using the following equation:

$$u^* = \frac{u \times k}{\log(z/z_0)} \qquad \text{(Equation 6.3)}$$

Where u is the measured velocity at z above the bed measured in (m/s), and z is the height of the instrument above the bed (instrument height 1 m). z_0 is calculated using the following equation:

$$z_0 = d/30 \qquad \text{(Equation 6.4)}$$

Where d is grain size diameter (measured in mm).

Initial model runs were undertaken with a bed roughness set to 0.001 as defined by Black et al. (1989) as suitable for estuaries, and a horizontal eddy viscosity of 1 m^2/s. However, to carry out calibration on 3DD hydrodynamics (current velocity and water elevation) for the estuary, adjustments were made to the calibration by varying the bottom friction co-efficient (bed roughness) in the model and finding the smallest error based off the Root Mean Square Error (RMSE) between measured and predicted data. Given that the model grid is at 20 m resolution, bed roughness is expected to be higher than that which can be inferred from a linear model for grain size. The nature of the grid size and the griding process means that smoothing of large-scale bedforms such as sand waves and macro-scale dune features occurs. To account for this smoothing effect, bed roughness is increased over what would be calculated just based off the grain size. Therefore, the simplest method for determining the appropriate bed roughness length for the 3DD model is a simple trial and error approach as discussed below. This was then used for the creation of a bed roughness file for the 3DD model.

The measured S4 and FSI current meter water velocities and elevations retrieved from the instrument deployments (see Chapter 4) were used in the model calibration. Water velocity and elevations from the corresponding grid cells in the model were extracted and interpolated using MATLAB at the same time-step as measured data, and then evaluated using RMSE (Root mean square error) to find the best model calibration. 3DD hydrodynamics for Mercury Bay and Whitianga Estuary were primarily calibrated by varying the bed roughness length in the model. Several model runs were undertaken changing the roughness length for each run over the entire model grid. By undertaking plots of the residual error between modelled and measured data (for water level and velocities see Appendix III), the appropriate bed roughness for each location could be determined. This was used as the basis for a bed roughness map that was used in the final model run (Figure 6.2). The bed roughness map was adapted from side-scan sonar work undertaken by Cooper (2003). Based on the grain size textural patterns, bed roughness lengths were varied between sites to reduce the residual error. The 3DD model allows the user to either individually specify the bed roughness for the modelled area by selecting specific cells and allocating a friction value, or alternatively through the addition of a friction file. For this study a full friction file for the Whitianga Estuary and Mercury Bay area was developed in ARC GIS and gridded to the same extent as the modelled area in SURFER™. Figure 6.2 is the ARC basis for the friction file created for 3DD. Higher friction values were applied to the coarser grain sizes found in the bay and were required to reduce to residual error in the modelled results. As there were no grain size data available for Whitianga Estuary, a uniform value of 0.001 was assumed to be appropriate for estuaries, and was applied to the entire estuarine area (Black et al., 1989).

6.5.1 Calibration of Eddy Viscosity

Calibration of eddy viscosity was undertaken by changing the 3DD model viscosity value until the ebb tidal jet predicted the eddy formations that occur as the tidal jet exits the entrance into Buffalo Bay. Fortunately there is an aerial photo available for this area taken in 2004, which clearly shows the eddy formations as a result of a high-suspended sediment load (see Appendix IV). The final horizontal eddy viscosity value was found to be most appropriate at the initial value of 1 m^2/s.

Bed Roughness Map

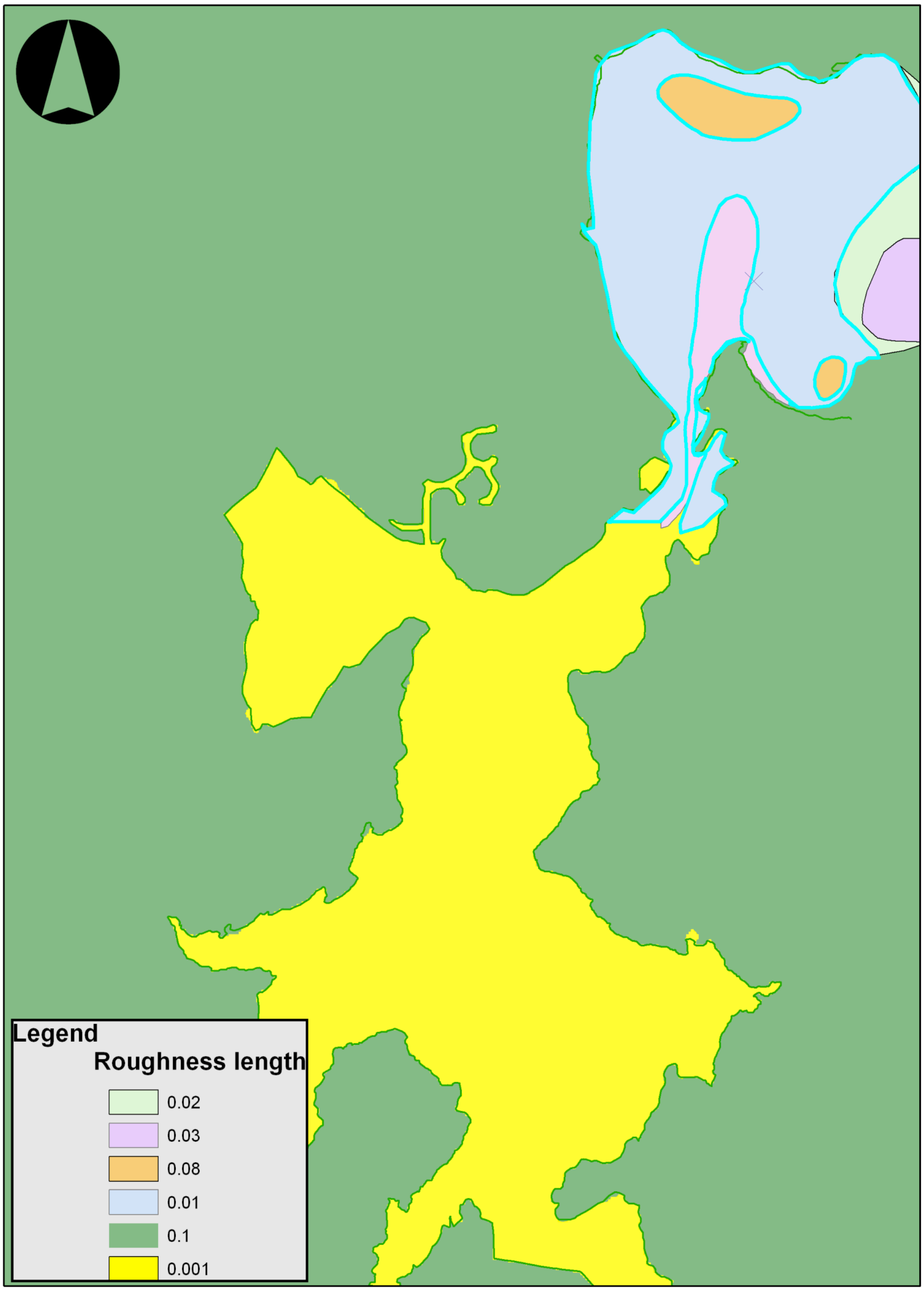

Figure 6.2: Bed roughness map developed for the 20 m model run. Map was developed and adapted from side-scan sonar work undertaken by Smith (1980).

6.5.2 Calibration & Validation Results

At present there are no accepted methods for evaluating the performance of numerical modelling results. The present practice is to compare the predicted and measured results, either in the form of simple statistics or simple graphs (Sutherland et al., 2004). There is some debate about the best method of analysis for the purpose of model validation and calibration. Furthermore, Brady & Sutherland (2001) found in their assessment using COAST3D that no one statistic is ideal for the evaluation of models, and subsequently suggested that the best method to compare morphodynamic model results is the Brier Skill Score (BSS). The BSS is a measure of the accuracy of a prediction in relation to the accuracy of a baseline prediction (Brady & Sutherland, 2001). It is useful for surface and vector data, in producing a quantitative result that can be comparable. Therefore, model performance will be assessed using BSS (Equation 6.5).

$$BSS = 1 - \frac{\left\langle (Y-X)^2 \right\rangle}{\left\langle (B-X)^2 \right\rangle}$$

(Equation 6.5)

Where $\left\langle (Y-X)^2 \right\rangle$ is Mean Standard Error (MSE) and $\left\langle (B-X)^2 \right\rangle$ is Mean Square Change (MSC). $\langle Y \rangle$ is the mean of the observations, $\langle X \rangle$ is the mean of the modelled predictions, and B is the baseline prediction.

For the purpose of this thesis the implication of the BSS was tested in relation to hydrodynamic model calibration. This tested the accuracy of not only the model but also the feasibility of the BSS in such an application. In part this approach is simple as the baseline prediction is assumed to be initial actual mean measured data. In much of the morphodynamic and climatic modelling applications where the BSS has been applied, the baseline prediction is assumed to be either (a) no change in morphology; or (b) a predicted climatic change such as (rain/no rain). Applying this methodology to evaluating tidal current velocities and heights, the baseline (B) is assumed to be the mean of the measured data. Therefore, if the assumption is made that tide follows a Gaussian distribution (which tides do) the mean prediction will be equal to zero (de Lange, pers comm. 2007). Taking this into consideration the equation can be simplified. The equation then becomes:

$$BSS = 1 - \left\langle \frac{(Y - X)^2}{X^2} \right\rangle$$ (Equation 6.6)

Where the equation becomes fundamentally coefficient of determination. Taking this into consideration a better/simpler measure of accuracy would be mean average error (MAE) or root mean square error (RMSE). One application for the BSS in hydrodynamic modelling is the calibration of the modelled result to determine if the model is improving or deteriorating. For example, the initial model value for the baseline (B) would be assumed to be zero. However, a comparison between model runs could be made to determine if changes are improving the model output. Therefore, for each model change the predicted will become the previous model result. This could further be applied by comparing the results between two different model applications of the same data.

The proceeding results (Figures 6.3 to 6.12) demonstrate the calibration and validation for the final hydrodynamic model. RMSE, BSS and Bias values shown on the following figures are the accumulative values recorded for a full 18-day spring neap tidal cycle. The full data set was used to produce better hydrodynamic calibration and validation results.

Results from the model showed good results for both spring and neap elevations and velocities within the estuary, which is the focus of this thesis. The cumulative results for the full model period were included so that absolute error estimates for RMSE, BSS and Bias could be evaluated. Through the inclusion of all data for statistics (not just a singular tidal cycle during neap or spring tide) a less biased assessment of model performance can be achieved. It is my own viewpoint that in only including results that are in better agreement of measured and modelled data for neap tides or spring tides introduces a bias. More often than not in numerical modelling, adjustments to variables such as bed roughness can be different for neap and spring tides which results in improvements in one and not the other (Li & Valle-Levinson, 1999).

Bias is a measure of the difference between the mean (used in this instance, however medium is also often used) values of the modelled and predicted data sets and the true value of the parameter being estimated. Bias divulges the tendency of a modelled result toward under or over-prediction, with a negative bias indicating that the model is consistently under predicting the observations (measured results), (Sutherland et al., 2004).

RMSE is a statistical measure of accuracy based on a 0-1 scale with values close to zero representing very little error. Therefore, the model and predicted findings are very similar. Accuracy is a measure of the average size of the difference between a set of predictions and the corresponding observations (the average error), so even when there is no bias in a model it may still have a low accuracy (Sutherland et al., 2004).

The BSS is a measure of skill. Skill is a non-dimensional measure of the accuracy of a modelled prediction comparative to the accuracy of a baseline prediction (Sutherland et al., 2004). Like RMSE, the BSS is a measure based on a 0-1 performance criteria. However, unlike RMSE, zero would indicate that the model is not predicting the results very well. Thus, the closer the value is to one, the better the model is predicting the results. One important aspect to remember is that the key assumption made for the model is that the predicted baseline value (B) is zero, or that the tidal wave is sinusoidal. However, for very shallow measurements this assumption will not hold true. Therefore, a simplification of the BSS equation cannot and should not be undertaken in very shallow water where the tidal wave becomes asymmetrical.

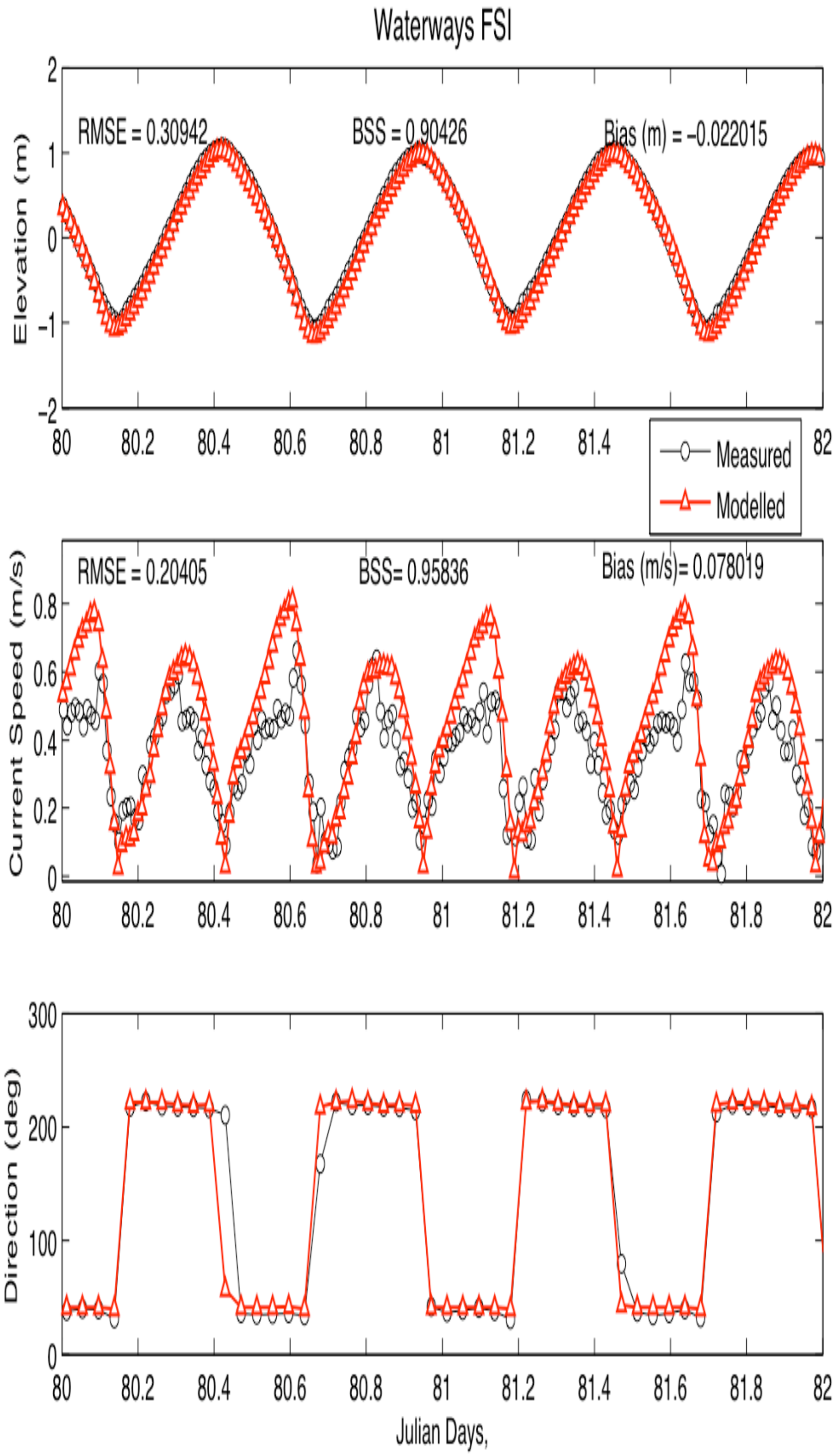

Figure 6.3: Final model calibration for Waterways FSI. Modelled prediction is shown in RED and measured is shown BLACK. Overall the predicted results are a good fit However, the RMSE and BSS show that the small phase differences means that there is room to improve results.

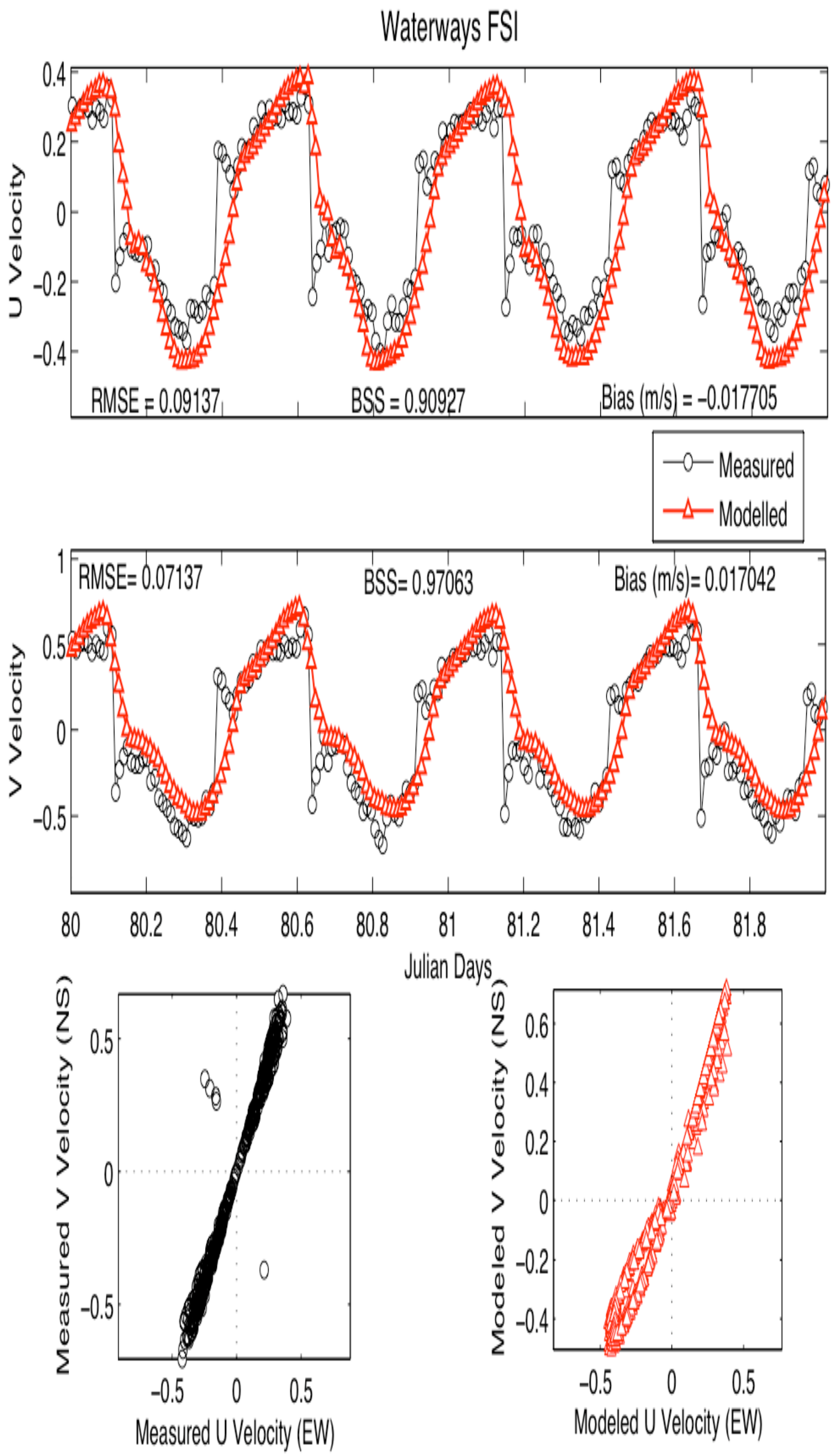

Figure 6.4: U and V velocities measured and predicted at the Waterways FSI. Overall the model predicted these results well.

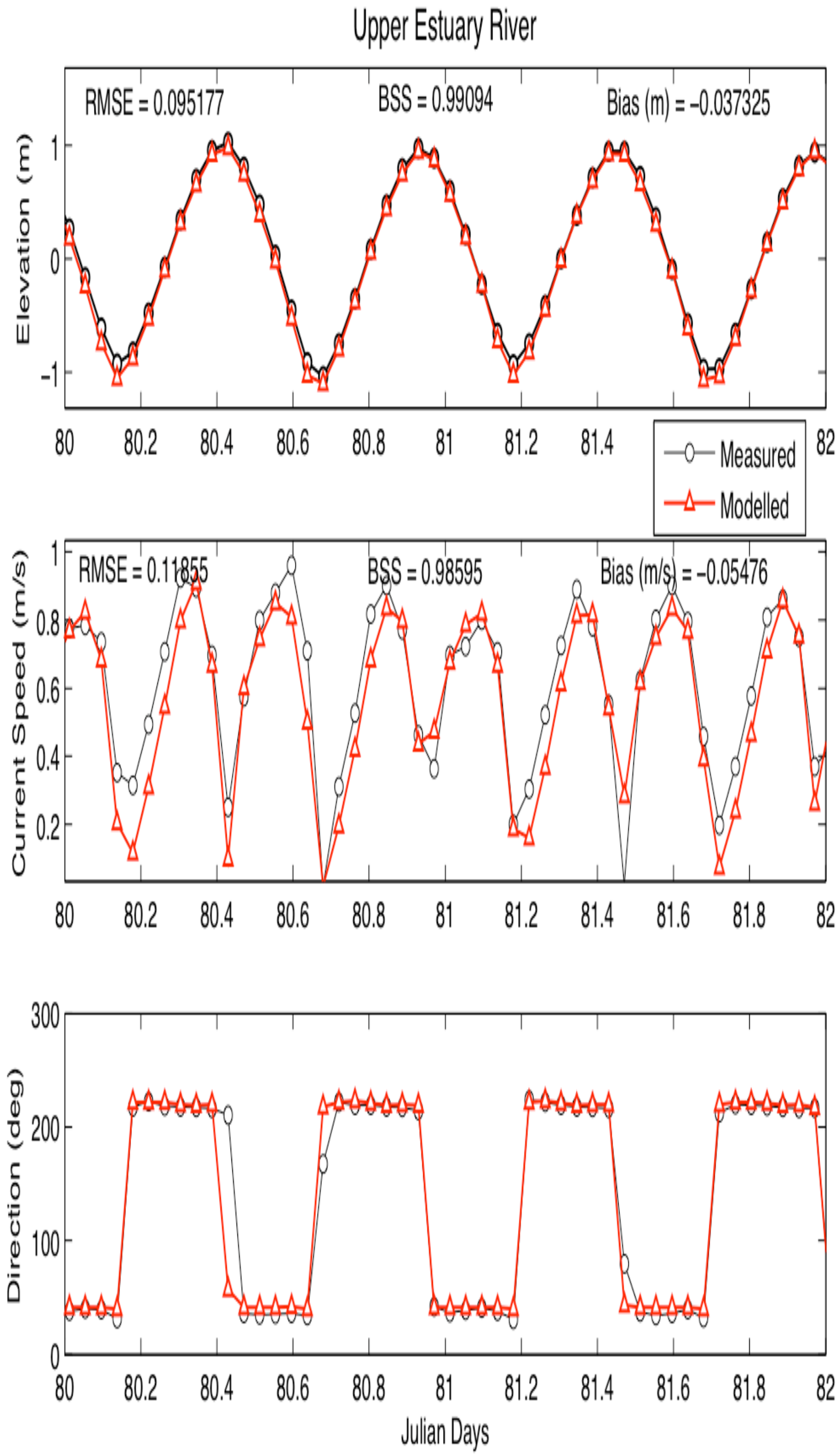

Figure 6.5: Measured and modelled tidal velocities, current speeds and direction at Upper Estuary River.

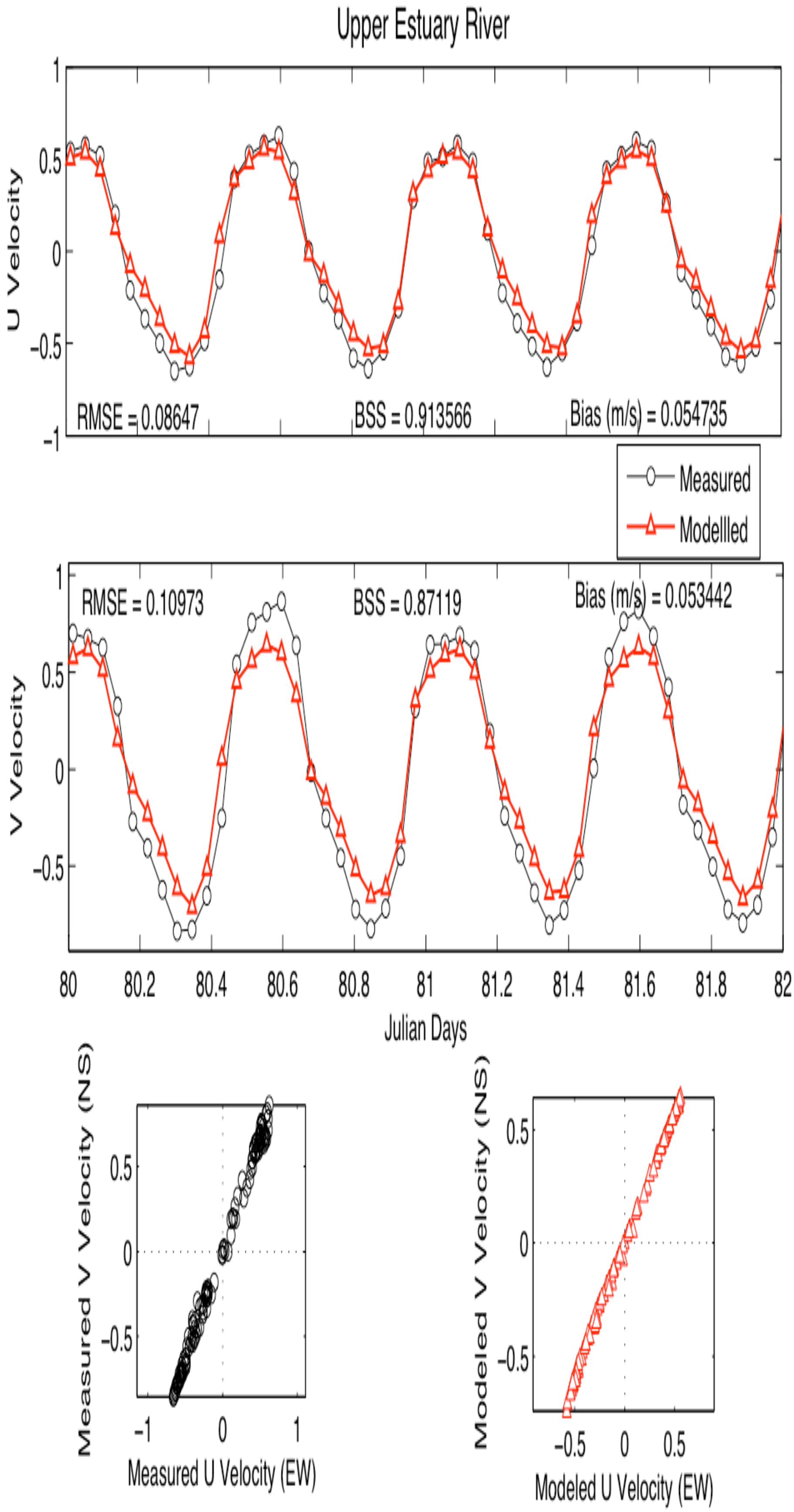

Figure 6.6: U and V velocities measured and predicted at Upper Estuary River S4. Overall the model predicted these results well.

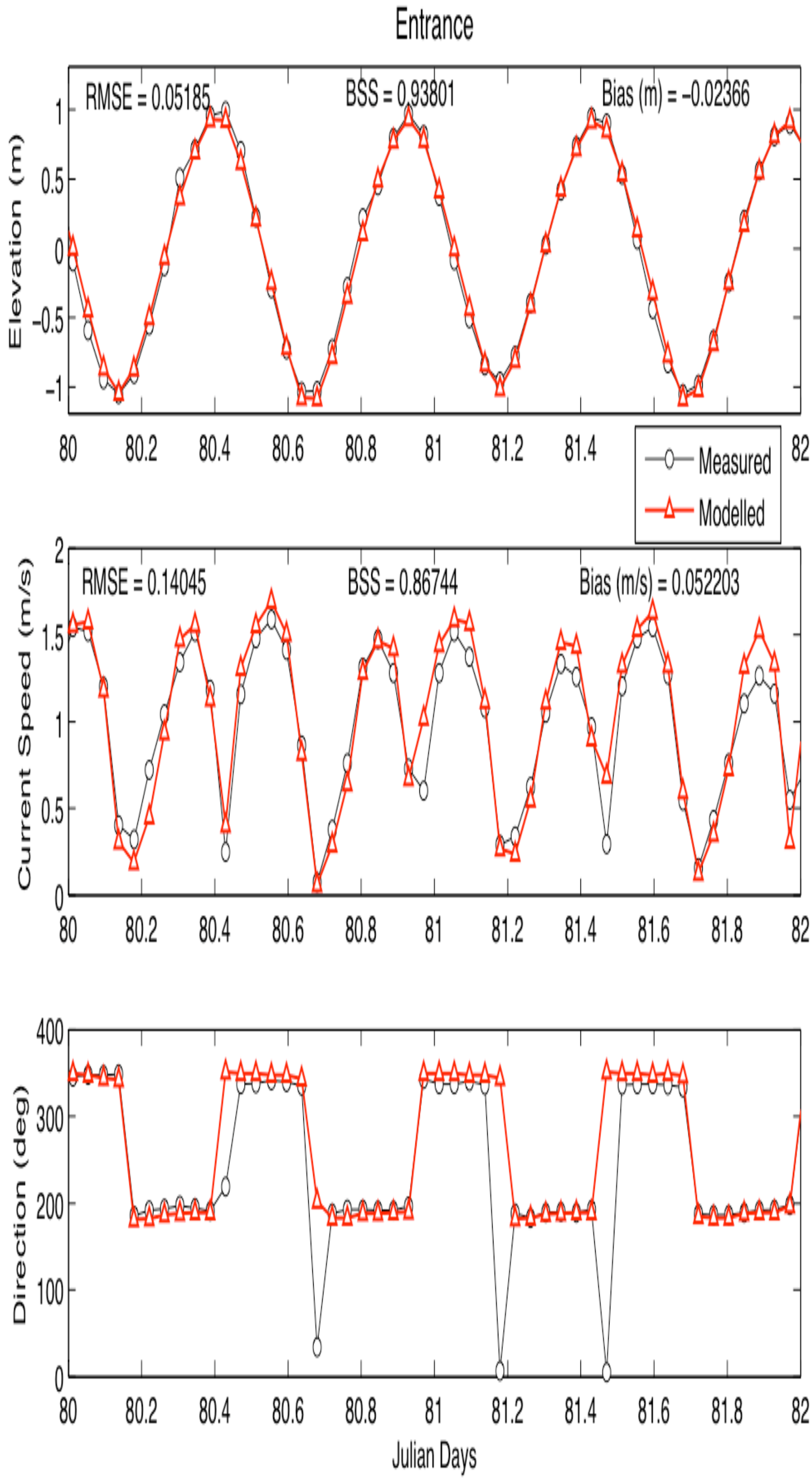

Figure 6.7: Measured and modelled tidal velocities, current speeds and direction at the Entrance.

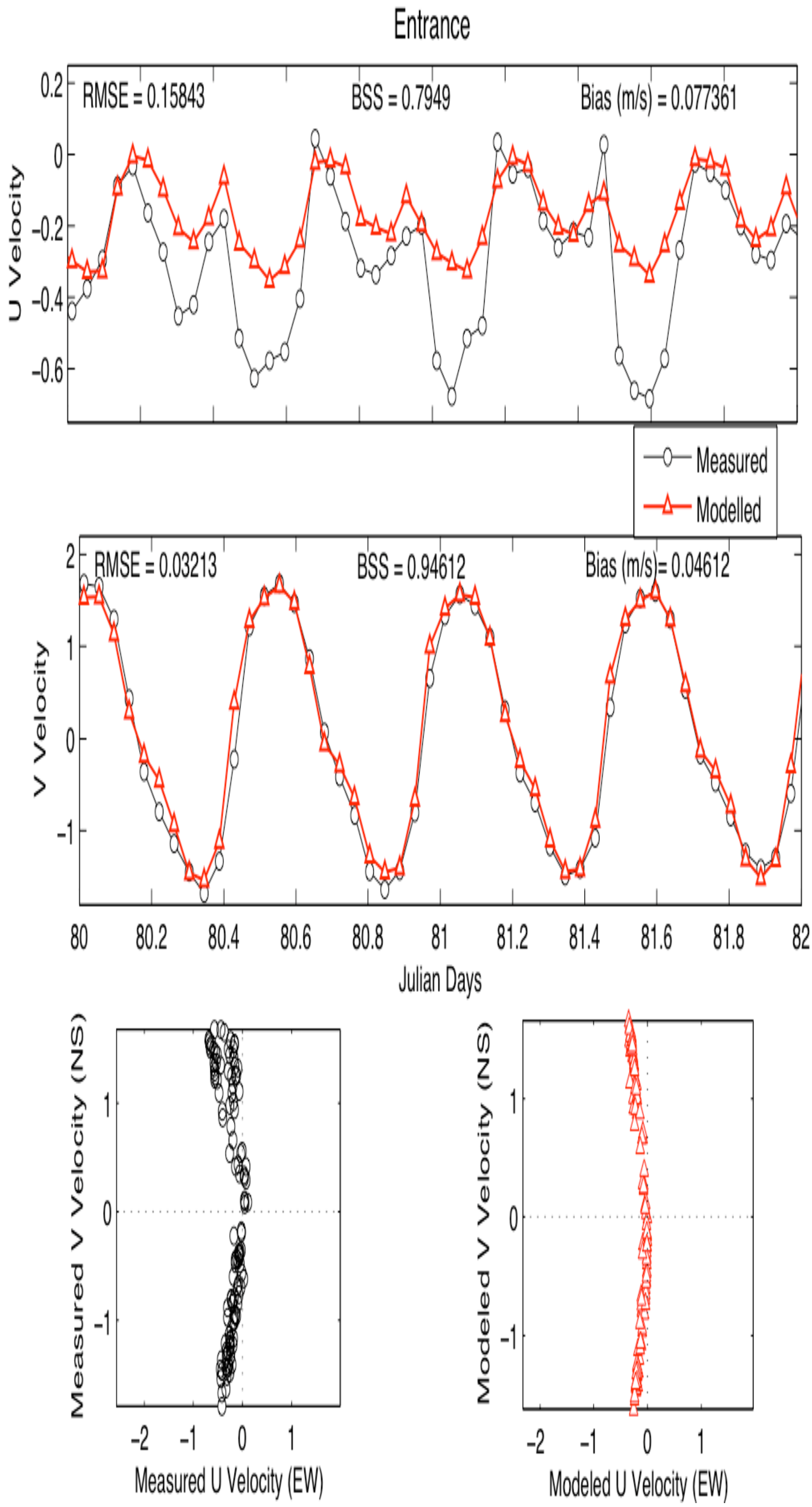

Figure 6.8: U and V velocities measured and predicted at the Entrance. Overall the model predicted these results well.

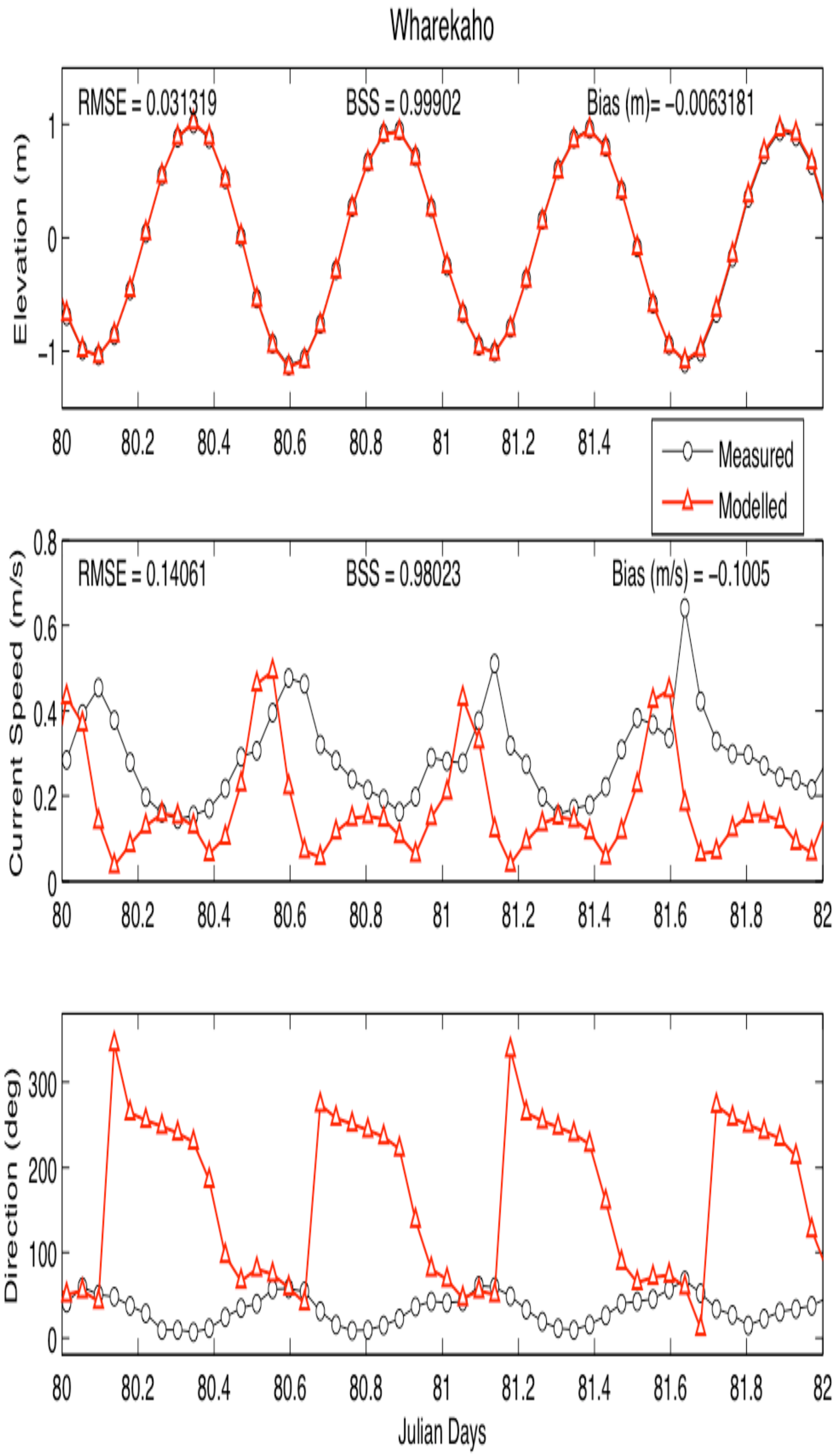

Figure 6.9: Measured and modelled tidal velocities, current speeds and direction at Wharekaho.

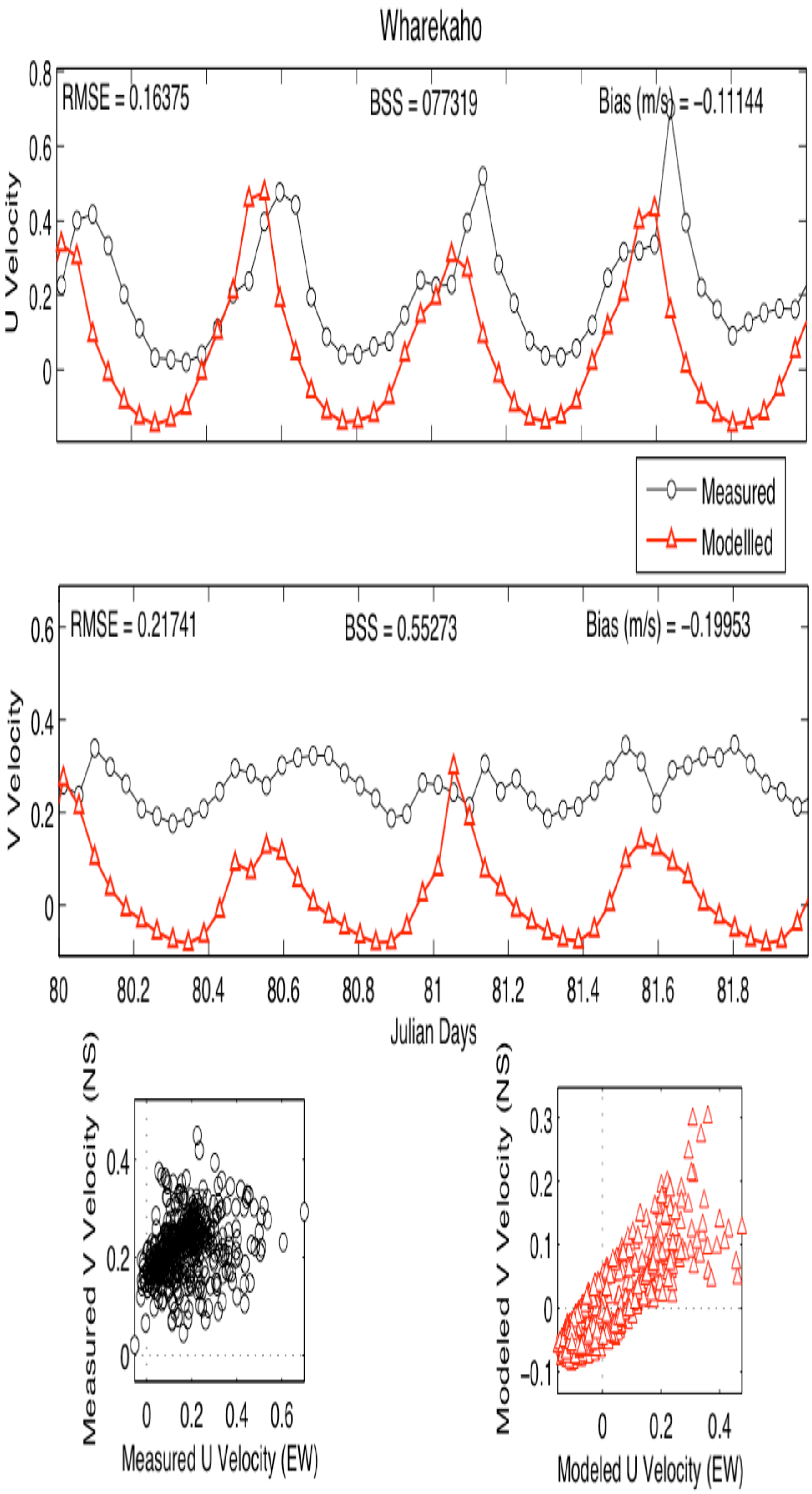

Figure 6.10: U and V measured and modelled velocities at Wharekaho.

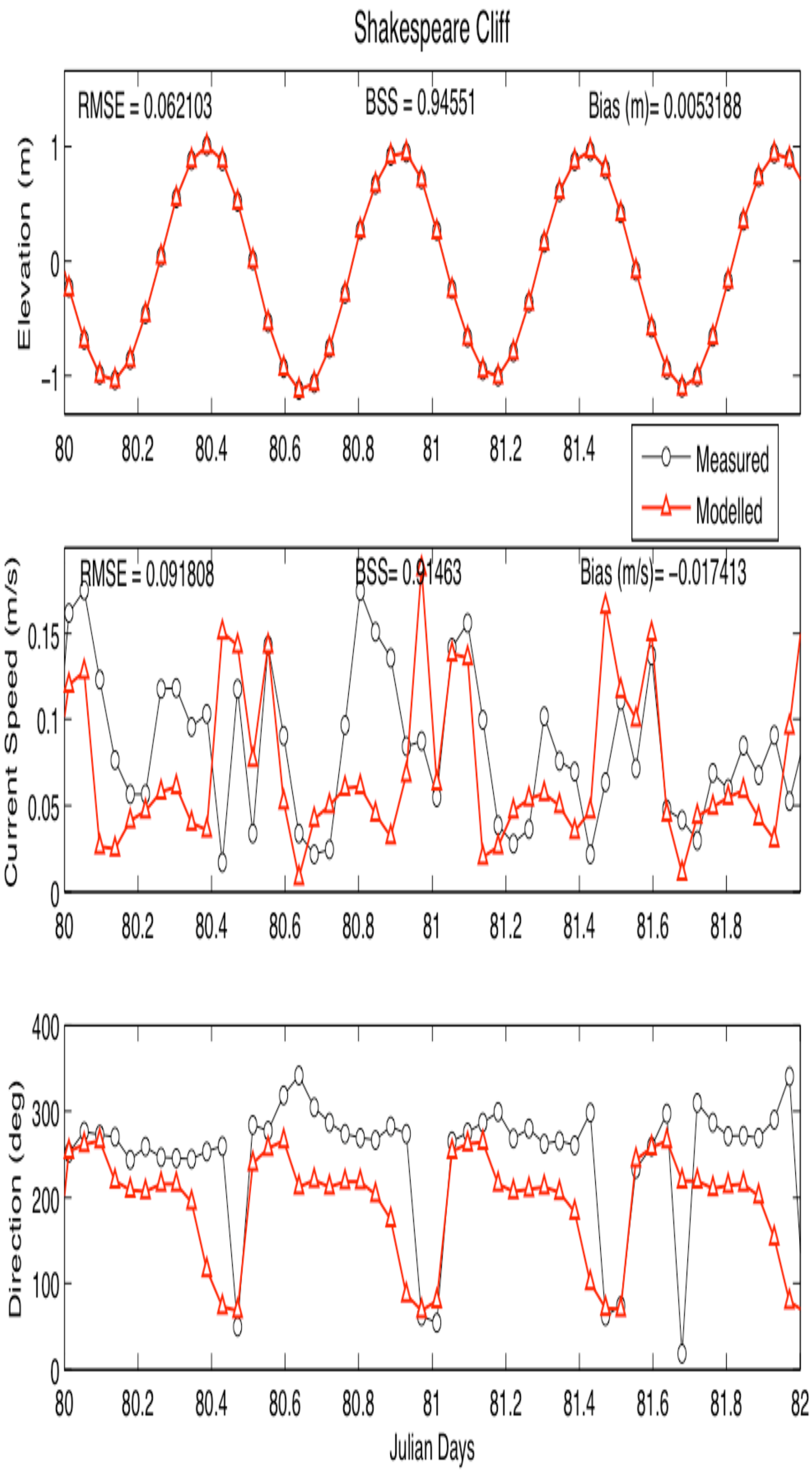

Figure 6.11: Measured and modelled tidal velocities, current speeds and direction at Shakespeare Cliff.

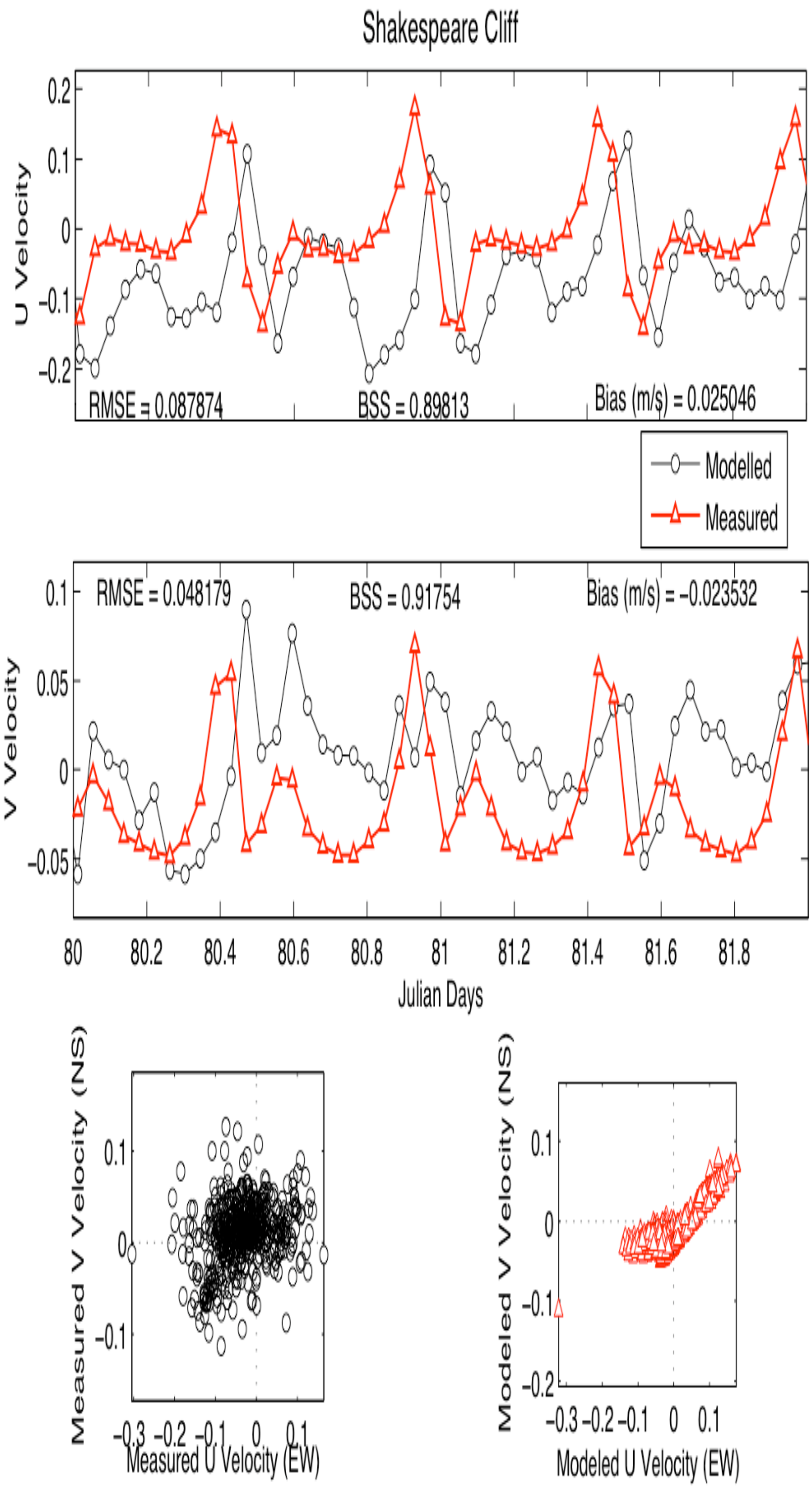

Figure 6.12: U and V measured and modelled velocity components for Shakespeare Cliff.

Tidal analysis of the S4 current data collected from the Shakespeare Cliff S4 shows that there is a large proportion of measured velocity data that is non-tidal. The analysis shows that the percentage of X variance removed by analysis is 74.96 % and the percentage of Y variance removed by fit is 54.37 %. Wharekaho also shows that there is a large proportion of data that are not explained. The analysis shows that the percentage of X variance removed by analysis is 78.0 % and the percentage of Y variance removed by fit is 69.9 %. The tidal analysis shows that 20-25 % of variance cannot be explained by a tidal analysis, and that within Mercury Bay atmospheric inputs are extremely important and therefore, required to reproduce currents found in the bay. Thus, by not including localised weather conditions to input into the climatic forcing of the 3DD model calibration, U and V current velocities are not well represented in the model.

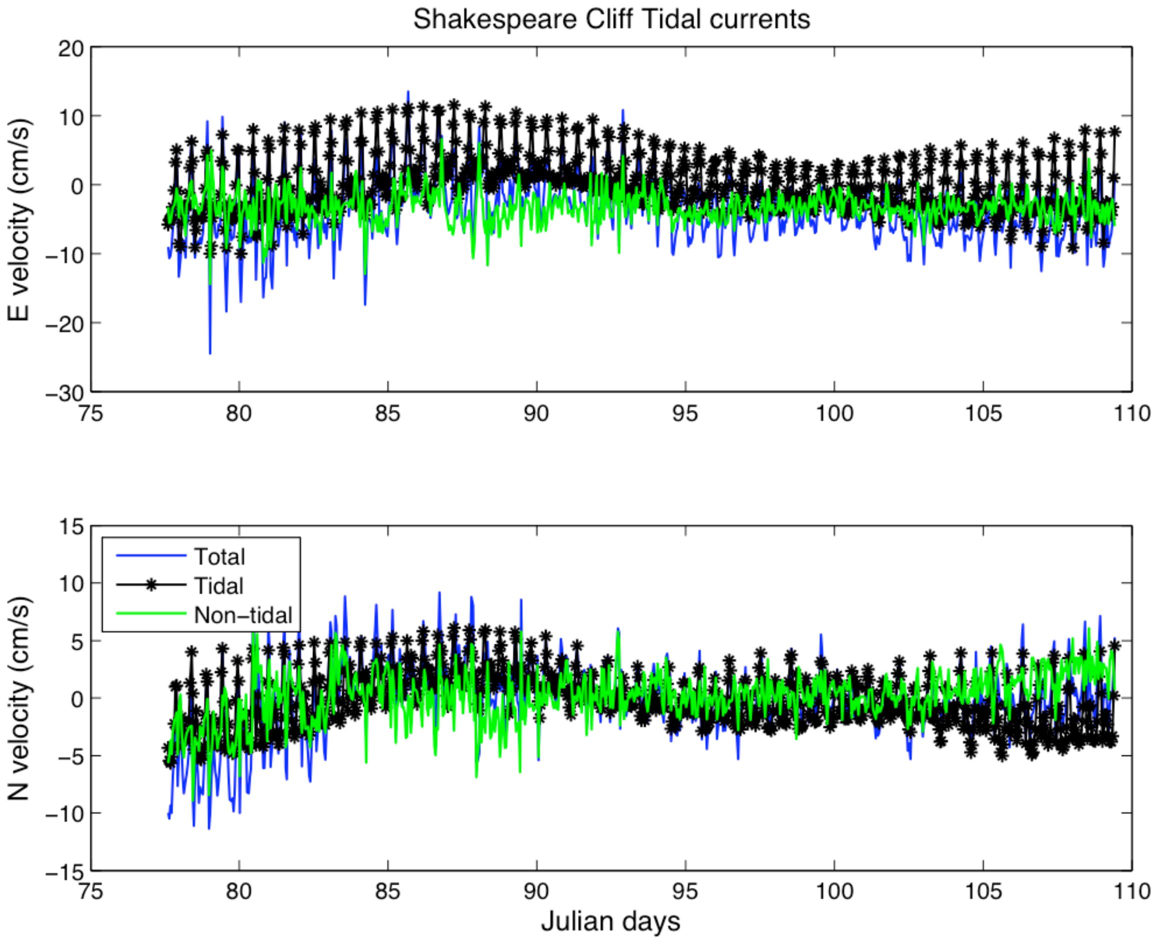

Figure 6.13: N and E velocities from Shakespeare Cliff S4 current meter. The green line shows the non-tidal constituent not explained in the data.

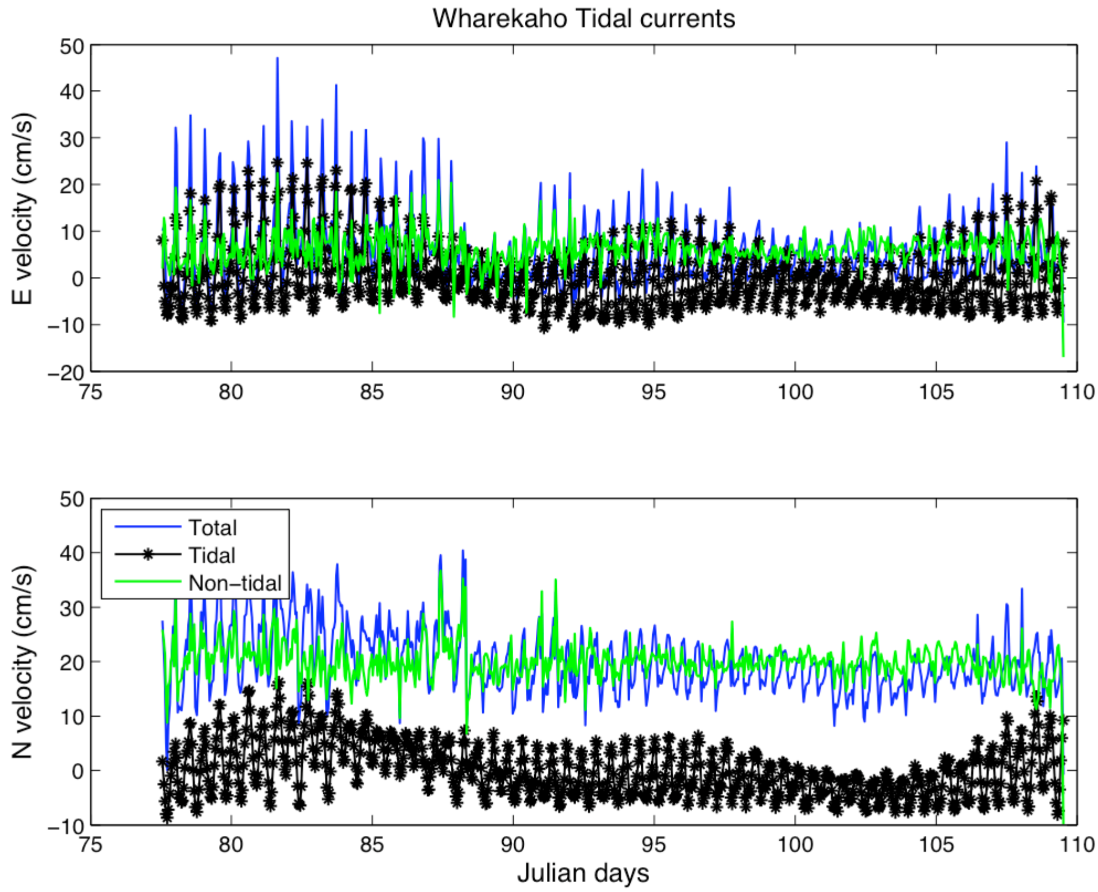

Figure 6.14: N and E velocities from Wharekaho S4 current meter. The green line shows the non-tidal constituent not explained in the data.

The poor calibration shown for the direction and V velocity can be seen in Figure 6.15 to be a malfunction of the S4 current meter at this location. The current meter seemed to only record in one directional axis. Therefore, the poor calibration that relates to the directional components of the model and measured data seen in Figures 6.9 and 6.10 should be overlooked.

It would seem from the tidal data in the entrance that the model does not predict the neap tide direction as well as it should. However, it can clearly been seen that there is an error in the tidal record during this period. This may be an artefact of the S4 current meter shifting due to a storm event that occurred.

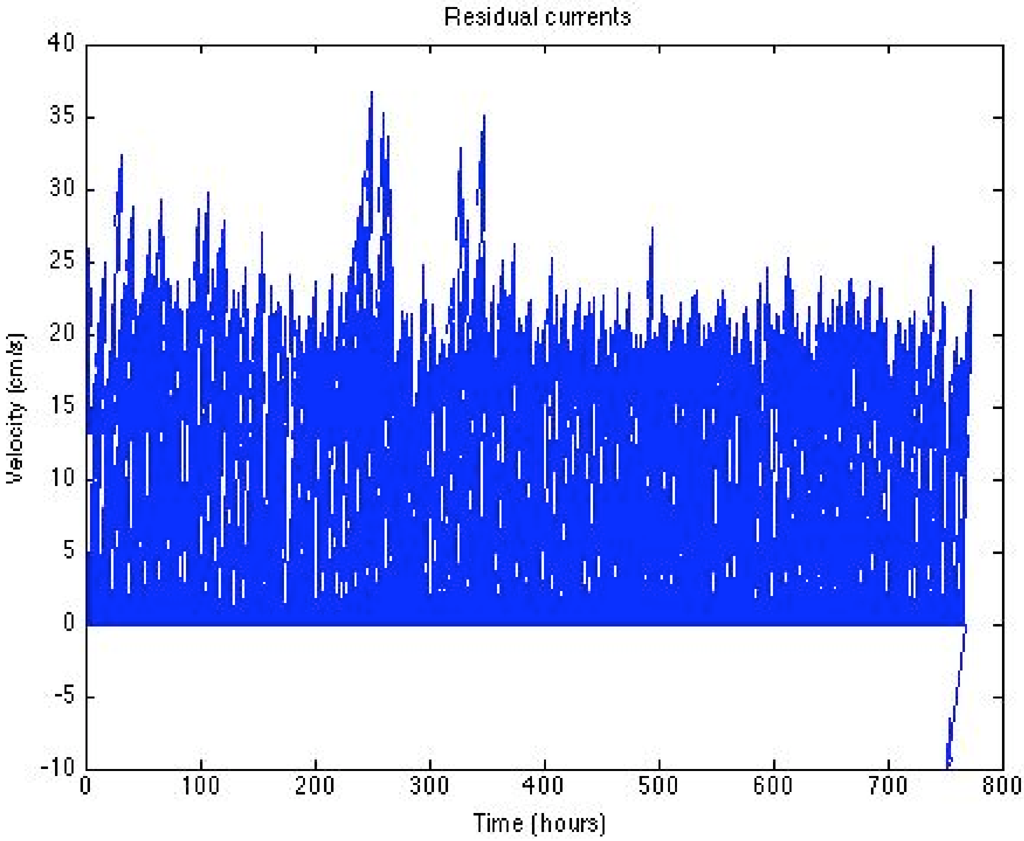

Figure 6.15: Residual currents as measured by the S4 current meter at Wharekaho, due to an error with the meter direction was only measured to be going one way.

A tidal analysis was undertaken of the modelled and measured data to determine how well the model was predicting the tide, the amplitude, and phase of the M2 tidal constituent. Undertaking a tidal analysis is a good way of validating the model performance in predicting the major tidal constituent. The predominant east coast tidal constituent such as that found in Mercury Bay and Whitianga Estuary is the M2 lunar semidiurnal tide (Goring et al., 1997). At the Wharekaho and Shakespeare Cliff sites within Mercury Bay the model is over-predicting the tidal amplitude. However, the modelled time series is very short (16 days). Therefore, detection of all the lower order tidal constituents does not occur (<28days). The M2 amplitude obtained through harmonic analysis contains a contribution of the N2 constituent that cannot be resolved (Bell, et al., 1998). The N2 constituent can account for a 10 % error (Bell et al., 1998). Taking this into consideration the modelled results compare well with the measured results.

Table 6.1: M2 Tidal constituent amplitude and phase recorded at each site by S4 current meter and the modelled predictions.

Location	Measured M2 (Amp) (m)	Modelled M2 (Amp) (m)	Measured M2 (Phase)	Modelled M2 (Phase)
Shakespeare Cliff	0.704	0.739	96.22	96.9
Wharekaho	0.704	0.739	97.0	96.35
Entrance	0.716	0.716	105.6	104.8
Rivers	0.719	0.708	111.9	111.7
Waterway	0.724	0.729	119.7	117.5

6.6 Numerical Model Results

This section discusses the results from the two-dimensional numerical simulation from the 3DD model. Aspects of the model results that are covered are hydrodynamics, residual circulation, and a particle-tracking model.

6.6.1 Results of Hydrodynamics

The relatively large tidal range for such a small, constricted inlet such as Whitianga generates strong tidal currents particularly in the entrance. Peak velocities coincide with mid-tide during both the ebb and flood cycles and occur as expected throughout the inlet. Velocities reach speeds of 2.6 m/s during peak spring ebb tidal conditions. The constrained nature of the inlet can be seen to create a large ebb tidal jet that induces increased velocities into central Mercury Bay (see Figure 6.16). These results concur with modelling outputs found by Steeghs (2007). During the flood tide, velocities decrease quickly as they enter the estuary. The maximum velocity reached during the spring flood tidal condition is 1.9 m/s (Figure 6.17). The currents are much weaker during flood flows than during ebb flows. As seen in Figures 6.18 and 6.19 the peak velocities during neap tidal conditions are significantly reduced. This is further confirmed by the measured S4 current meter findings illustrated in Table 6.2.

The velocity vectors intensify where the currents suddenly change direction such as converging flows or where sand banks are forming. Velocity fields for the intertidal areas of Whitianga Estuary show uniform tidal circulation (i.e. no major converging flows and low current velocities) during all phases of the tide (see Figures 6.16 to 6.19). The flow becomes stronger and more complex only as it enters the main channel and where the flows converge between the two estuarine areas.

Table 6.2: Current Velocities recorded at each site by S4 and FSI current meters (see location map in chapter 4). It is important to note that the entrance current meter was not located in the most constrained section of the entrance (see deployment map in Chapter 4)

Location	Peak Ebb Neap Velocity	Peak Flood Neap Velocity	Peak Ebb Spring Velocity	Peak Flood Spring Velocity
Shakespeare Cliff	0.4m/s	1.2m/s	1.0m/s	1.5m/s
Wharekaho	0.24m/s	0.15m/s	0.25m/s	0.45m/s
Entrance	1.6m/s	1.4m/s	2.1m/s	1.9m/s
Rivers	0.63m/s	0.65m/s	0.96m/s	0.90m/s
Waterway	0.10m/s	0.15m/s	0.18m/s	0.35m/s

The most complicated velocity and circulation patterns in Whitianga Harbour arise within 3 km of the entrance of the harbour. The circulation is strongly controlled by the bathymetry and complex shoreline of this area. There are several features of note: a) the ebb tidal jet; b) current convergence due to Whitianga Rock point; c) the eddy that forms in the entrance of the marina; and d) mid river where the two sub estuaries meet (the entrance to the waterways canal).

The ebb tidal jet in Buffalo Bay is discussed in Appendix IV as it is an area of interest but outside the scope of this study. The jet dispersal into Buffalo Bay and the associated eddy formations were used as part of the calibration and validation of the model and horizontal eddy viscosity.

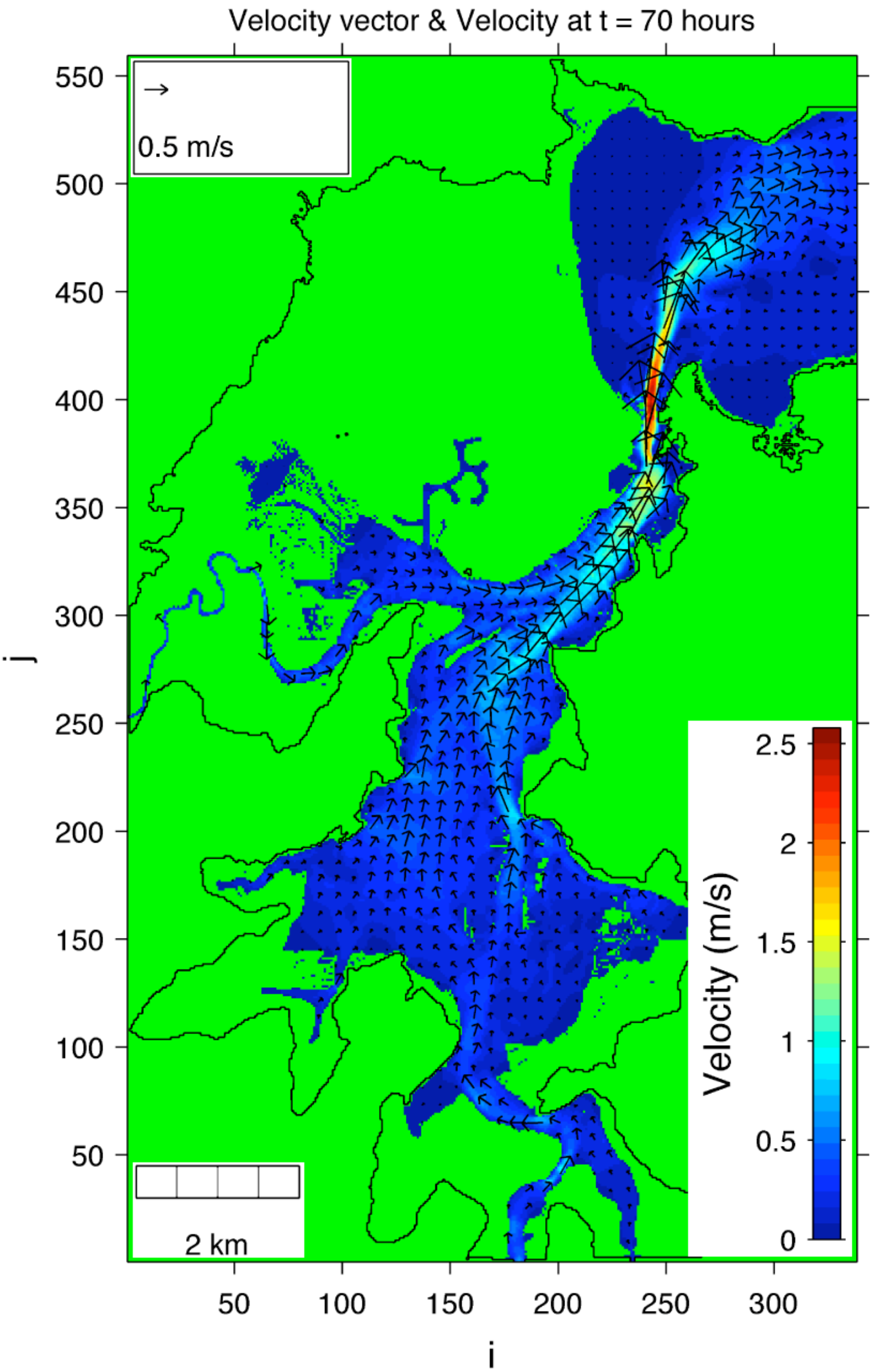

Figure 6.16: Spring ebb tidal hydrodynamics. Peak velocities can be seen to reach 2.6 m/s in the entrance to the harbour.

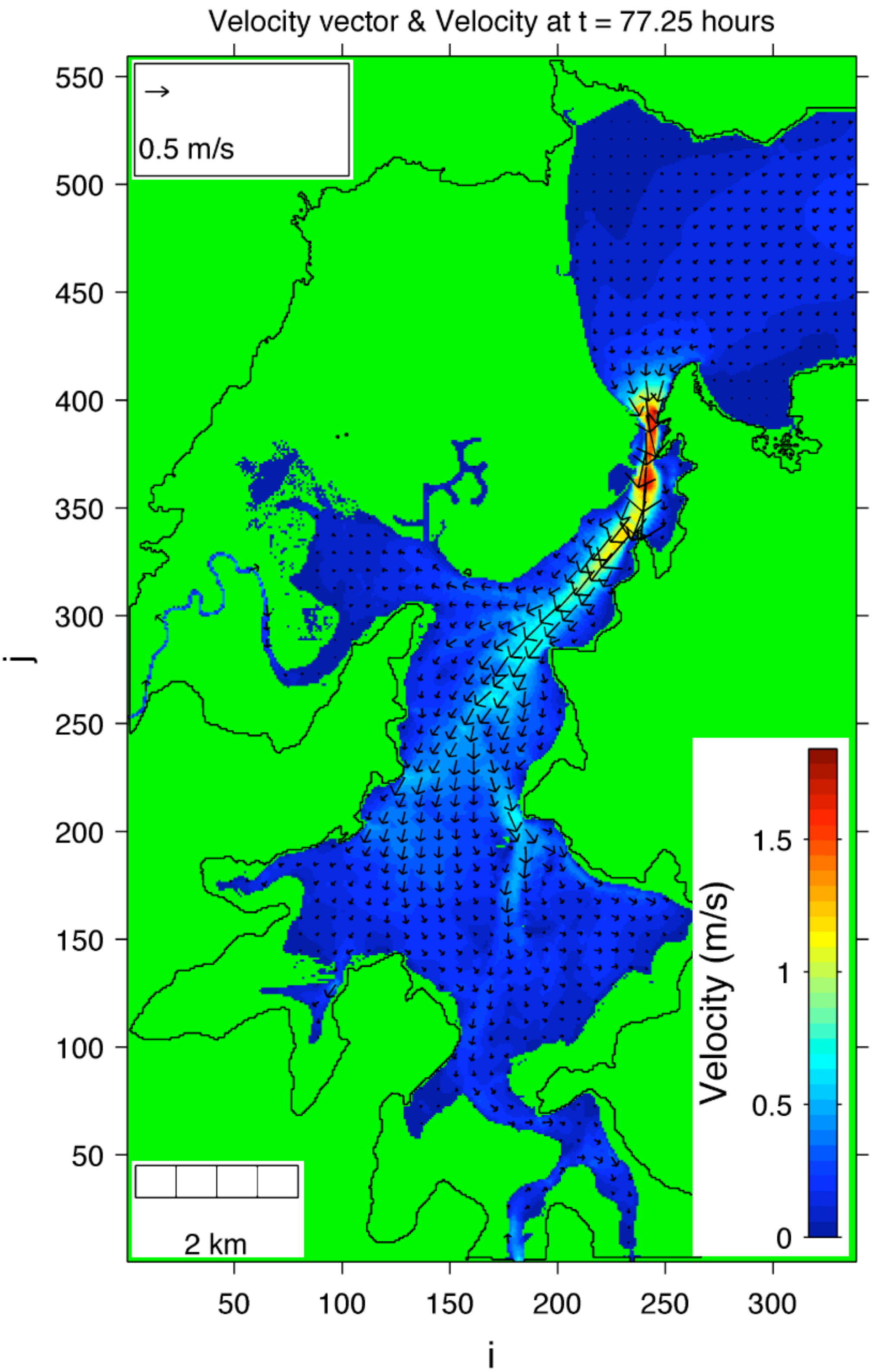

Figure 6.17: Spring flood tidal hydrodynamics. Peak velocities can be seen to reach 1.9 m/s in the entrance to the harbour.

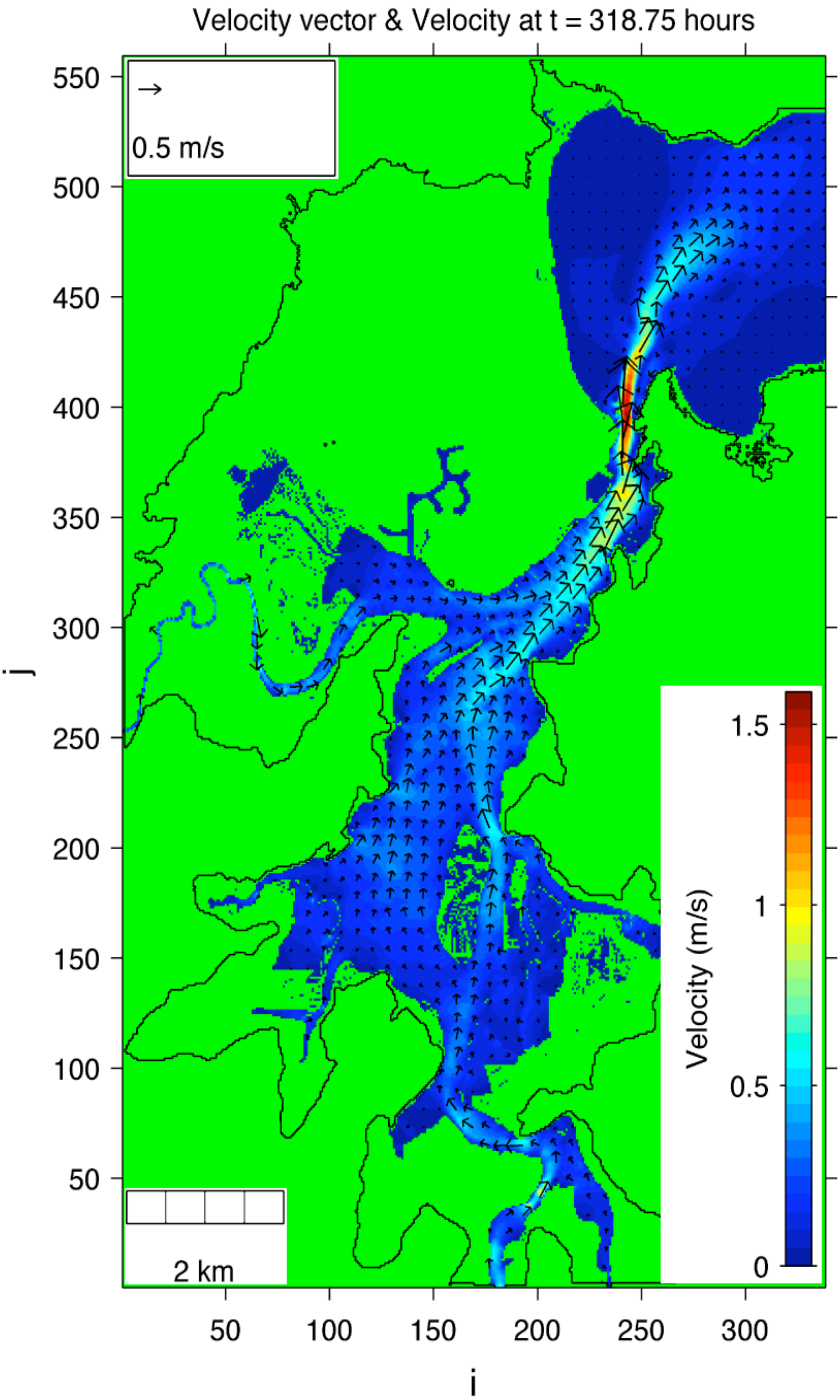

Figure 6.18: Neap ebb tidal hydrodynamics. Peak velocities can be seen to reach 1.7 m/s in the entrance to the harbour.

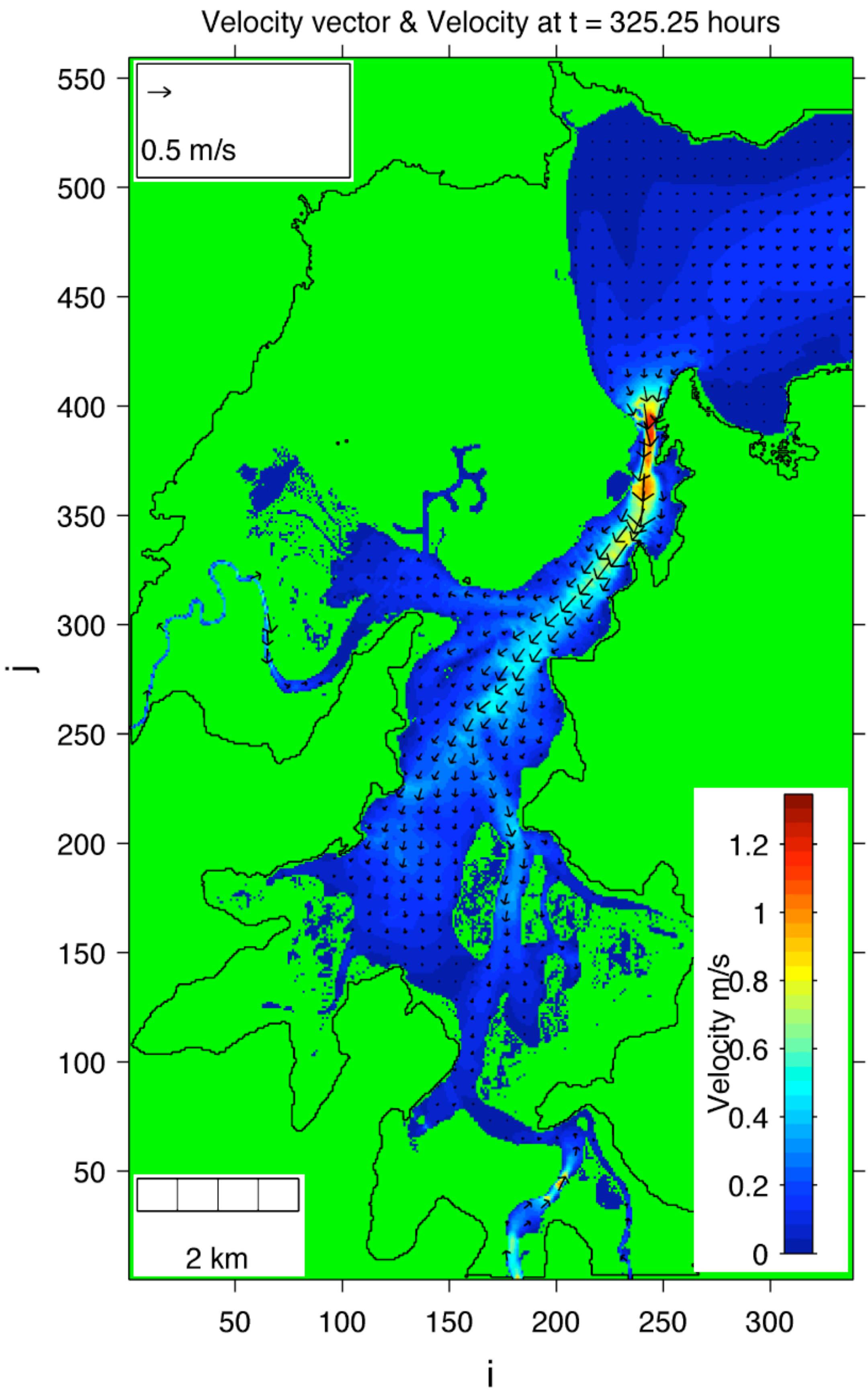

Figure 6.19: Neap flood tidal hydrodynamics. Peak velocities can be seen to reach 1.4 m/s in the entrance to the harbour.

6.6.1.1 Whitianga Rock

During ebb tide, large tidal current velocities are focused onto Whitianga Rock. This headland causes the tidal flow to change directions as it exits the bay through the entrance. The increased velocities seen at Whitianga Rock are a plausible explanation for the scour hole situated to the southwest side of the inlet channel (see Figure 6.20).

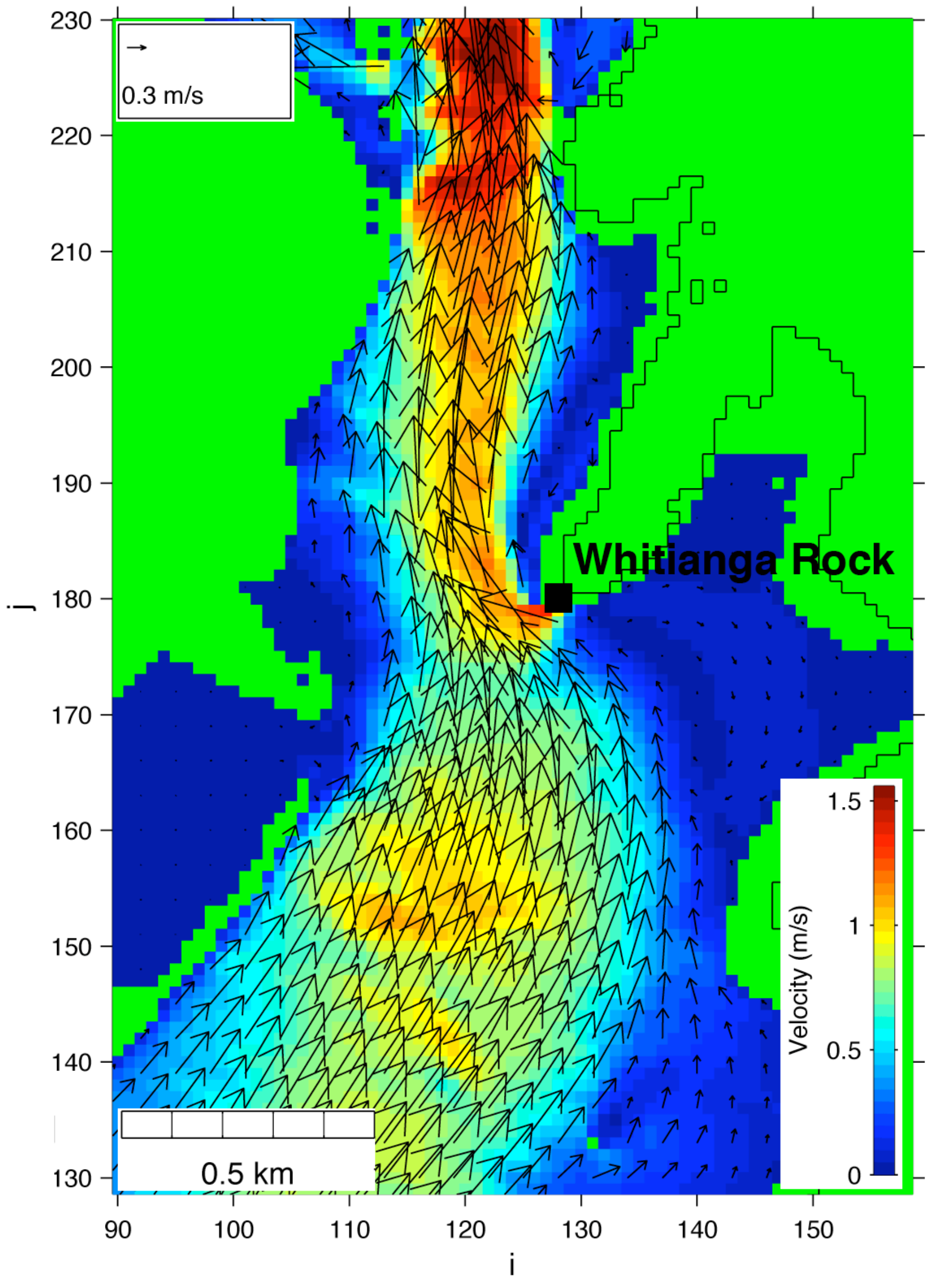

Figure 6.20: Peak ebb tidal velocities exiting Whitianga tidal inlet. Note the high velocities are forced to accelerate around Whitianga Rock and result in the scour of sediment from this point, which consequently results in the formation of a large hole.

6.6.1.2 Whitianga Marina

Whitianga Marina is located just inside the entrance to Whitianga Harbour, on the intertidal foreshore between Monk Street and Dunbus Street. The overall design was for the marina to be well protected from wave attack, and have minimal impact on localised hydrodynamics (Wilkins & Davies Group, 1986). The marina construction consisted of dredging 7.2 ha of intertidal sand flat to a depth of between 2 m and 2.6 m below chart datum. Rock breakwaters then enclosed the area. The breakwater structures have caused an eddy to form in the marina. Existence of this eddy is visible in Figures 6.21 and 6.22. Internal friction and the associated generated vortices led to the creation of a circular wake in the lee of the breakwater structures.

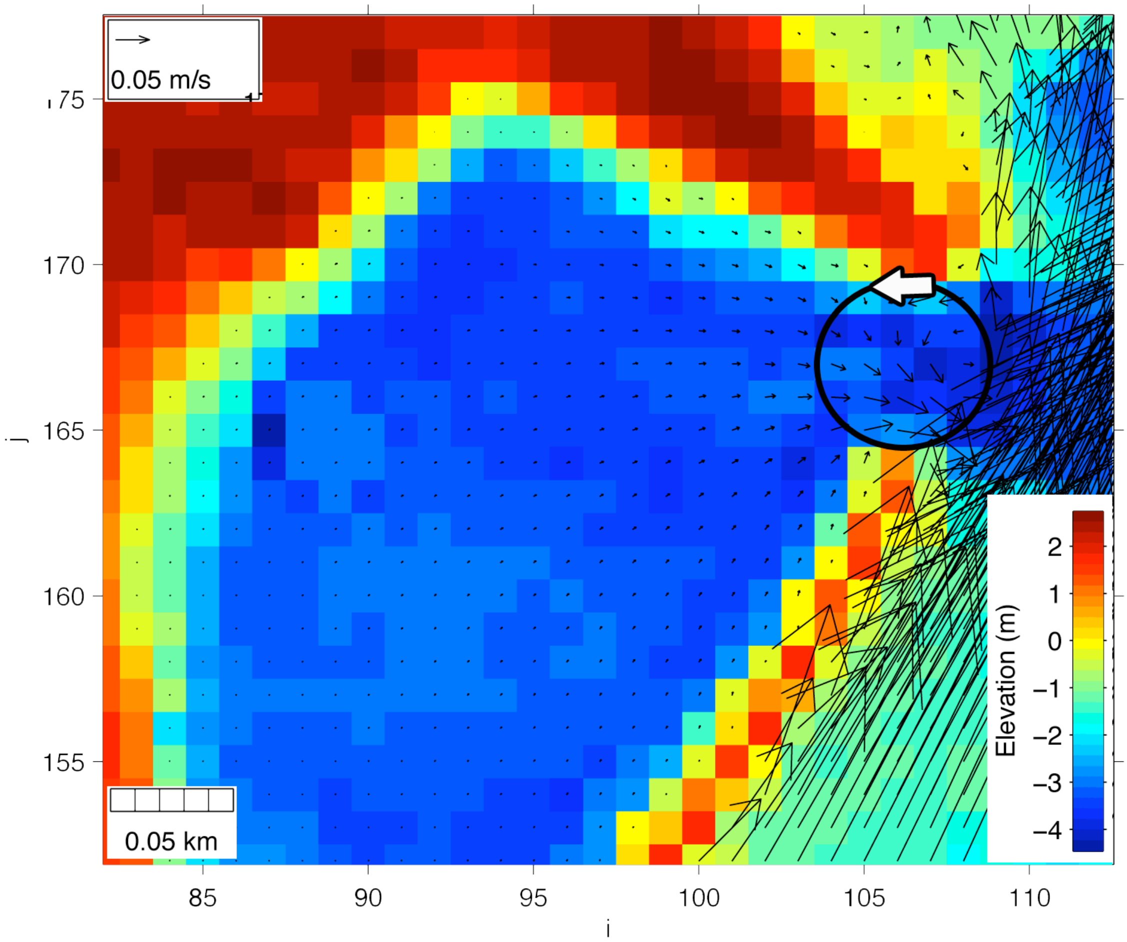

Figure 6.21: Entrance to marina showing the eddy that forms during ebb tide.

A fundamental characteristic of Whitianga marina is that the resulting structures designed to protect it from storm surge and wave attack, also result in sheltering it from any type of tidal circulation. Therefore, any suspended sediments that are deposited due to the eddy formation at the entrance or weak tidal currents will settle in the low energy environment and are likely to remain, resulting in sediment accumulation.

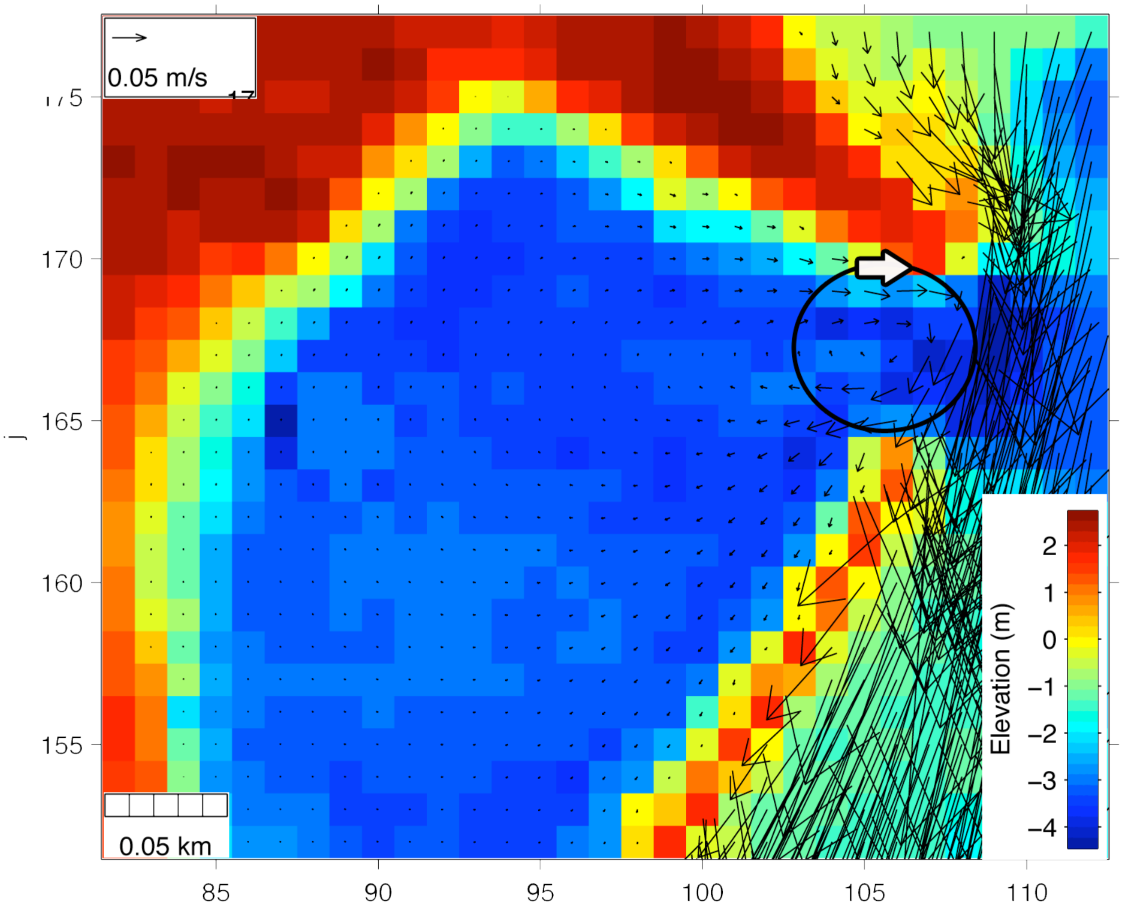

Figure 6.22: Entrance to marina showing the eddy that forms during flood tide.

6.6.2 Residual Circulation Results

Mean residual circulation within Whitianga Estuary is seen to be ebb dominated (Figure 6.23). The typical residual circulation for the intertidal flats is less than 0.04 m/s and for much of the flow in the main channels has velocities of approximately 0.1 m/s. Due to the increased water levels during periods of spring tidal elevations there is a weakening of the ebb-dominated circulation. This suggests that the estuary is close to being in balance with incoming and outgoing velocities being much the same. Subsequently, during a neap tidal cycle when water levels and velocities are lower, river flows start to dominate and the net residual circulation towards the entrance shows an increase. Findings suggest that the net circulation will cause sediment to be deposited within Mercury Bay.

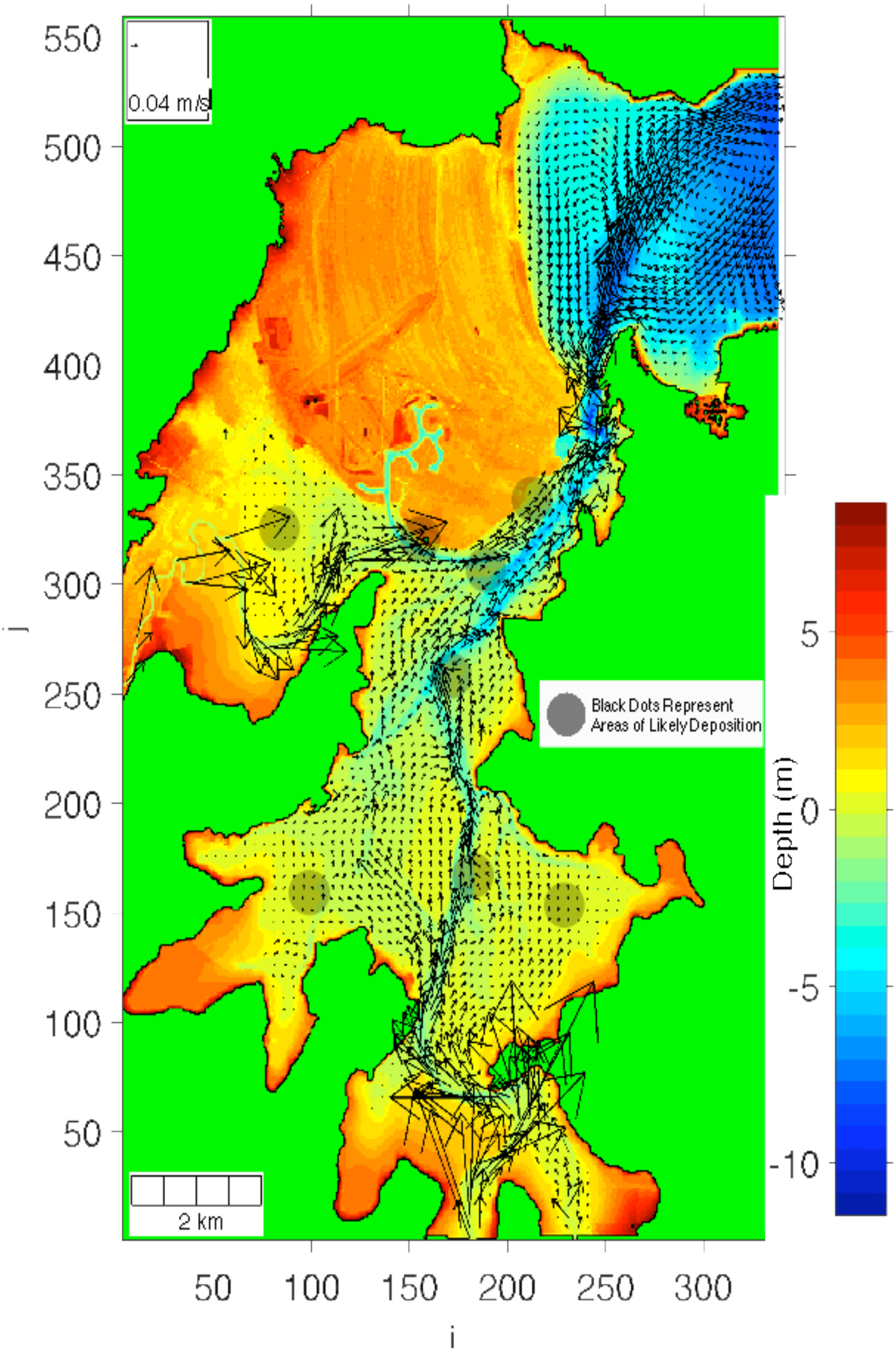

Figure 6.23: Mean residual circulation within Whitianga Estuary. Residual currents are ebb dominated over the 18-day model period. Black dots imply key areas of sedimentation within the estuary.

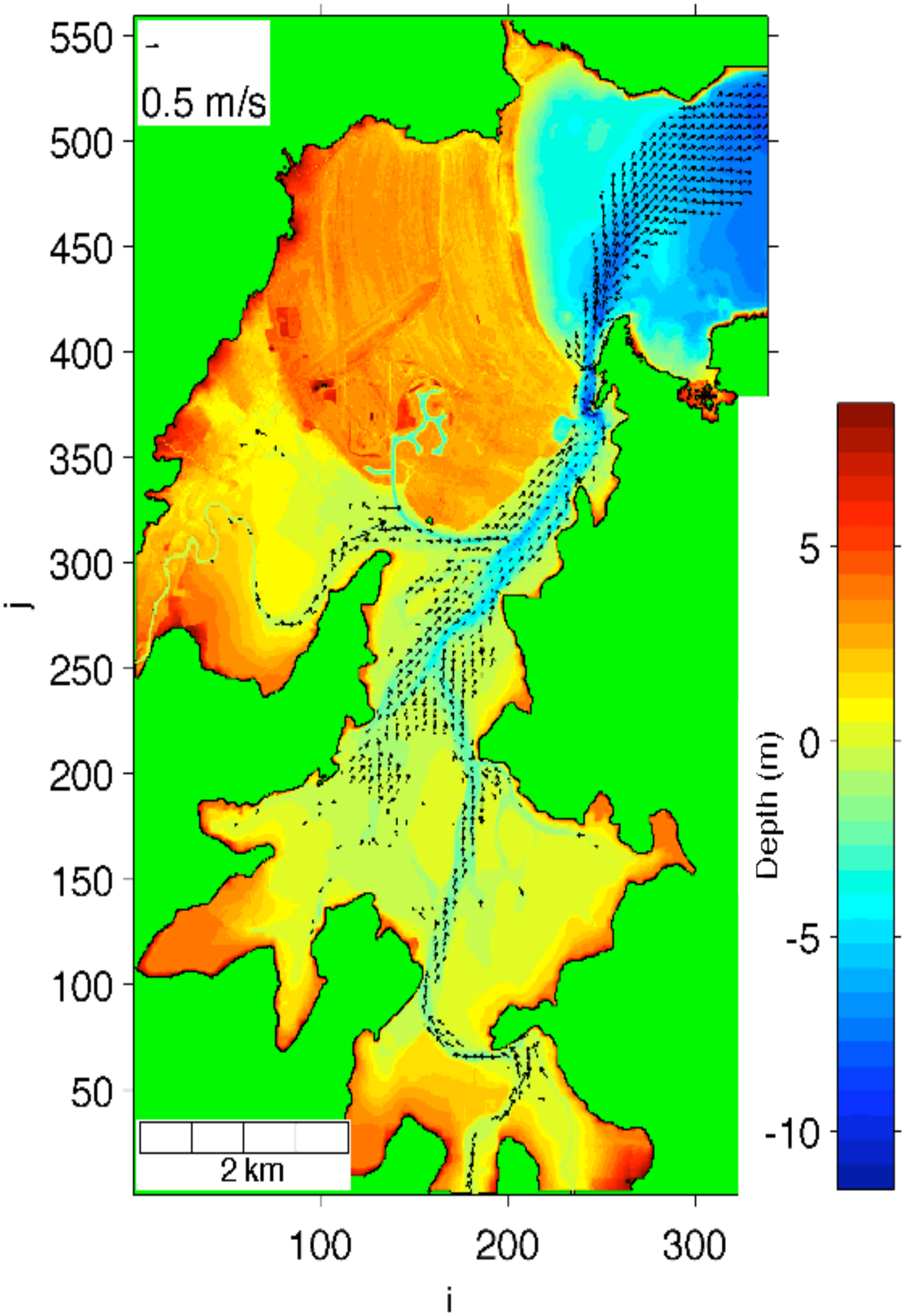

Figure 6.24: Mean residual circulation within Whitianga Estuary for velocities high enough to transport sand (greater than 0.5 m/s).

Black dots are illustrated on Figure 6.23 as zones of sediment deposition. Discussed below will be some key areas of interest for the thesis. Residual circulation on the intertidal flats has a low residual velocity and sediment that is transported to the intertidal flats will become deposited. This is consistent with the high accumulation rates that have been found in the upper reaches of this estuary. One key feature is the high residual velocities present in the river channels. The high residual current velocities seen exiting the rivers indicate the major sediment transport pathways for sediment to the lower harbour. Residual flows exiting the Whangamoro River in the western estuary basin show a sediment transport pathway across the intertidal flats into the dredged waterway navigation channel. This transport pathway indicates a significant zone of sediment deposition (see Figure 6.23).

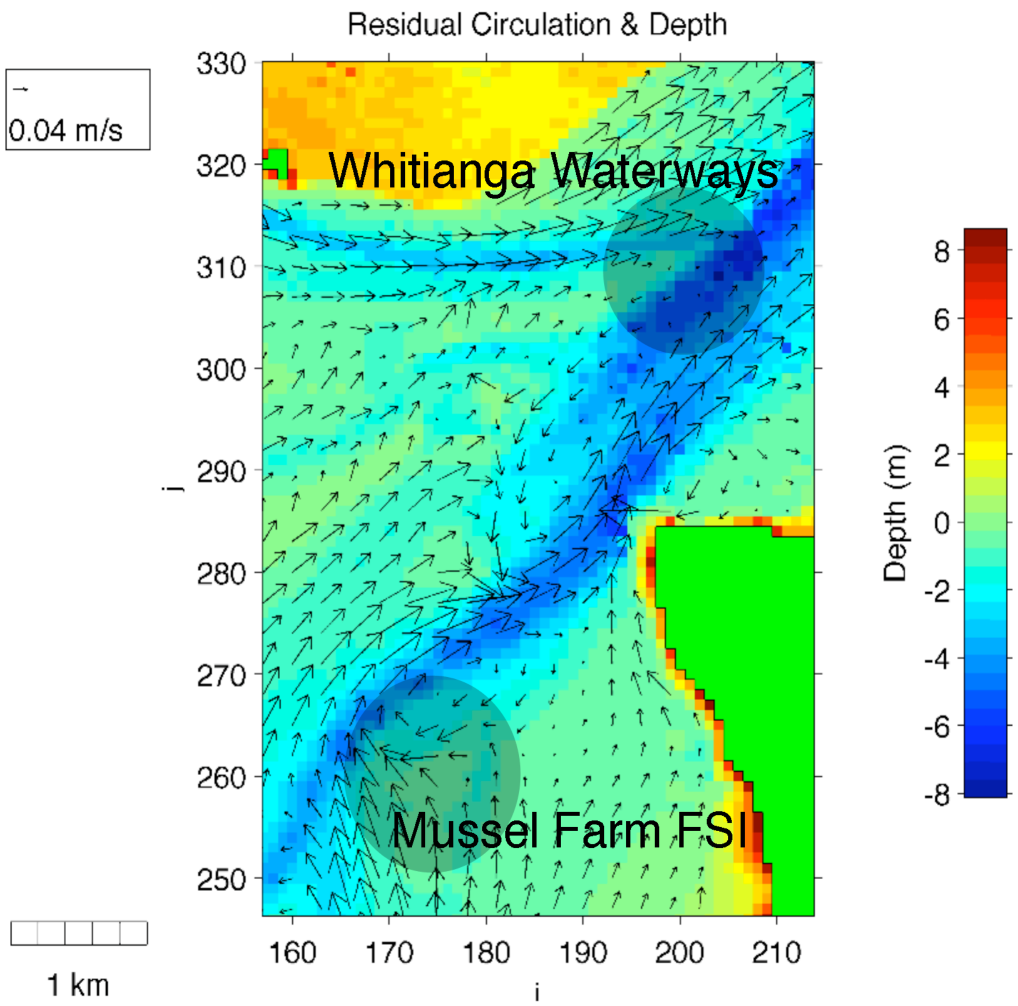

Figure 6.25: Mean residual circulation for the upper estuary. At the top of the image the waterways canal can clearly be seen to enter the main harbour channel.

As illustrated in Figure 6.24, sands are transported into the main channel where velocities are high enough to entrain particles and deposit them into Buffalo Bay and at the upper estuary where the flood tide flows converges before dispersing onto the intertidal flats in the larger southern estuary. Residual flow can be seen to be greater than 0.5 m/s. Furthermore, it clearly shows that any particles that are transported onto the intertidal flats that are coarser than fine sands will likely not be eroded by tidal currents, and therefore will accumulate. The overall residual circulation shows that much of the sediments supplied via the river systems exit the estuary to become deposited into Buffalo Bay.

Converging residual flows illustrated in Figure 6.25 at the Mussel Farm FSI location, show the position of the mobile sand bar that was responsible for smothering the recording instrument during deployment. During periods of high river flow this sand bar is likely to move in a downstream direction, as the converging residual flows become more river dominated.

At the entrance to the dredged waterway channel (where the two sub estuaries meet) residual circulation is very complicated (Figure 6.25). The shallow nature of the intertidal flats can be seen to cause a reduction in residual velocity. However, the waterways and main harbour channels either side have significantly higher residuals. In the wake of the converging channel flow a zone of no residual circulation occurs, representing a zone of high sedimentation. Furthermore, the residual flow exiting the waterway canal shows a tendency to exit more to the north of where the canal is situated. The combined effect of the low flow behind the canal and the tendency for the flow to exit in a more northward direction, provide some evidence to explain the problems connected to the current canal migration and sediment problems at the entrance to the waterway canal.

The entrance of the tidal inlet at Whitianga shows two residual eddy formations (Figure 6.26). The resulting pattern of Eulerian residual velocities that are generated either side of Whitianga Rock creates a residual flow similar to that of a headland (Signell & Geyer, 1990). To the south of Whitianga Rock a counter-rotating phase eddy forms and to the north a clockwise rotating eddy can be seen. The development of the entrance eddies is curtailed due to the narrow nature of the inlet channel and the sand bank/intertidal flats located either side of marina development.

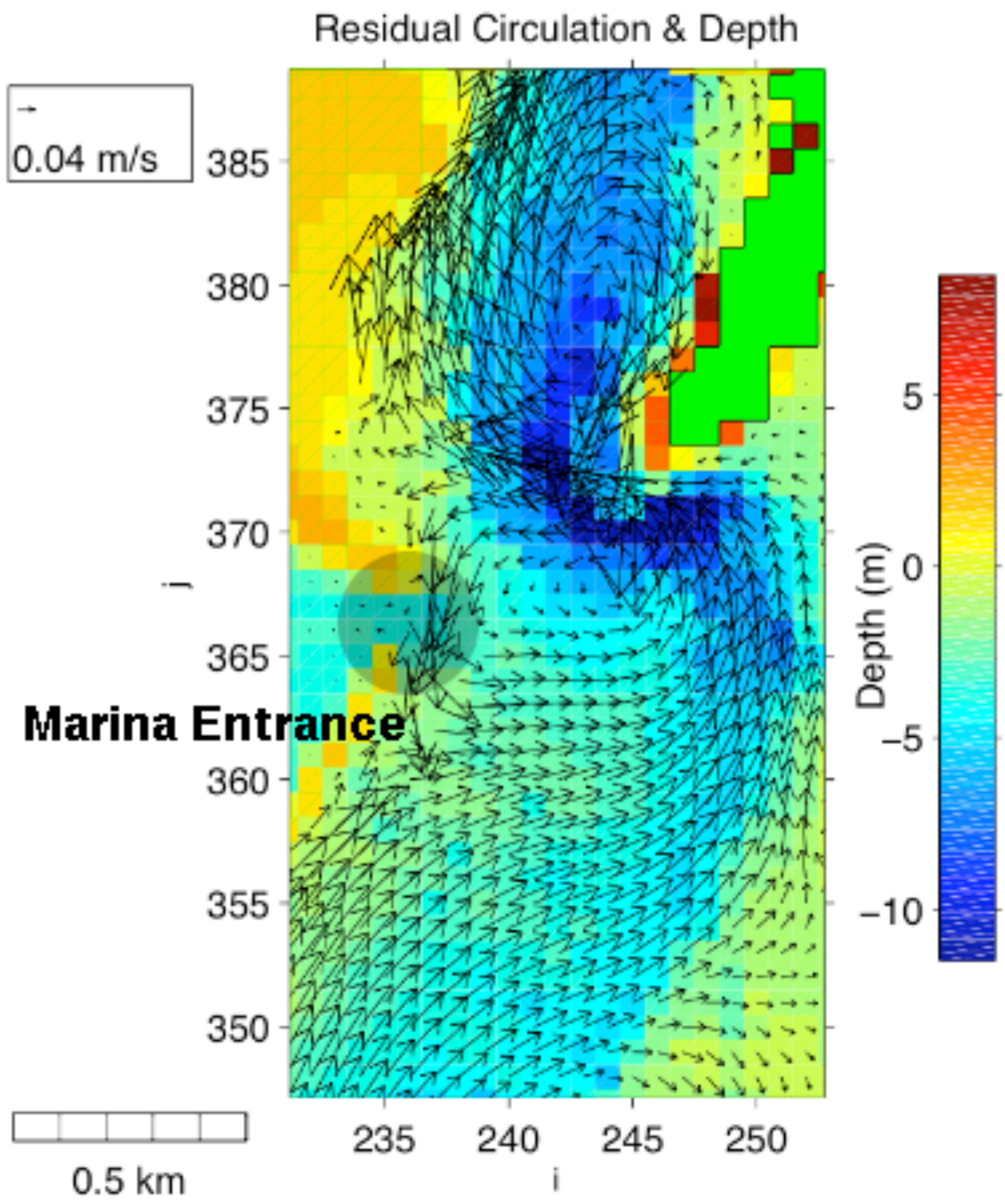

Figure 6.26: Mean residual circulation for harbour and marina entrance.

Residual flow fields adjacent Whitianga Rock are very high. Velocities of greater than 0.5 m/s are evident. This further supports the notion that the resulting focusing of the ebb tide at this location (as discussed earlier) results in the erosion and development of the very deep scour hole at this site.

Residual flow fields at the proposed site for the new boat ramp (bottom left of Figure 6.26) show that the flow in this area will not encourage deposition of fine sediments, as the residual flow velocities found at this location are greater than 0.3 m/s. However, coarse sediments, which can be entrained by the main channel velocities may possibly fall out of suspension and be deposited.

6.6.3 Particle Tracking

The final phase of the model was to undertake particle-tracking modelling of sediments in order to visualize sediment transport pathways and assess the areas of sediment accumulation within the estuary. This was accomplished using Lagrangian model POL3DD, where the pollution dispersion model (POL) is coupled to the calibrated 3DD hydrodynamic model (Black, 1987; Black, et al., 1999). POL3DD is coupled to the hydrodynamic model via sea level measurements and currents. Black et al. (1999) explain that when using a two-dimensional hydrodynamic model for areas such as Whitianga, a logarithmic shaped velocity profile is assumed as the velocities from the hydrodynamic model are vertically averaged. The particle transport model used the velocity and water level fields predicted by the calibrated 3DD hydrodynamic model to track the movement of hundreds of particles, which represent hypothetical sediment inputted. The movement of particles between grid cells and between vertical layers was calculated as a combination of (i) the established fall velocity of the particle being modeled; (ii) horizontal and vertical movement of water; and (iii) random diffusion (Black, 1995).

For the purpose of this thesis, sediment grain size fall velocities for the particle-tracking model were established from fall velocities outlined in Black et al. (1999). Grain size was set to represent sand sized particles with a fall velocity of 0.0220 m/s. This was also the sediment fall velocity recorded by Steeghs (2007) as being in suspension in the entrance. Particles were then released from the three major river inputs, namely the Whenikite, Waiwawa and Whangamoro Rivers. By releasing the particles into the major river systems it was then possible to establish the likely sediment sources responsible for known sediment accumulation sites within the estuary.

The model outputs a time series of the dispersion of each particle released over the run period. The POL3DD model outputs a time series of particle movement (see DVD Appendix V), which gives an approximate path of the suspended particle over the time of model run. Model run time was 10 days of central tidal flows. The central tidal flows are associated with the approximate mean residual circulation. The purpose of this was so that an assessment of the long-term sediment transport pathways could be made.

6.6.3.1 Particle Tracking Results

Results of the particle tracking model show that the intertidal sand flats of the lower estuary, and the areas of intertidal sand flats where the rivers discharge into the estuary, are associated with areas of accumulation of fine sands. The modelled output seen in Figure 6.27 shows that the highest suspended sediment concentrations for sediment supplied and transported by the Whangamoro River occurs at the entrance to the waterway canal development, and on the opposing sand flats where the mangrove stand exists. The key finding of this assessment is that sedimentation in the waterway canal will be an ongoing issue for the developers. The sediment transport pathway can be seen to be ebb dominated as particles move across the intertidal flats and deposit into the waterway canal. From this point, sediment is entrained by the higher velocities located in the main estuary channel and suspended sediment concentrations are much more dispersed as sediments are carried to the tidal entrance. Particles at this point are transported out into Buffalo Bay where velocities diffuse quickly, or accumulated on the intertidal sand flat area located to the south just behind the marina development. This area shows a higher suspended sediment concentration indicative of an area with a tendency for sediment accumulation (see full particle tracking movie Appendix V).

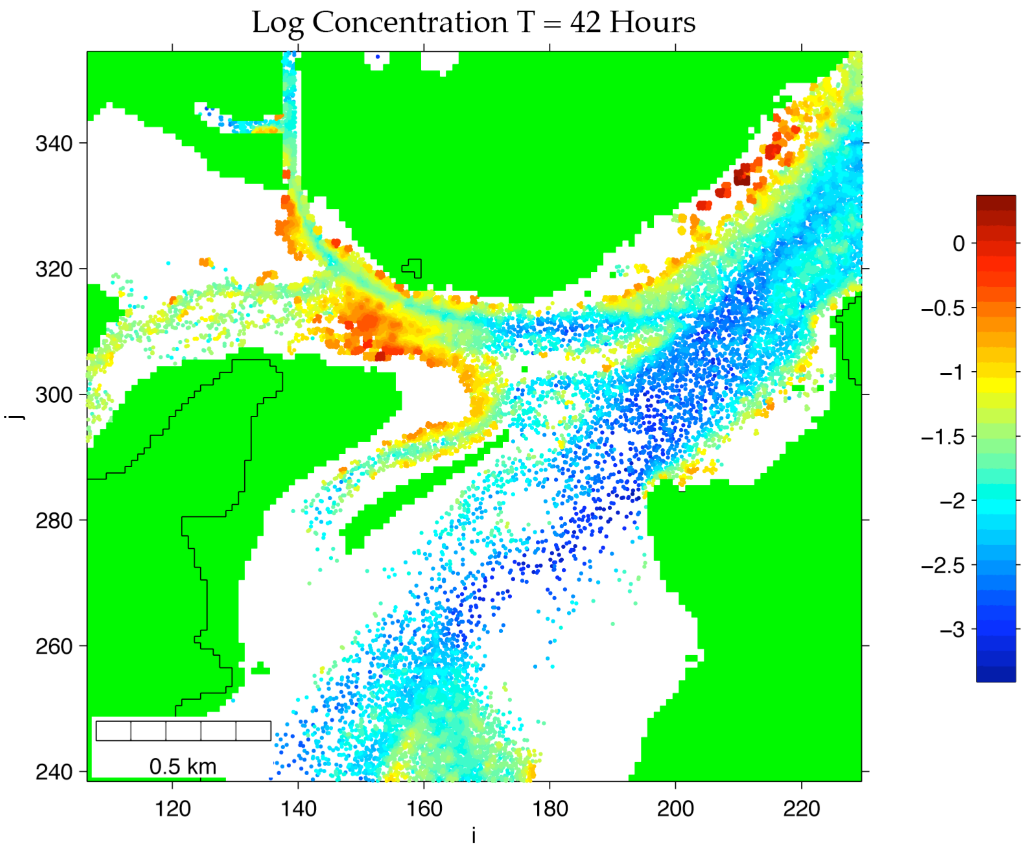

Figure 6.27: Log_{10} of suspended sediment concentration for the upper estuary. The lagrangian particle model of fine sand grains released in the Whangamoro and Waiwawa Rivers. The legend shows the log of the concentration to the base 10. The scale ranges from $10^{0.5}$ (= 5 kg/m) to $10^{-3.5}$ kg/m.

Release of particles into the harbour entrance and the marina was undertaken during a neap tidal cycle in order to represent worst-case scenario aspects for the dumping of dredge spoil that occurs in the inlet of Whitianga marina. It is important to note that particle sizes were reduced to very fine sand and a fall velocity of 0.0025 m/s was used to represent the fine fractions that accumulate in the marina.

Worth noting is that the model resolved vectors of residual circulation show a relatively smooth velocity field, where the residual eddy formation is clearly distinguished. However, as shown in the particle-tracking model undertaken during the neap tidal period for the same location at the entrance, the released particles exhibit a more chaotic behaviour. Particles released during neap tide or at times when climatic conditions result in reduced water levels in the estuary, will subsequently be transported within the entrance, resulting in a portion of sediment being brought back to the entrance of the marina. The potential effect of this weak circular sediment transport will be an accumulation of sediment on the sand flats located either side of the marina and within the marina entrance as shown in Figure 6.28 (full model run Appendix V DVD).

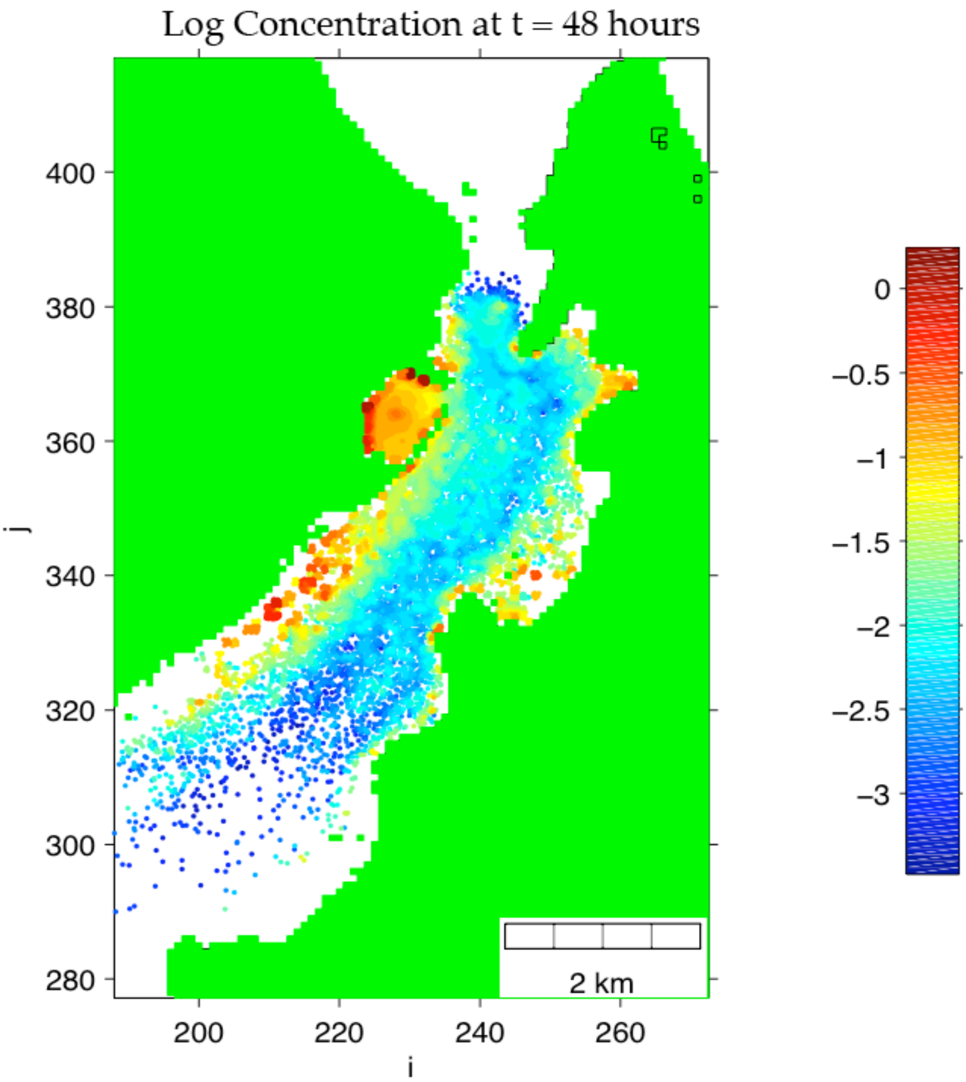

Figure 6.28: Log$_{10}$ of suspended sediment concentration for the lower estuary. Lagrangian particle model of fine sand particles that were released in the harbour entrance and marina. The legend shows the log of the concentration to the base 10. The scale ranges from $10^{0.3}$ (= 3 kg/m) to $10^{-3.5}$ kg/m.

6.7 Discussion

Advances in computer performance and computer resources have enabled sophisticated, physically based numerical techniques such as modelling to now be available for the investigation of complex real-world situations (French & Clifford, 2000). Numerical simulations of real-world scenarios have replaced the physical scale modelling techniques used in the past as the preferred tool for the analysis of complex coastal and ocean problems (French & Clifford, 2000; Williams, 2006). Two-dimensional modelling schemes have had a large application in geomorphic estuarine research. They have proven their worth by providing high spatial and temporal resolution data, illustrating the interactions of practical problems such as shallow water flows over complex terrains (French & Clifford, 2000).

The Whitianga Estuary hydrodynamics model was used for two purposes: a) to assess currents and circulation; and b) to assess sediment transport pathways. Predictions of currents can be used to assist interpretation of sediment transport rates and pathways (Dyke, 1966). The particle-tracking model is one method of assessing sediment transport pathways. However, results from this hydrodynamic model could be used with other aspects of the 3DD model. For example, more in depth sediment transport or advection diffusion models could be created to estimate the sediment transport rates and pathways more directly. Unfortunately, such aspects were beyond the scope and time frame of this thesis. However, a sediment transport model was created for the 10 m grid discussed in Chapter Seven.

Most estuaries have flood channels in which the flood current dominates, and ebb channels in which the ebb current dominates. The process whereby a preferential direction is set up for the residual circulation is known as tidal pumping (Nguyen et al., 2006). Two types of residual circulation exist. These are a) shearing of tidal flow through preferential ebb and flood channels; and b) interaction of tidal flow with the irregular bathymetry (Nguyen et al., 2006). Interaction of the tidal flow with irregular bathymetry is found in most estuaries. An example of such an interaction can be seen in the formation of residual eddies and converging tidal flows associated with Whitianga Rock. The resulting bathymetric and tidal interactions of Whitianga tidal inlet result in a very complicated hydrodynamics within the 3 km tidal harbour.

Sedimentation due to the development of eddies can be seen to effect the entrance to Whitianga Marina where a persistent eddy forms during both ebb and flood tides. It has been suggested that sand banks situated in the vicinity of coastal headlands (for example the sand bank forming off the tip of Whitianga marina) arise from a phenomena known as "tidal stirring" or the "teacup effect" which is associated with tidal residual eddies (Signell & Harris, 2000; Bastos et al., 2004). This process involves an inward directed pressure gradient that causes sand to accumulate in the centre of the residual eddy, and become "stirred" by the tidal flow (Signell & Harris, 2000; Bastos et al., 2004). Because the sediment cannot readily escape from the centre of the eddy a certain proportion is deposited (Signell & Harris, 2000; Bastos et al., 2004).

The nature of the marina design having breakwater structures for protection from wave attack results in a friction boundary where the development of an eddy occurs. The creation of this eddy results in the reversing of the tidal flows. With reversal of tidal circulation, flow accelerates in the wake of the structures, the free stream channel currents of the harbour decelerate, and an eddy evolves (Black & Gay 1987; Black et al., 2005). The end points of the breakwater define the extent of eddies, where zones of recirculating flow, with very low velocities relative to the downstream current, evolve in the centre of the Marina entrance. Suspended sediment is transported into an eddy across the shear layer that separates it from the core flow. Ebbesmeyer et al. (1991) have shown that several tidally induced eddies form along the eastern basin of Dungeness Spit in the Strait of Juan de Fuca. These eddies have been found to be partly responsible for the deposition of materials on the shores of the southern end of Lopez Island. Taking findings by Ebbesmeyer et al. (1991) into consideration, it can be suggested that the eddy at the entrance of the Whitianga marina is responsible for the accumulation of sediment that occurs here. Furthermore, the residual circulation shows that a large counter-clockwise eddy formed by Whitianga Rock will have a tendency to transport suspended sediment to the entrance of the marina, exacerbating the infilling of the marina entrance.

Sediment deposition predominantly occurs around slack water tide in areas where current velocity is less than the entrainment threshold (Haslett, 2000). Within Whitianga Estuary sediment deposition is occurring on much of the upper estuary intertidal flats where residual circulation and current velocities are shown to be very weak. Further evidence of sediment deposition over the upper estuary intertidal flats is apparent by the high sedimentation rates for the upper estuary as calculated by ^{210}Pb dating (Chapter Five). As the intertidal flats accumulate sediment, water levels reduce, and this leads to a reduction in current velocities, which aggravates the sedimentation problem. Therefore, the importance of catchment management and practices to reduce the sediment supply to Whitianga Estuary is important for the longevity of this community resource.

6.8 Conclusion

Given the 20 m model grid resolution, the hydrodynamic model calibration shows that the modelled outputs accurately predict the tides and tidal currents within Whitianga Estuary. Results from the particle-tracking model concur well with current evidence of local sediment accumulation problems within the estuary. However, some of the limitations include a lack of full hydrographical data for the entire estuary, model resolution limitations due to computational time restrictions, and a lack of localised weather data.

It can be seen that the low residual current velocity on the intertidal flats and channel edges will cause any sediment entering the estuary to settle in these areas. Analysis using Lagrangian particle tracking, confirms that sediment settles on the edges of the channels and in the dredged upper Whitianga waterway canal entrance channel. Therefore, factors such as climatic pressures, river flows, tidal cycles, and wave set-up through the inlet could all result in an outward or inward movement of sediment.

The regular eddy formation that occurs at the marina entrance can be attributed to the sedimentation issue that arises at this location. This will remain an ongoing issue for the marina. The implication for the marina is that dredging of the accumulated sediment is a cost needing to be factored into the development. For this reason it is recommended that a complete investigation be carried out to ascertain whether a suitable design change is (i) feasible to reduce the problem; and (ii) economically worth undertaking to diffuse this issue.

Another key point that should not be overlooked is the disposal of dredged material from the marina into the scour hole adjacent to the entrance to the marina development. Residual circulation and particle tracking show that there is a high likelihood that a portion of the material deposited at this point will be carried back to the entrance of the marina due to the large residual eddy formation that is situated between Whitianga Rock and the present marina. Furthermore, particle tracking shows that disposal of sediment within the entrance during the wrong stage of the tide, or during atmospheric conditions that reduce the current velocities in the entrance, can result in substantial suspended sediment concentrations on the intertidal flats above and surrounding the marina.

Residual circulation shows ebb domination, which results in a down estuary movement of sediment. Low residual circulation on the intertidal flats of Whitianga Estuary, indicate that sediments that are entrained and carried to this vicinity will be deposited and remain to accumulate. Within the main channels it can be seen that residual circulation is much stronger suggesting that fine sand particles will be transported.

CHAPTER SEVEN: PROPOSED BOAT-RAMP APPROACH CHANNEL MODELLING

7.0 Introduction

It is the intention of the Whitianga Community Council to develop an additional boat-ramp to service the community need for small craft access to the sea. One suggested site is upstream of the marina at an existing facility located at the eastern end of Dundas Street. At present there is no design criteria for the new ramp as the proposal is still in its infancy.

The establishment of a new boat-ramp and associated approach channel will require initial dredging, as well as probable future maintenance dredging. There is also the possibility of potential adjacent shoreline erosion. Accordingly, optimisation of the design depends on developing an extensive understanding of the sediment transport processes occurring within the lower estuary tidal inlet. Advancement in the development and application of numerical models that couple the relevant hydrodynamic mechanisms driving sediment transport with associated morphological response, has enabled assessments of the feasibility of the navigation channel design to be undertaken.

This chapter models various potential channel configuration scenarios. These scenarios are then used to assess the feasibility of the proposed location for a boat-ramp, including the relative amount of dredging for an approach channel and the relative ongoing maintenance dredging that would be required.

7.1 Design Criteria

Design criteria that needed to be considered were (a) that the ramp would be workable to small recreational trailer craft throughout the tidal cycle; and (b) that the proposed boat-ramp be situated adjacent to the marina where ample public parking for trailer vehicles is available. In order to meet these criteria, it would be necessary to dredge the approach channel for the boat-ramp to a depth of 1 m below low tide (LWS) so that small craft can navigate the channel at low tide. Also the boat-ramp would need to be established in close locality to the marina.

7.2 Methods

The 3DD model was used to undertake scenario modelling of the proposed approach channel. The model was nested inside the 20 m larger grid (discussed in Chapter 6) at a 10 m resolution. The x-origin of the 10 m nested grid is located at grid cell 108 of the 20 m grid, and the y-origin of the 10 m grid is located at grid cell 260 of the 20 m grid. The size of the 10 m nested model grid is 2950 x 1750 m. Each of the boundaries of the 10 m model were forced through the extraction of velocity and water level data from the 20 m calibrated model. Navigation channel designs are constructed around the 10 m grid size. Therefore, channel sizes are limited to 10 m increments. Channels were designed using SURFER™ and the initial bathymetry was used as baseline and subtracted from the modified to calculate the volume of material removed.

Hydrodynamics for each of the scenarios were modelled during a mid spring tidal period. The numerical simulations were undertaken for a period of 10 tidal cycles for each scenario. A grid co-ordinate for the central channel was extracted from the initial 10 m scenario water levels, and velocities were extracted compared to the associated 20 m model grid cell. This was the only model performance measure undertaken for the 10 m numerical simulations. The author recognises the need to undertake calibration and the need to assess model performance. However, as the forcing boundaries for the nested models are extracted from a calibrated model it is assumed that no more calibration is required.

7.2.1 Sediment accumulation

Sediment accumulation for the proposed scenarios was assessed in three ways:

1) A 3DD Rapid sediment transport model was undertaken to assess bedload transport. Parameters used for this model were:

Median grain size = 0.18 mm

Sediment density (quartz) = 2650 kg/m^3

Bed porosity = 0.65 (65%) sand particle to pore space ratio.

2) A 3DD sand transport model was simulated to assess the movement of the sand within the nested grid area. This model takes into account the sediment in suspension.

Parameters used for the sand transport model were:

Medium grainsize = 0.18 mm

Bedload threshold = 0.25 m/s

Suspended velocity = 0.5 m/s

Sediment thickness = 10 m

3) Assessment of the 20 m grid particle tracking findings and use of the Shields equations were undertaken to calculate whether particles would fall out of suspension due to a reduction in velocity.

The Shields parameter is a measure of initial sediment motion in a steady flow (Nielsen, 1992). The Shields parameter can be defined as:

$$\psi = \frac{\tau_b}{[\gamma(S_s - 1)d]}$$ (Equation 7.1)

Where, Ψ is the Shields parameter, τ_b is the shear stress exerted by the fluid flow on the bed, γ is the specific weight of the fluid (i.e. seawater), S_s is the specific gravity of the sediment, and d is the diameter of the sediment particle.

Equation 7.1 can be simplified by replacing the bed shear stress (τ_b) with its equivalent, ρfU2/8. Where ρ is fluid density, f is the Darcy-Weisbach friction coefficient, and U is fluid velocity (Nielsen, 1992). The equation then becomes:

$$\psi = \frac{(\rho f U2/8)}{[\gamma(S_s - 1)d]}$$ (Equation 7.2)

Where $\gamma = \rho g$ (g = acceleration of gravity = 9.81 m/s^2), f = 0.01 (typical of bed roughness), and $S_s = 2.5$. This further reduces the equation to:

$$\psi = \frac{0.000170U2}{d}$$ (Equation 7.3)

Equation (7.3) was solved for the current speeds modelled inside of the proposed approach channel for a range of sediment particle sizes that have been found in suspension in the estuary.

7.3 Problems Encountered Nesting

Within Whitianga Estuary there are large areas of intertidal flat. This caused considerable problems with the nesting of the 10 m grid models. When the model was forced over a wetting and drying boundary (i.e. areas of intertidal flats), acceleration terms became incorrect. Problems arose when the model cell size was reduced over boundaries that contained significant changes in topography. For example at a 20 m grid resolution some areas of the estuary were interpreted as being underwater. When the resolution of the model grid was increased to a 10 m resolution these areas could then be interpreted as intertidal sand-flats. When the boundaries were extracted for the nested grid, the zones that became intertidal contained velocities that were significantly too high for intertidal areas, which caused instabilities in the nested model. The first step taken to decrease this error was to limit the nested area so that intertidal areas were very small. The second step was to artificially extend the grid at each boundary by ten cells to allow some cells of the model to stabilise before forcing the actual modelled area. The final step was to create a two-dimensional eddy viscosity file and increase the eddy viscosity on the wetting and drying boundary surfaces.

After undertaking the above steps to stabilise the nested model, outputs calibrated well against the measured data and replicated circulation predicted in the coarser 20 m forcing model.

7.4 Modelled Scenarios

For the purpose of determining the hydrodynamic effect of dredging a boat-ramp approach channel in the locality of Whitianga Marina, hydrodynamic numerical modelling of tidal circulation and river discharges into the harbour were undertaken. Alternative configurations of the dredged boat-ramp channels were investigated with the hydrodynamic model.

Initial model scenarios were undertaken using the 10 m model grid where no morphodynamic alterations had occurred (see Figure 7.1).

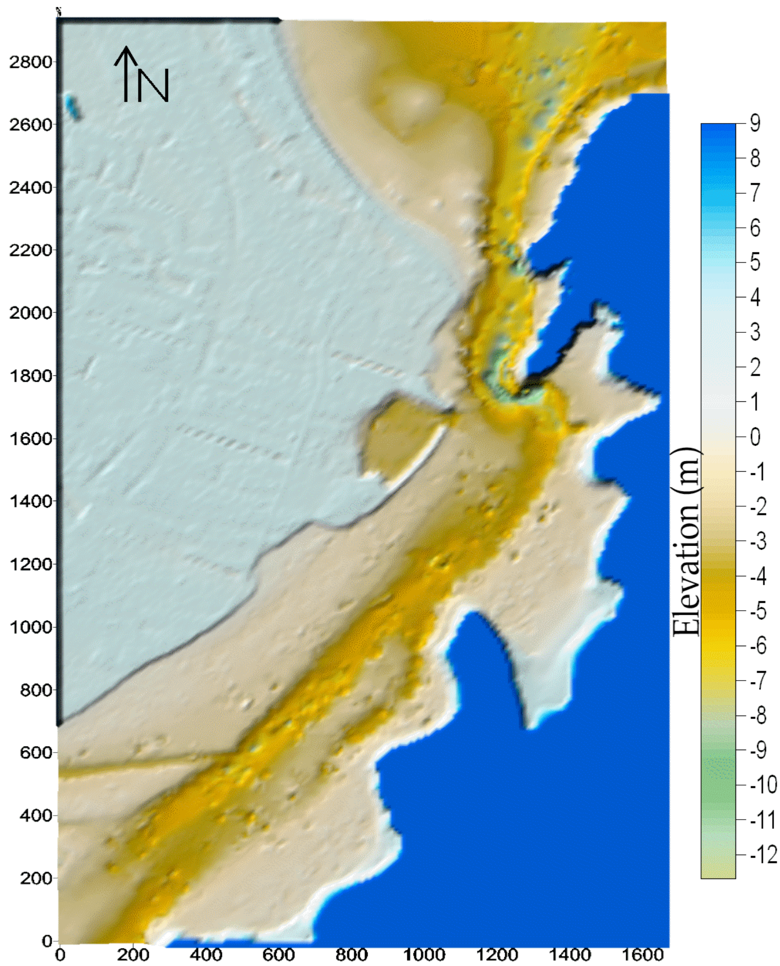

Figure 7.1: Digital terrain model of the nested 10 m grid resolution area. Figure axis represents grid size in metres. The forcing boundaries were designed with the minimal possible wetting and drying area.

Hydrodynamic results from the initial model became the benchmark for hydrodynamic comparisons of all scenarios modelled. This allowed for an assessment of the reduction in tidal velocities due to the dredging of each approach channel to be made.

7.4.1 Scenario One

Scenario one is a basic channel design (Figure 7.2). It is designed to be 20 m in width. The design characteristic of scenario one is a basic dredging of the existing boat-ramp and access route. Table 7.1 shows that this basic design requires the removal of approximately 4600 m^3 of sediment. This makes this scenario simple and minimises the volume of sediment removed.

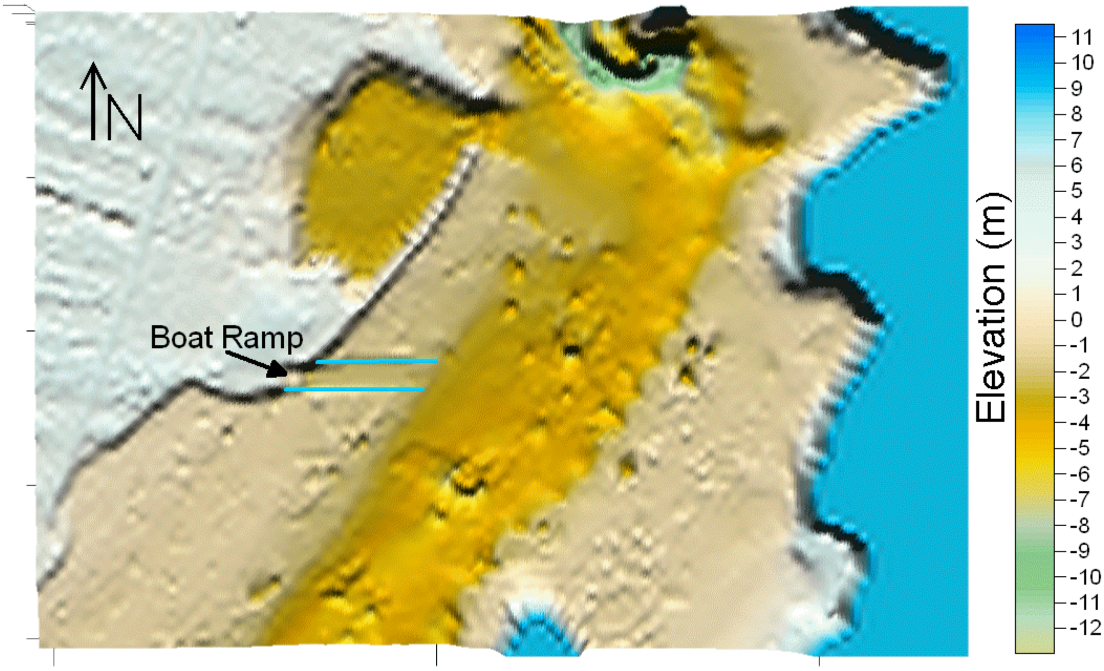

Figure 7.2: Scenario one. This scenario uses the existing loading ramp with a navigation channel dredged to 1 m below LWS so it is workable throughout the tide.

7.4.2 Scenario Two

Scenario two takes advantage of the shortest dredged area design (Figure 7.3). This scenario involves dredging a simple channel situated at right angles to the main harbour channel. The analysis of volume of sediment removed for this potential design (shown in Table 7.1) will require the removal of about 3900 m^3 of sediment. The shortcomings of such a design are that the channel is situated at right angles to the flow in the main channel, which may be expected to act as a sediment trap.

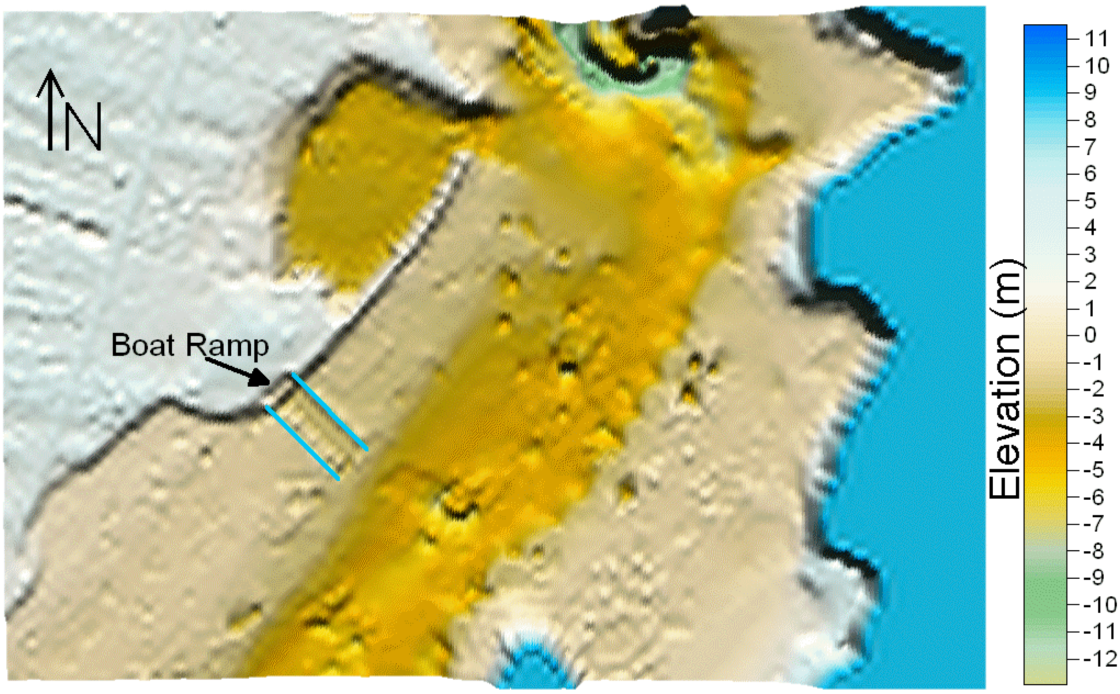

Figure 7.3: Scenario two is designed to have the shortest dredged area, which will reduce costs. Scenario two navigation channel has been dredged to 1 m below LWS so it is workable throughout the tide.

7.4.3 Scenario Three

Scenario three is a combination of scenario one and scenario two (Figure 7.4). For this design the opening of the approach channel has been widened in an attempt to slow down the migration of the dredged channel, which may occur at this point due to the high velocities that are occurring in the main harbour channel (see Figure 7.9). It is suspected that due to the high velocities that are present in the main channel, the entrance to the approach channel will be pushed to the north (towards the harbour entrance), resulting in sediment accumulating at this location. Scenario three is designed to take advantage of the higher outgoing current velocities at this location, using ebb flows to flush the lower channel section.

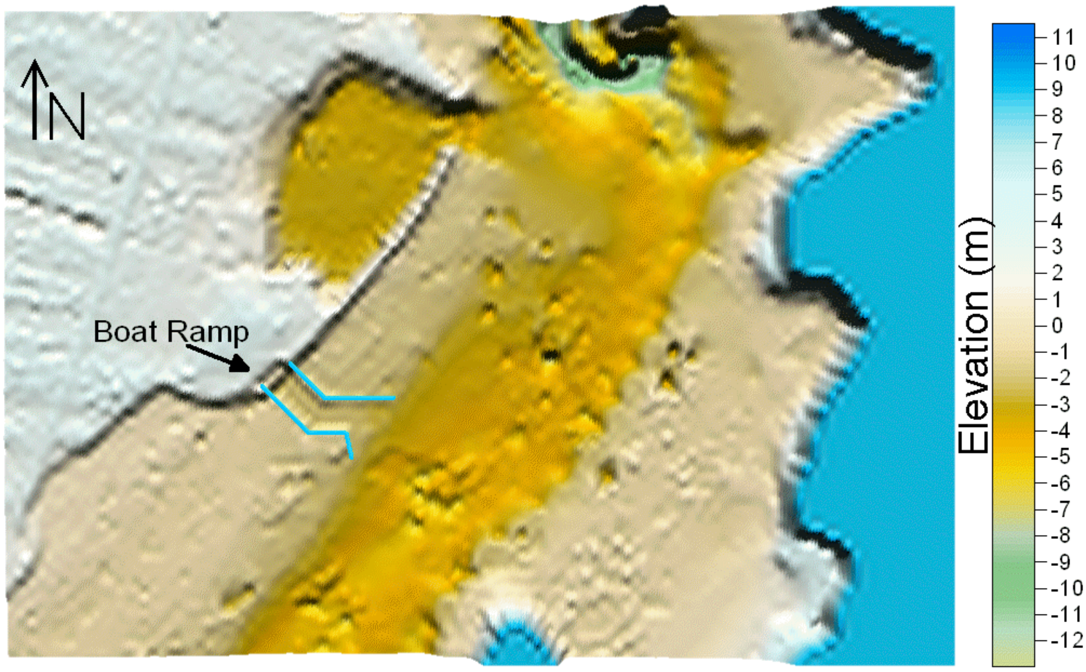

Figure 7.4: Scenario three is designed to be a combination of scenario one and scenario two. This scenario has been dredged to 1 m below LWS so it is workable throughout the tide.

7.4.4 Scenario Four

Scenario four is an expansion of the design seen in scenario three (Figure 7.5). The design for scenario four involves the removal of about 7250 m^3 of sediment for the formation of the approach channel (see Table 1). Like that of scenario three, scenario four has been designed to alleviate the sedimentation and shifting of the channel. It is anticipated that by diversion of a portion of the tidal stream (which can be seen in Figure 7.13), the current velocity in the channel will remain high enough to entrain sediments into suspension. It is also anticipated that by dredging the channel into a half round to allow for through flow of currents, velocities will be maintained and therefore sedimentation will be prevented. This will reduce maintenance costs associated with regular dredging of such estuarine developments.

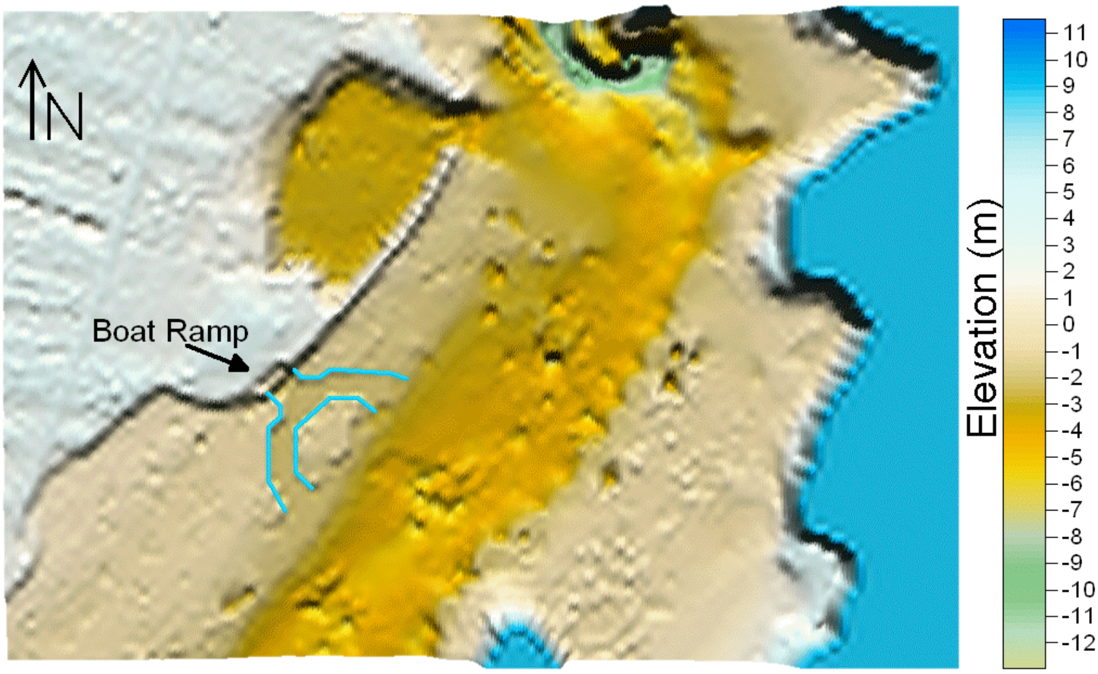

Figure 7.5: Scenario four would require the largest amount of dredging. It has been designed to allow for circulation so that currents can pass through to entrain sediments. Scenario four has been dredged to 2 m below LWS so it is workable throughout the tide.

7.4.5 Scenario Five

Scenario five envisages a simple straight dredged channel design (Figure 7.6). It is similar to scenario two in that it is a simple straight channel. However, the design for scenario five is to dredge the channel to twice the width (40 m) of scenario two. Also, the entrance closest to the main harbour channel will be increased in order to reduce its potential for infilling. Additionally, the channel is to be dredged to a depth of 2.5 - 3 m, and the sides have been contoured in order to reduce the slope, which will represent a more natural channel design. Therefore, the channel will be in a more equilibrium state for an area of sandy morphology. The design criteria was to experiment with “over dredging” to assess whether this approach would show a more long-term stable platform for small navigation channels.

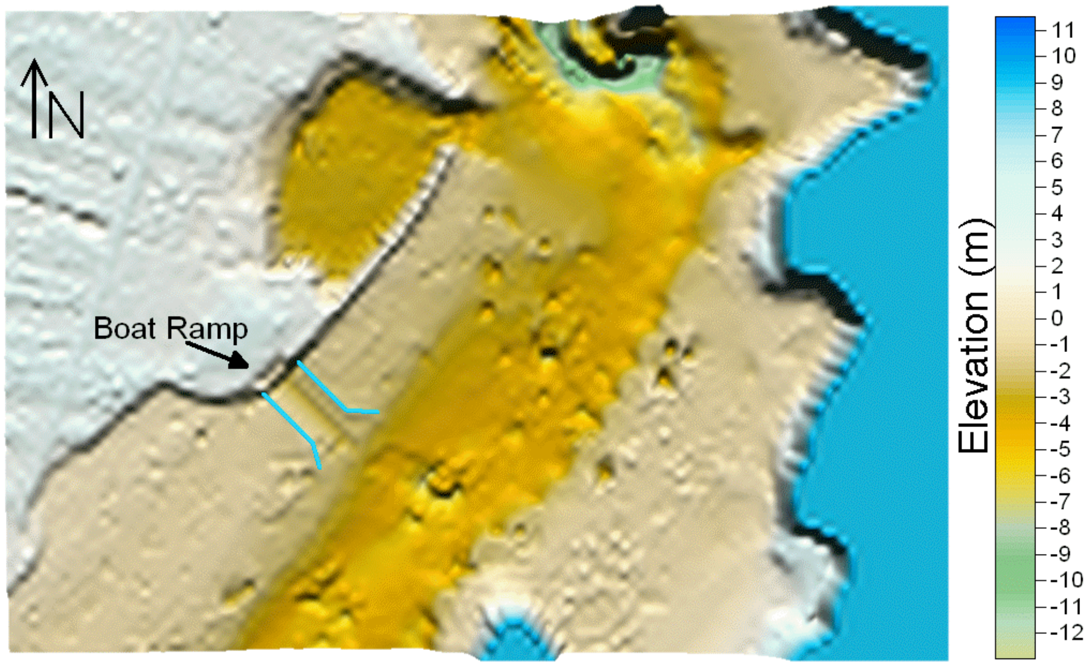

Figure 7.6: Scenario five is designed to have the shortest dredged distance such as in scenario two. However, it has been "over dredged" to a depth of 2.5 - 3 m and a width of 40 m. The channel edges have been contoured to make shallow sloped sides. The overall dredged volume is very large at about 7250 m^3.

7.4.6 Scenario Six

An alternative boat-loading zone is assessed in scenario six. As shown in the initial hydrodynamic model (Figure 7.9), there is an area located behind the marina development that is sheltered from the flood tidal flow. Although this area is prone to sedimentation, the sheltered nature of this bay would make an ideal boat-launching zone. The design of scenario six is a 20 m wide dredge approach channel that turns through a right angle into the sheltered bay created by the reclaimed land to the south of the marina development (Figure 7.7). Due to the extended nature of the approach channel in this location, the volume of material required to establish this channel is approximately 6400 m^3.

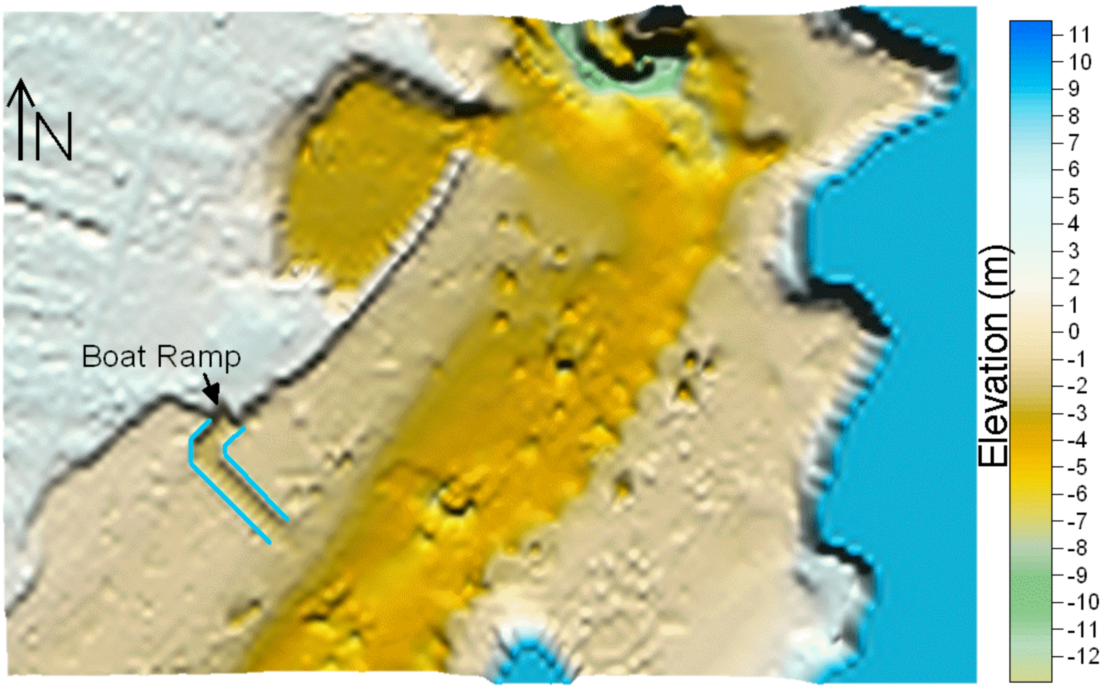

Figure 7.7: Scenario six has been shifted so that the loading zone is sheltered from waves. This scenario the navigation channel has been dredged to 1 m below LWS so it is workable throughout the tide.

Table 1 shows the volume of material that will be required to be removed for each scenario. The two largest proposed approach channels are those relating to scenarios four and five where the quantities of sediment to be removed are above 7000 m^3. Scenario two and three can be seen to require the least amount of dredging and therefore, can be considered the most cost effective designs.

Table 7.1: Volume of material needing to be dredged for the creation of each boat-ramp approach channel.

Scenario	Volume Dredged (m^3)
Scenario One	4600
Scenario Two	3900
Scenario Three	4000
Scenario Four	7250
Scenario Five	7250
Scenario Six	6400

7.5 Results

The following section presents the results of the modelled hydrodynamics for each boat-ramp approach channel scenario. It also presents the findings from the sediment transport modelling and accumulation assessments.

7.5.1 Numerical Simulation results

Initial model results show that the proposed area where the boat ramp is to be developed has very low tidal velocities during incoming flood tidal flows, with velocities reaching only 0.2 m/s (Figure 7.9). These flood flows are seen to be sheltered from the intertidal sand flats on the north-western side of the 3 km harbour entrance. The orientation of the tidal inlet causes the flood tidal flows to travel into the southern side of the entrance. The position of the marina also acts to shelter this location from the current, and creates a barrier to the flood tidal flow. During periods of ebb flow, current velocities increase significantly with velocities reaching speeds of 0.5 m/s.

The morphological changes associated with the dredging for scenario one can been seen to produce a significant reduction in velocity (Figure 7.10). Dredging of the approach channel can be seen to have some effect on the current velocities in this location, with a reduction in flow for this scenario resulting in a 27 % decrease in the current velocity at this location (Figure 7.8). Velocities reduce from approximately 0.46 m/s during peak ebb flow to 0.36 m/s, and during flood flows they reduce from 0.18 to 0.14 m/s.

Scenario two consists of the simplest design through the shortest section of intertidal sand flat. Current velocities for this design show a reduction by 35 %. This results in current speeds reducing from 0.45 to 0.31 m/s during the ebb tide and 0.2 to 0.13 m/s during the flood tide. A close inspection of the velocity vectors during ebb flows (seen in figure 7.11) shows that there is some disturbance in the vector pattern at the entrance to the approach channel. This indicates that the ebb flow is showing a tendency to be deflected into the entrance of the channel. Such patterns suggest deposition will occur on the updrift side of the channel.

The design objective of scenario three is to take advantage of the ebb flow current velocities, by partial re-direction into the opening of the dredged channel, in a hope to maintain a stable inlet and to improve velocity reduction in the channel. The velocity pattern shows an affinity to change its flow path (Figure 7.12). Unfortunately the flows in the main channel are too strong to significantly change the current direction. Therefore, the added expense of extra dredging may outweigh the small benefits that this design would create. However, some improvement in velocity "drop-off" did occur with a reduction of 24 % occurring, which is the best of the simple design cases (Figure 7.8). The peak ebb velocity drops from 0.45 to 3.6 m/s while the flood flows reduce marginally from 0.21 to 0.19 m/s.

Hydrodynamics for scenario four are illustrated in Figure 7.13. Results show that during flood tide there is little circulation through the dredged channel. On the other hand, tidal currents during the ebb tide can be seen in Figure 7.13 (image to the right) to show signs of circulation through the channel. Overall, scenario four shows the lowest percentage of "drop-off" in current velocity with a 15 % reduction being measured. Ebb flows show a reduction of 0.05 m/s with speeds reducing from 0.45 to 0.4 m/s and flood flows reducing from 0.21 to 0.2 m/s (Figure 7.8). To mitigate the reduction in current velocities caused by a dredged channel, it would appear that scenario four is the best option.

Scenario five involved "over dredging" of the navigation approach channel. Figure 7.14 shows a large reduction in the flow velocity in comparison to that of the pre-dredging model run initially undertaken. Velocities reduce a considerable 42 %. As a result the initial ebb speeds reduce by 0.17 m/s and flood speeds by 0.09 m/s.

The current velocities measured at the proposed location for scenario six show a lower initial velocity than those of the previous five scenarios. This is because the location of scenario six is situated to take advantage of the sheltered area to the south of the marina, which is ideal for launching boats (see Figure 7.15). As with all the modelled scenarios, it can be seen that the current velocities over the dredged channel reduce. Nevertheless, the current reduction measured for scenario six is very significant (64 %). The reduction in velocity during flood flows in the dredged channel is so great that velocities become significantly reduced (Figure 7.8). Although this makes for an ideal boat loading area, sedimentation in the channel would likely become a significant issue for this development and there will be an added expense associated with an expected increase in maintenance dredging.

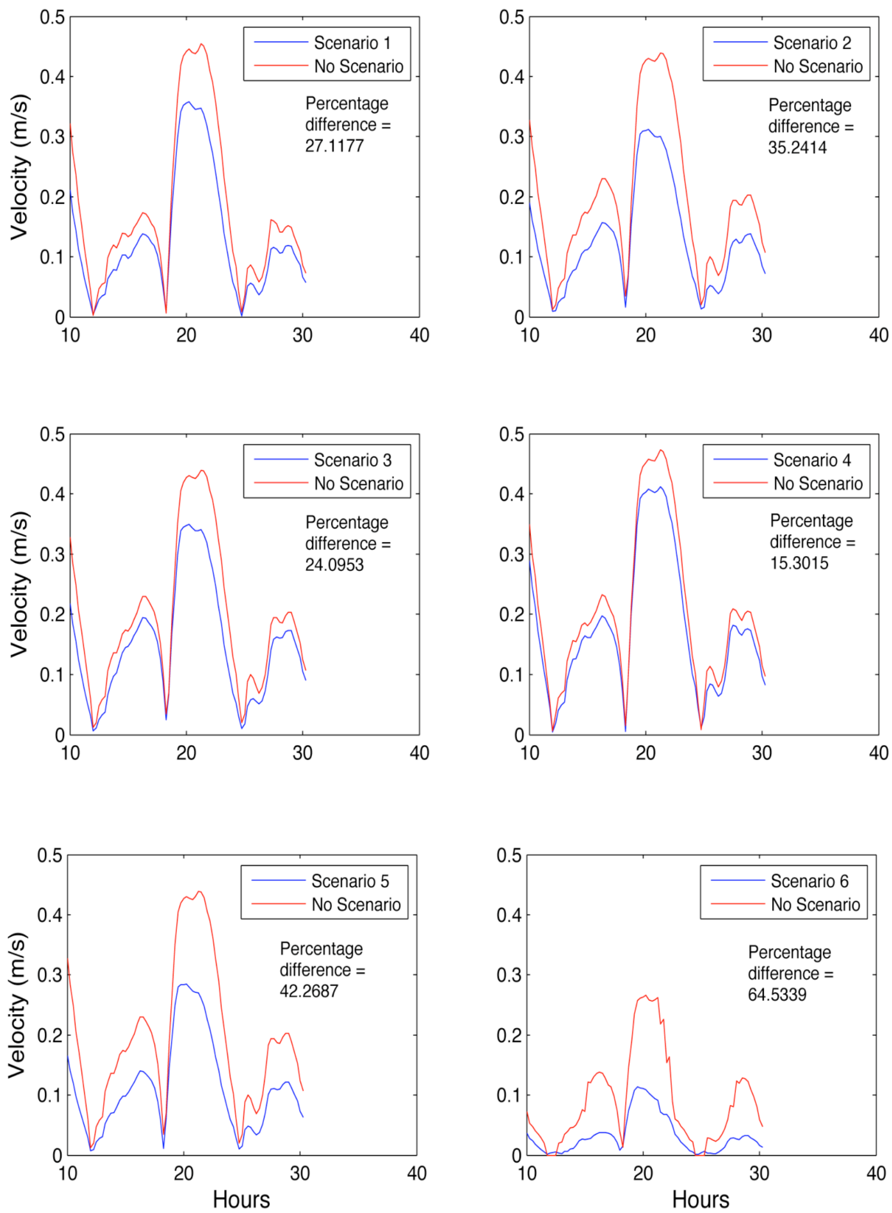

Figure 7.8: Velocity plots showing the reduction in velocity in the approach channel associated with each of the proposed scenarios, compared to that of the initial baseline modelled currents.

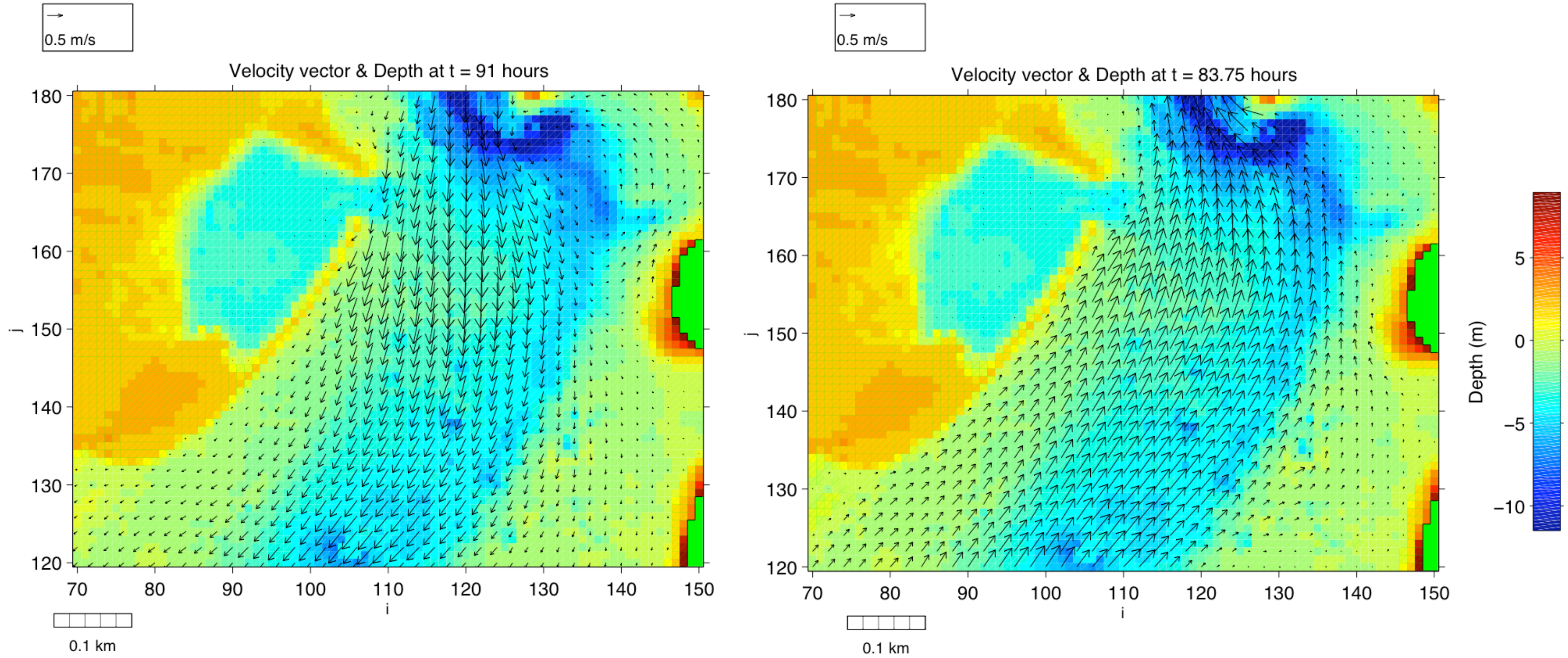

Figure 7.9: Hydrodynamic model results for the initial 10 m model grid. Image to the left gives the flood tidal currents and image to the right gives ebb tidal currents. During the flood tide the tidal velocities in behind the marina development are seen to be very low.

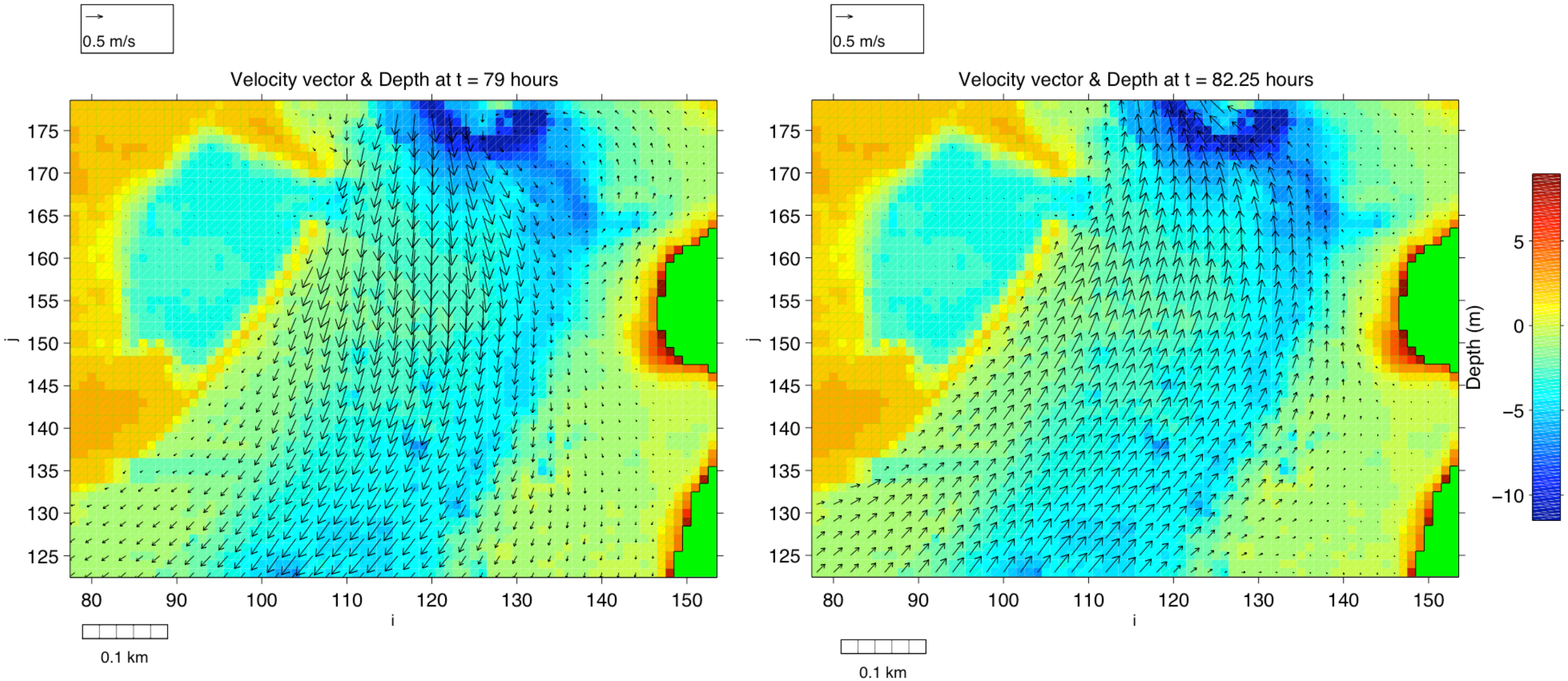

Figure 7.10: Scenario one is a basic dredged channel. The design is based around the existing shore boat-ramp infrastructure. During both flood and ebb tides current velocities in the channel can be seen to decrease. Velocities tend to be more effected at the head of the channel.

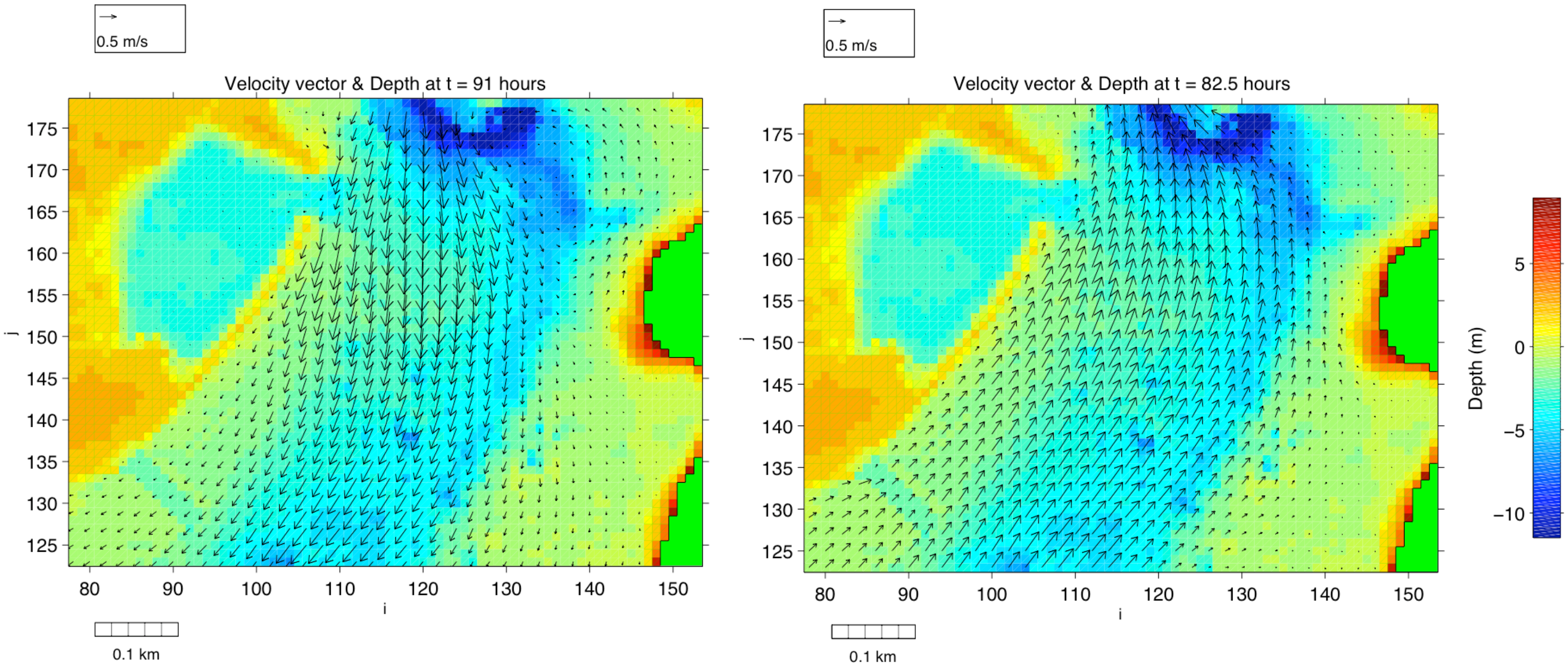

Figure 7.11: Hydrodynamic modelled results for scenario two. Scenario two hydrodynamic results show that like scenario one there is a decrease in tidal current velocity in the flood tide (left) and ebb tide (right) over the dredged boat-ramp channel.

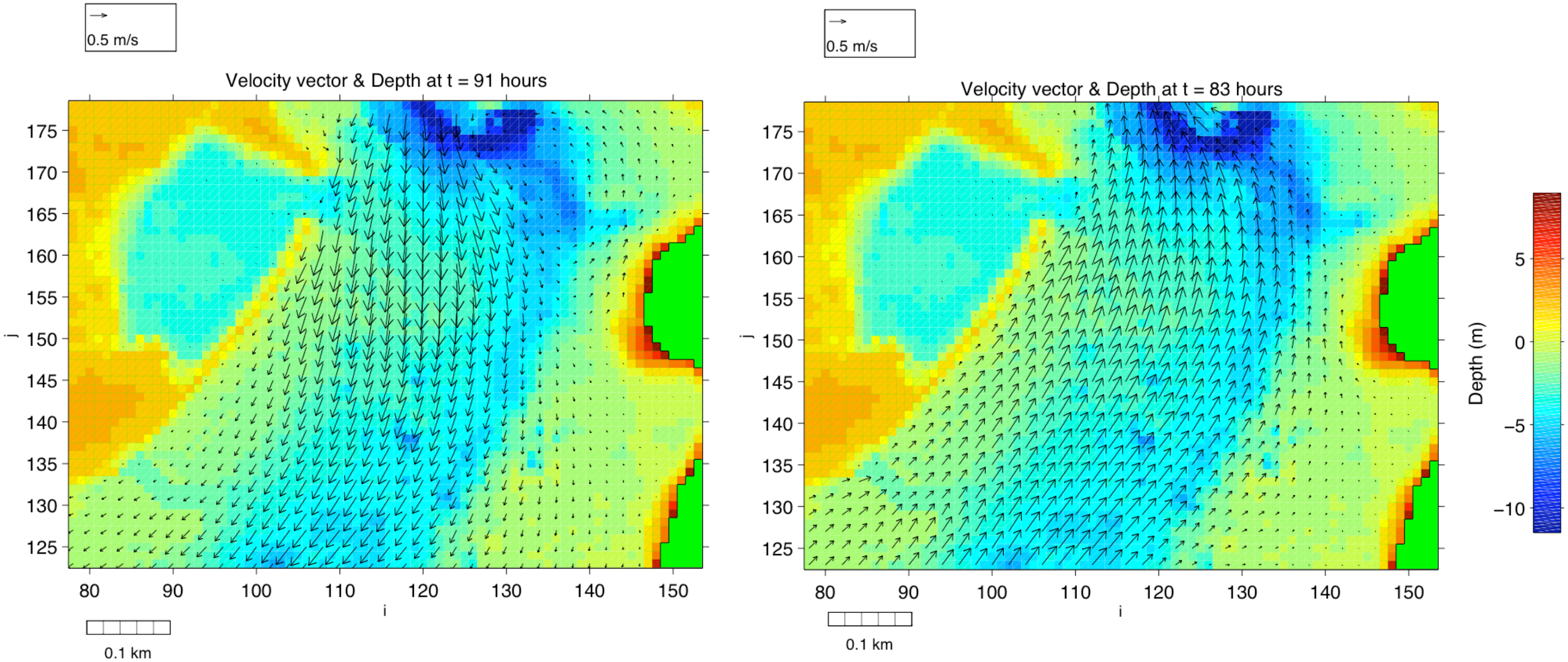

Figure 7.12: Hydrodynamic modelled results for scenario three. Scenario three hydrodynamic results show that like scenario one there is a decrease in tidal current velocity in the flood tide (left) and ebb tide (right) over the dredged boat-ramp channel.

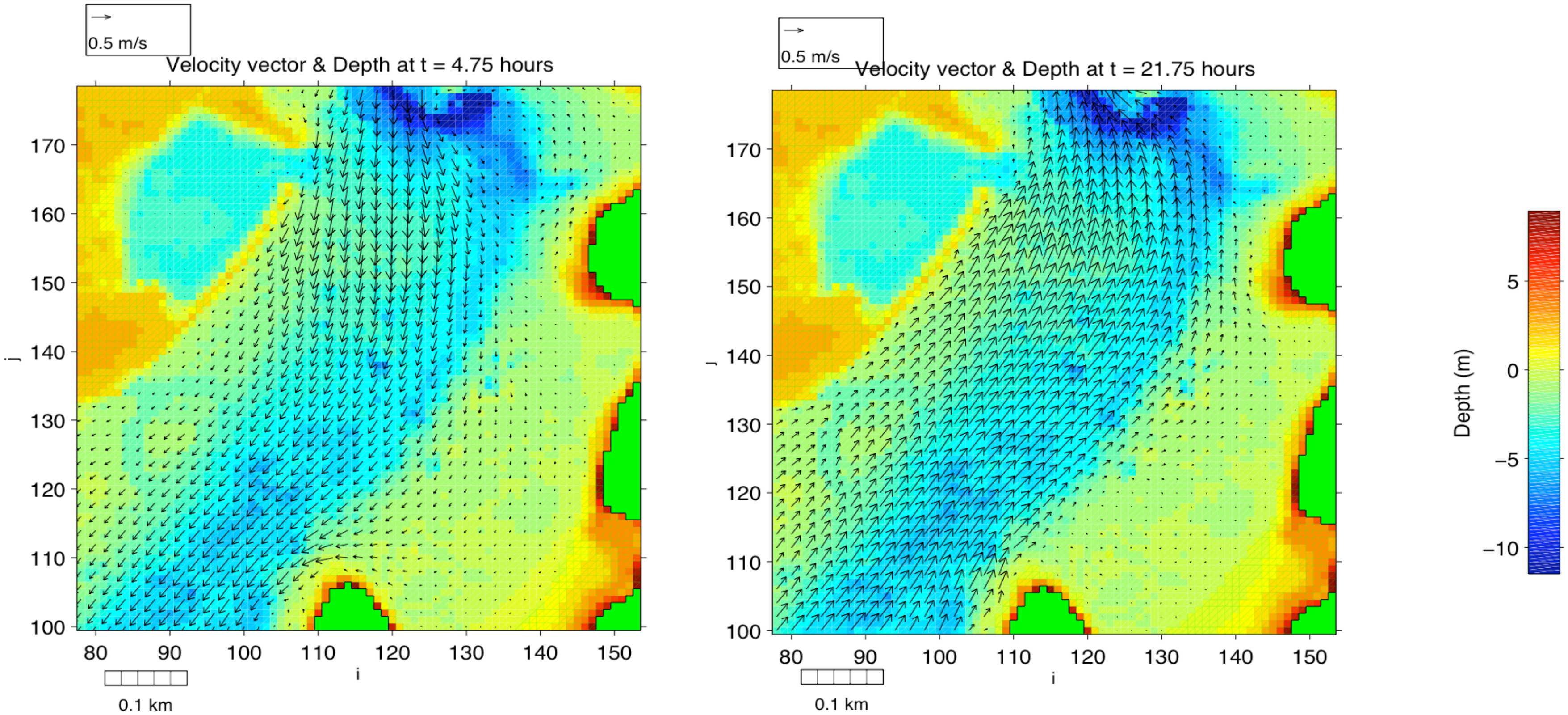

Figure 7.13: Hydrodynamic modelled results for scenario four. Scenario four hydrodynamic results show that tidal current velocity during the flood tide (left) and ebb tide (right) are partially diverted into the dredged channel. There is less of a reduction in current velocities when compared with scenarios one and two. However, the most significant difference occurs during ebb tide when velocities at this location are higher.

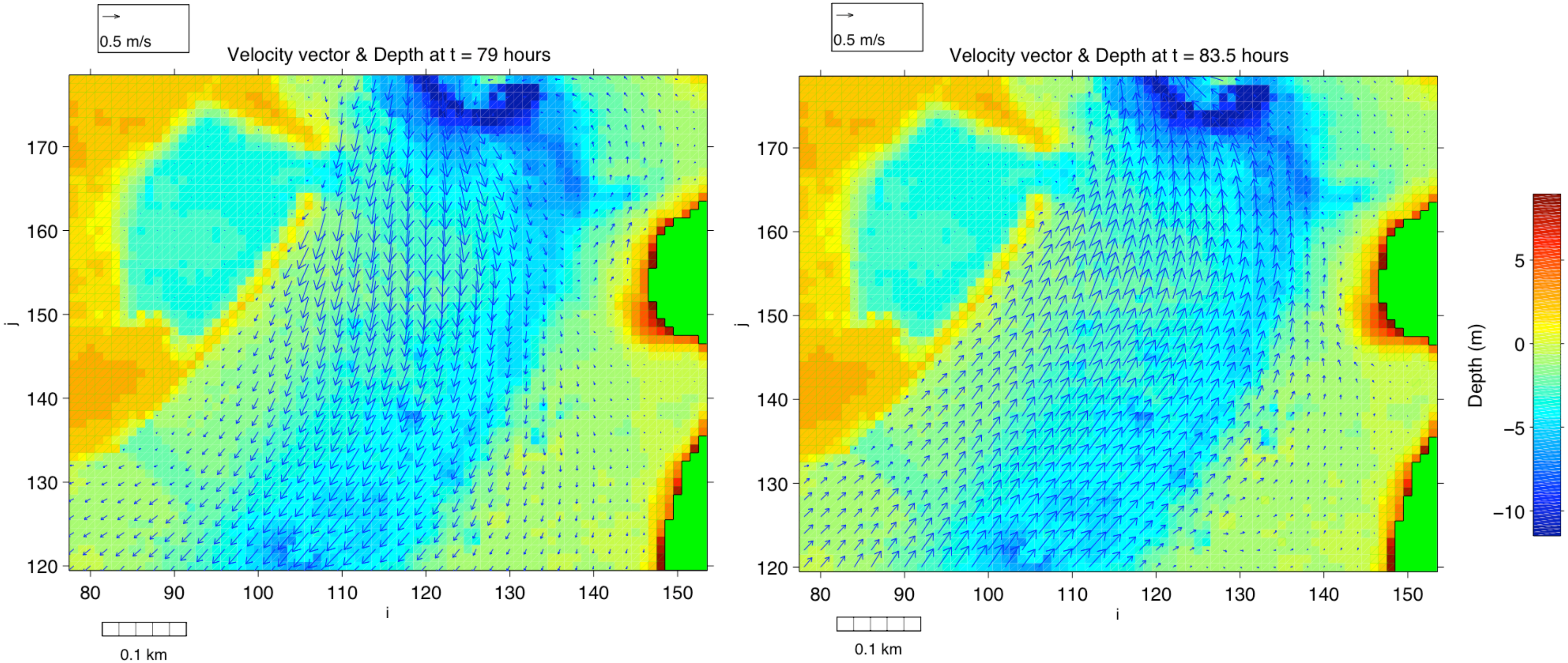

Figure 7.14: Scenario five requires the largest volume of sediment to be removed and has been "over dredged" compared to all other scenarios. The approach channel has been dredged to a depth of 2.5 - 3 m and the width of the channel is 40 m. The increase in depth and width can be seen to have the largest effect on current velocities, with velocities in the centre of the channel reducing significantly.

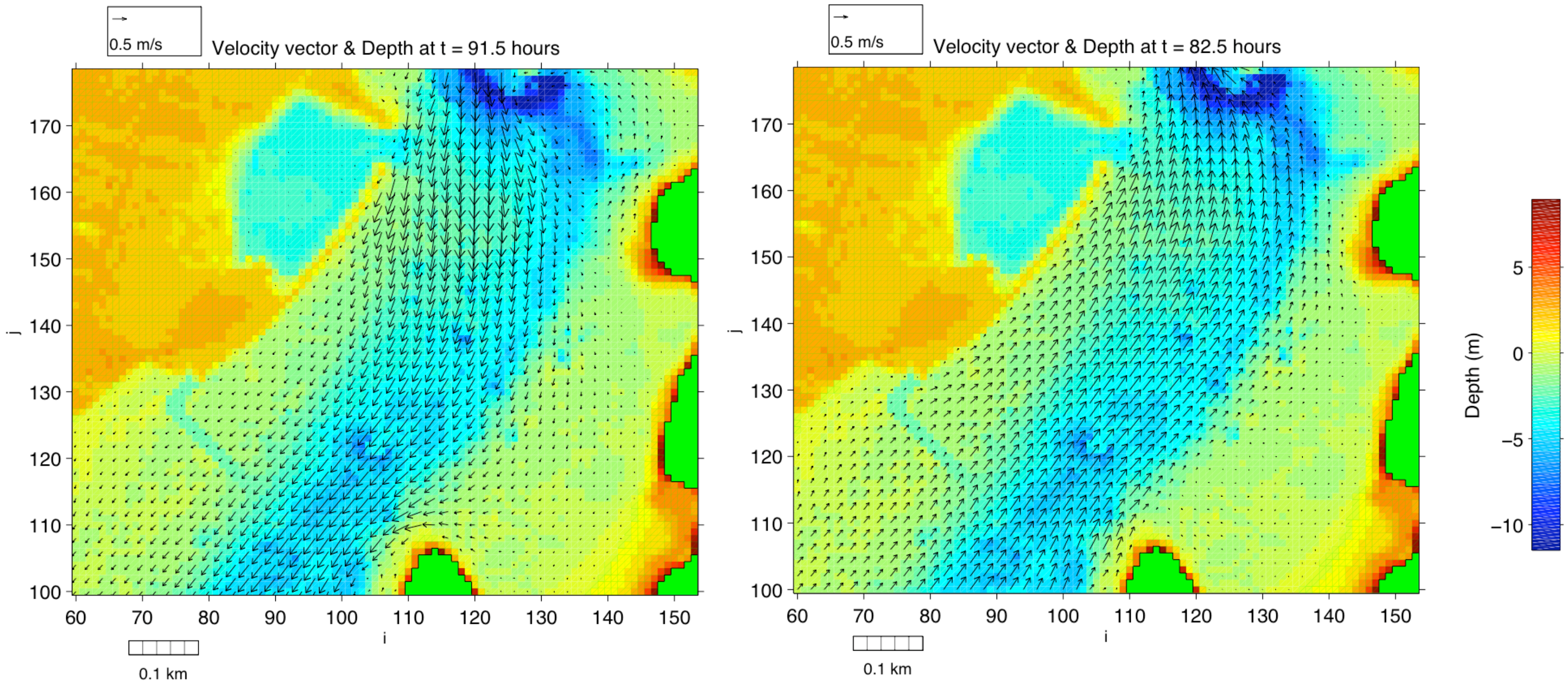

Figure 7.15: Hydrodynamic model results for scenario six. Image to the left shows flood tidal currents and to the right shows ebb tidal currents. Tidal velocities during the flood tides in behind the marina where the "head" of the channel is situated are very low. Velocities behind the marina have been found to be low at this location. These low velocities are due to the sheltered nature of this location and not the dredged channel.

7.5.2 Rapid Sediment Transport Model

The rapid sediment transport model is a simple model that solves the Engelund Hansen equations for concentration and bed level change. Results for the modelled scenarios indicate that the intertidal sandflats in the locality of the new boat-ramp will be affected by bedload transport. However, the most significant transport of sediment can be seen in the entrance of the estuary. Significant bedload transport of sand occurs in the entrance to the harbour where velocities are high (see Figure 7.16). Results show the formation of sand waves at the entrance leading into Buffalo Bay. This indicates the residual ebb domination (as noted in Chapter 6). Erosion and accretion can also be seen to occur in the scour hole located in front of Whitianga Rock. The rapid sediment transport model predicts the movement of the particle only once. The model shows that once the particle has been suspended and then deposited it no longer can be entrained. However, in reality the particle can be entrained many times.

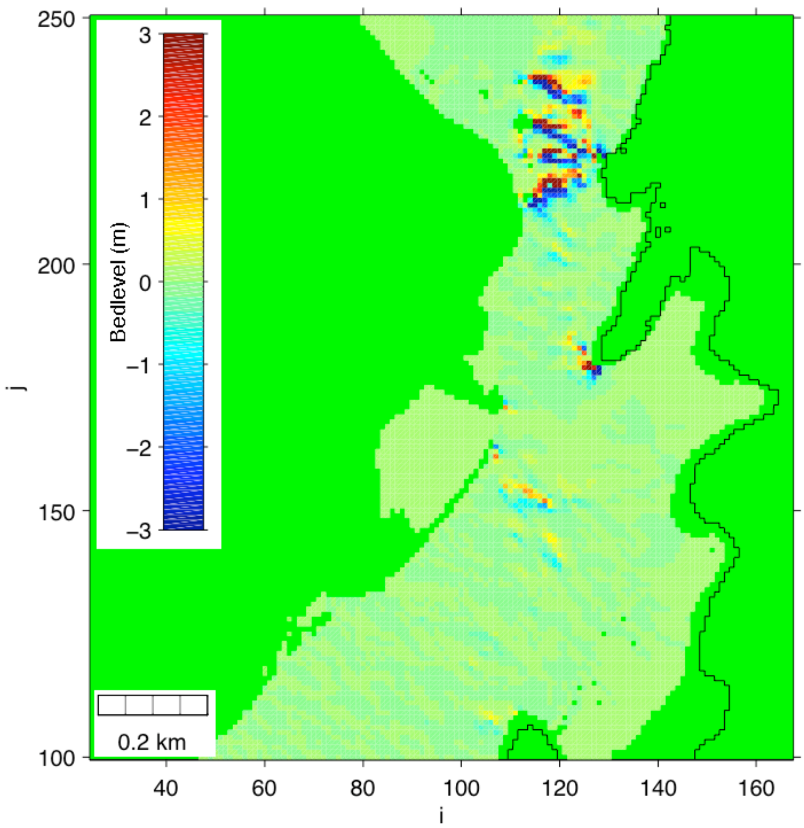

Figure 7.16: Rapid sediment transport model output of bed level changes induced by tidal currents after a 30-day period.

7.5.3 Residual Circulation and Sand Transport Modelling

Residual circulation for each hydrodynamic scenario model was extracted and compared to the baseline numerical simulation. By undertaking differencing of the baseline and model results, an output of the variation in residual circulation could be produced (see Figures 7.18 to 7.23: images on the left). This allowed for the effect in residual circulation due to the proposed boat-ramp approach channel to be compared.

Figure 7.17 shows the residual circulation on the intertidal sand flats in the vicinity of each scenario. The residual circulation shows a uniform shore parallel ebb dominated flow of approximately 0.1 m/s.

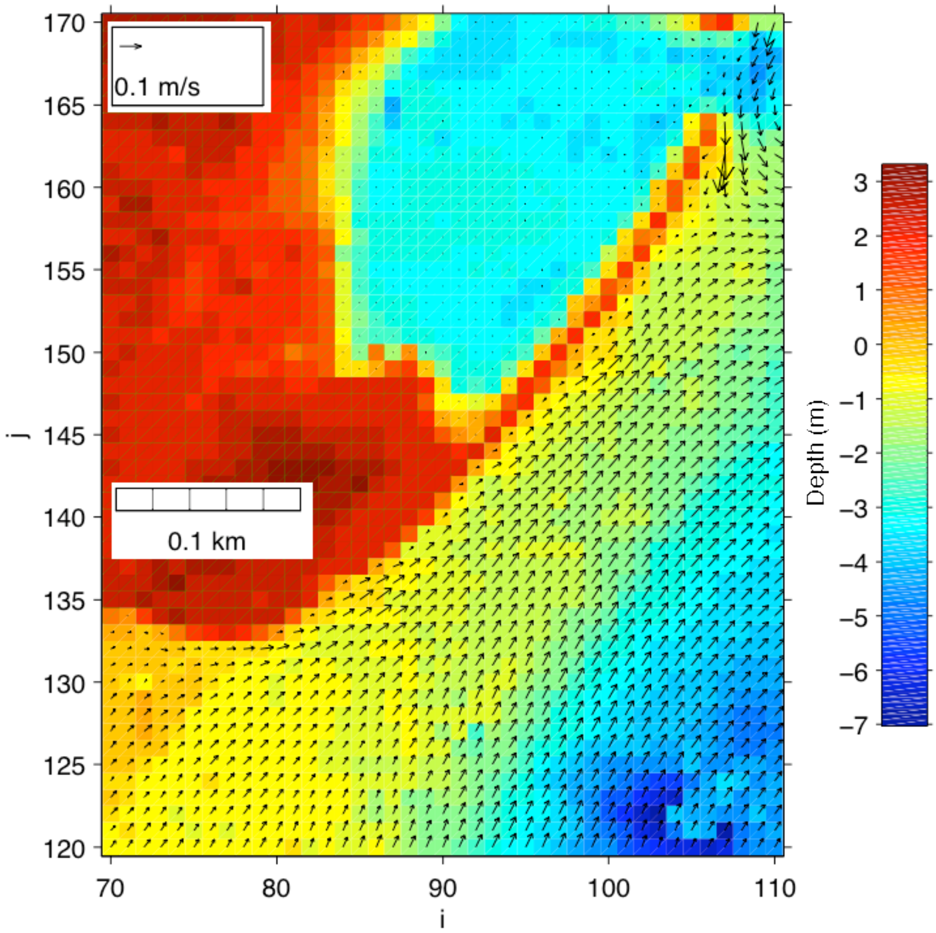

Figure 7.17: Residual circulation in the locality of the proposed boat–ramp approach channel.

It is important to note that for the residual circulation plots (Figures 7.18 to 7.23) the vector length is orders of magnitude smaller than that seen in Figure 7.17. Therefore, the reduction in velocity may not be as extreme as indicated by the shown vector length. However, to show the significance of the modelled scenarios the scale was exaggerated. Furthermore, arrows illustrating flood flow are actually indicating that the boat ramp has produced a reduction in the ebb-dominated flow shown in Figure 7.17.

Sediment transport models (STM) were run for a period of 30-days. Sediment transport results enable some interpretation of the likely long-term morphodynamic changes to the intertidal area associated with the development of the proposed boat loading ramp and channel (see Figures 7.18 to 7.23: images to the right).

Figure 7.18 illustrates a reduction in residual circulation, which is a result of the channel construction. A large reduction in residual velocity is very significant closest to the shore where the depth of dredging to produce the required 1 m below LWS is the most significant. This would likely create a zone of silt and fine sand accumulation. The STM for scenario one shows the reduction in flow associated with the dredging (see Figure 7.18).

Changes to the residual flows created by scenario two show that the there is a large reduction in velocity in the southern side of the formed channel. However, the residual velocity exiting the northern side of the channel accelerates then decreases (see Figure 7.19). This may suggest an erosion of the northern bank and sedimentation in the southern extent of the channel. Results from the STM show the accumulation of sediment in the southern channel modelled results predict approximately 0.5 m of sand accumulation within the 30–day period. Furthermore, the erosive nature of the induced accelerating flow results in the removal of over 1 m of sediment from the southern side of the channel (see Figure 7.19).

Scenario three indicates change in residual circulation direction, with the lower channel portion showing a reduction in flow speed and a change in direction more to the west (see Figure 7.20). The resulting changes to the flow appear to lead to the development of a sand bank. This is consistent with the STM results, which suggest significant accumulation at this point in the channel. Modelled sedimentation in the channel is similar to that seen in scenario one, with accumulation of approximately 0.5 m, but the localised effect of sedimentation associated with the channel is much more noteworthy (see Figure 7.20).

Residual circulation relating to scenario four is complicated due to the dredging design of the channel. Similar to results seen for scenarios one to three, flow can be seen to reduce significantly in the channel closest to the shore. However, in the southern sector of the dredged channel, residual circulation has increased and changed direction. STM results suggest the development of a sand bar formation in the northern arm of the dredged proposal. The changes in the direction of residual circulation in the southern arm of the dredged channel design imply that there will be scour of the sector closest to the main harbour channel.

The changes to the intertidal area associated with the channel design represented in scenario five, result in a very similar morphodynamic response to that of scenario two, with erosion of the northern bank and sedimentation on the southern side of the channel suggested. Of interest is that modelled erosion to the northern channel edge is reduced in scenario five.

Scenario six shows a very high level of sediment accumulation along the entire length of the southern side of the channel. However, the effect on the residual circulation is less significant than that seen in the other scenarios, particularly in the area closest to the shore where the other scenarios show large reductions in residual velocity.

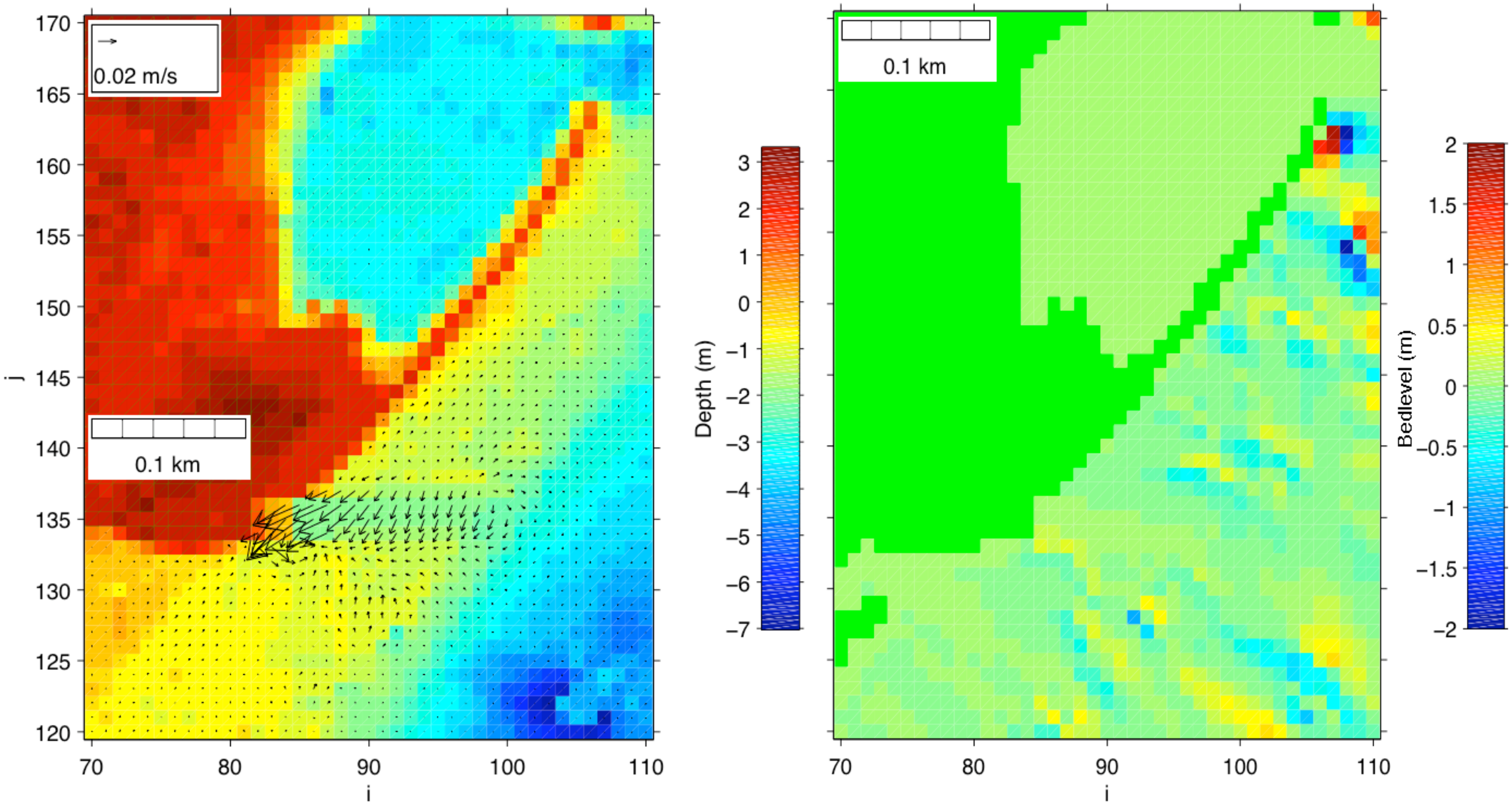

Figure 7.18: Left image shows difference in residual circulation due to dredging for scenario one. Arrows represent the reduction in residual velocity. Image to the right shows scenario one and the modelled bed level change produced by the sand transport model.

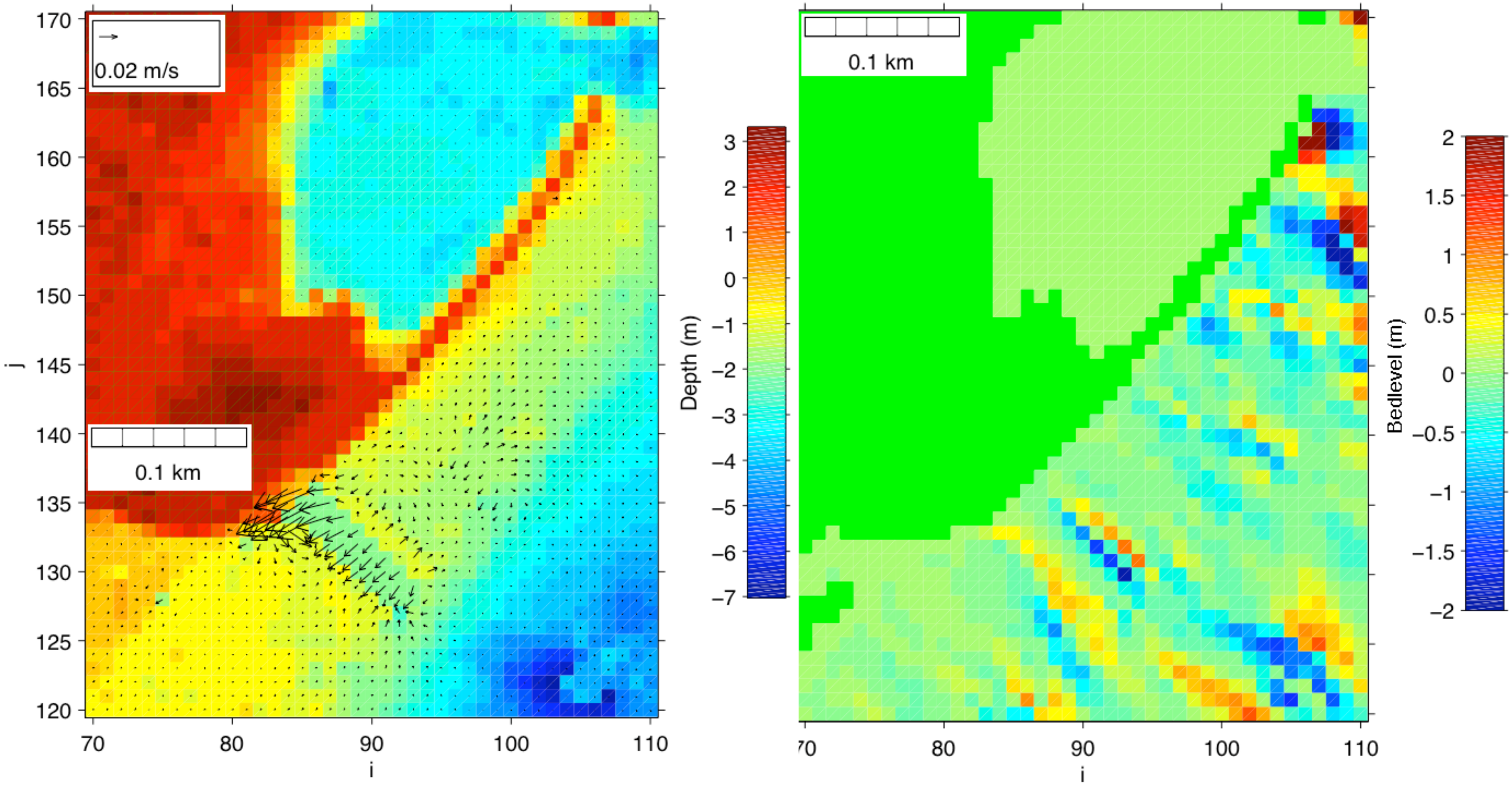

Figure 7.19: Left image shows difference in residual circulation due to dredging for scenario two. Arrows represent the reduction in residual velocity. Image to the right shows scenario two and the modelled bed level change produced by the sand transport model.

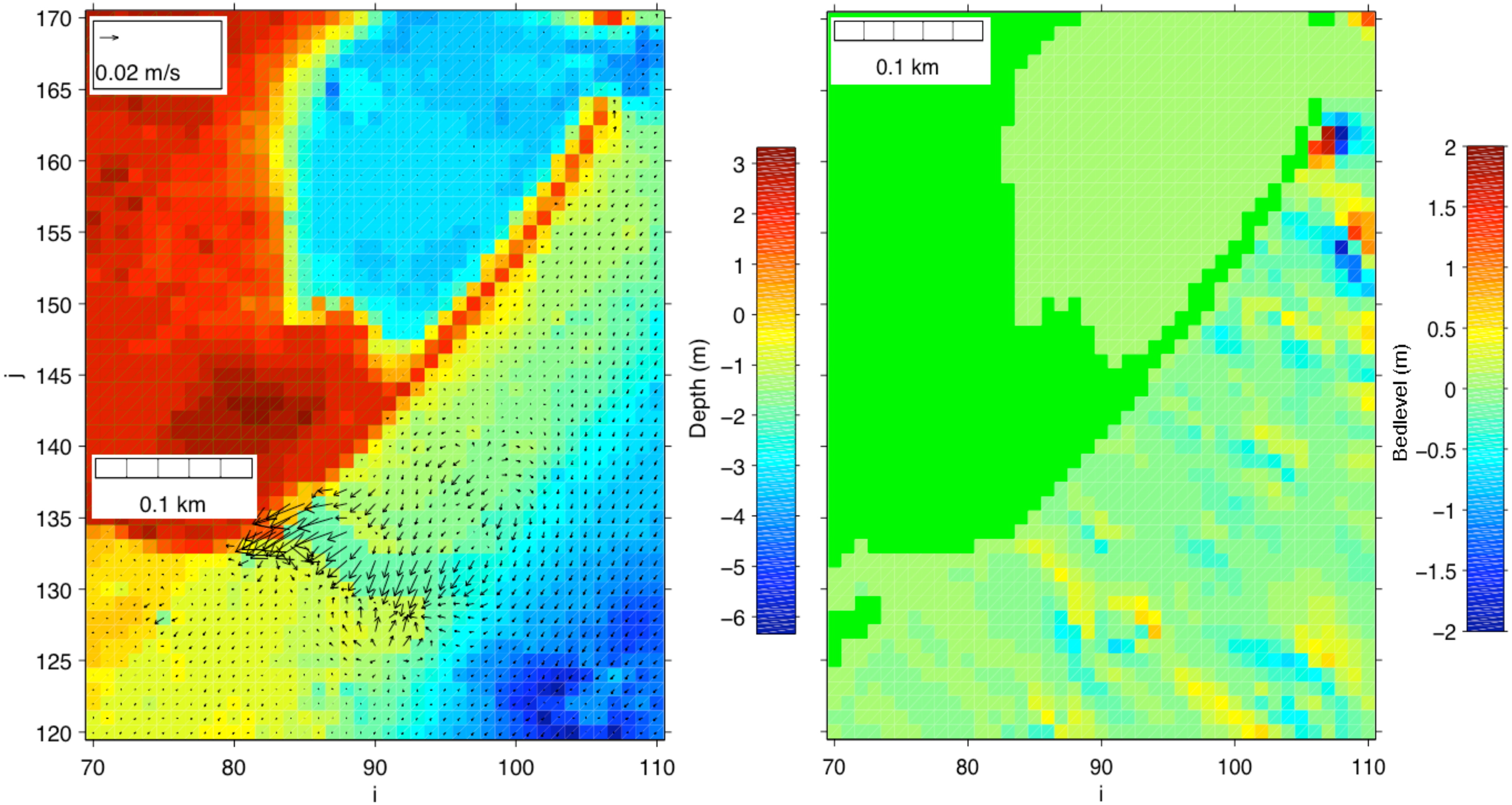

Figure 7.20: Left image shows difference in residual circulation due to dredging for scenario three. Arrows represent the reduction in residual velocity. Image to the right shows scenario three and the modelled bed level change produced by the sand transport model.

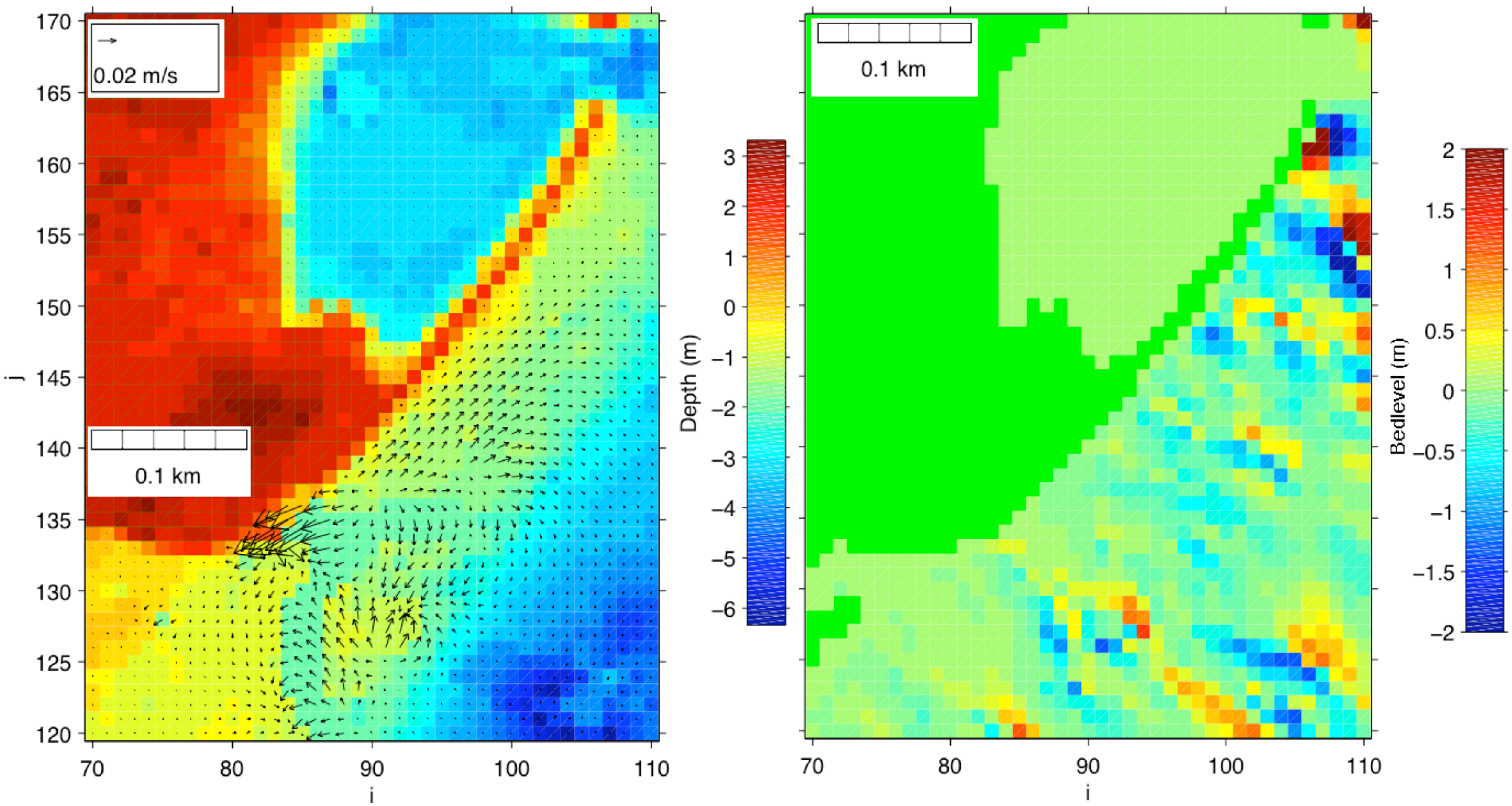

Figure 7.21: Left image shows difference in residual circulation due to dredging for scenario four. Arrows represent the reduction in residual velocity. Image to the right shows scenario four and the modelled bed level change produced by the sand transport model.

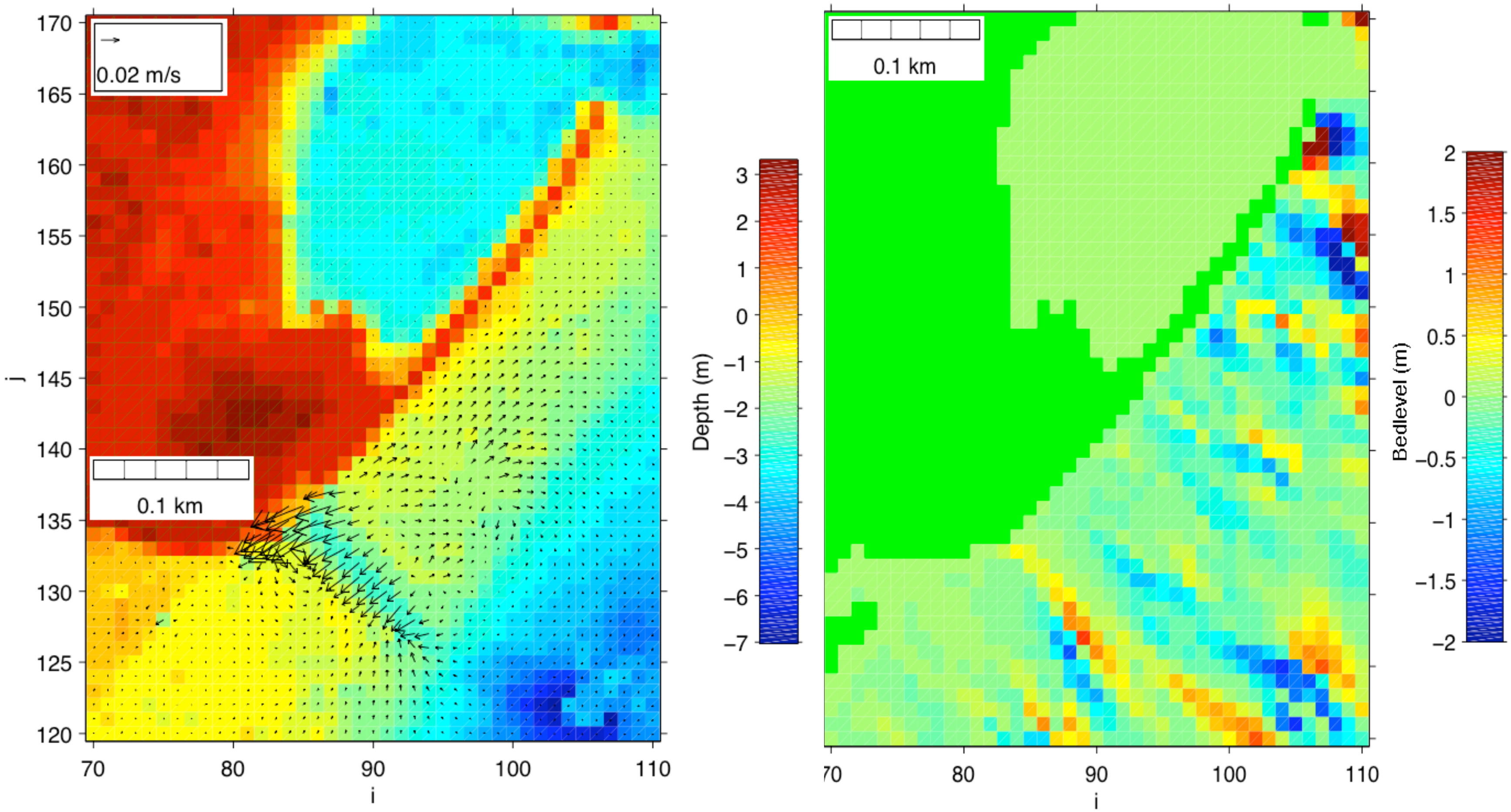

Figure 7.22: Left image shows difference in residual circulation due to dredging for scenario five. Arrows represent the reduction in residual velocity. Image to the right shows scenario five and the modelled bed level change produced by the sand transport model.

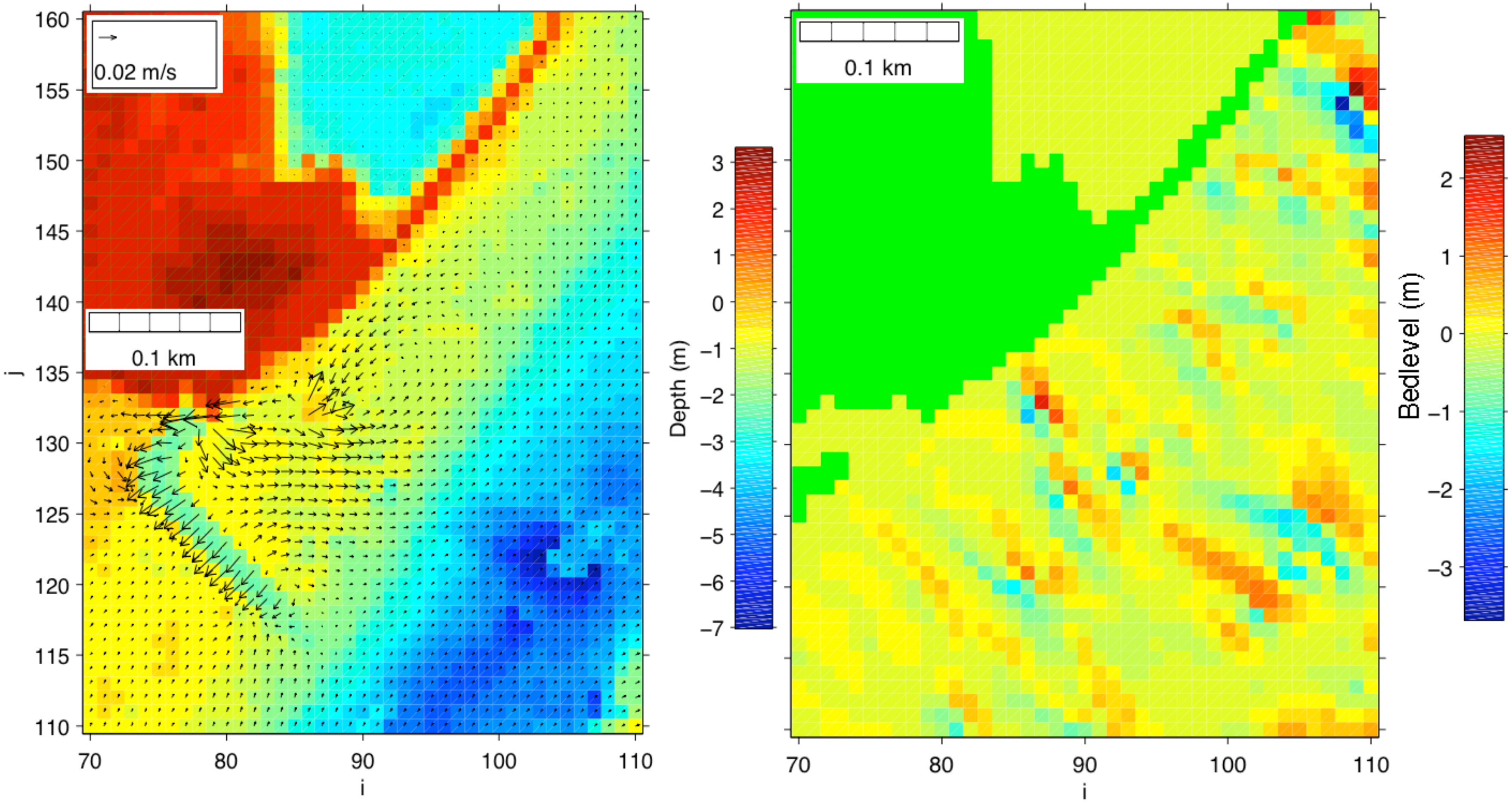

Figure 7.23: Left image shows difference in residual circulation due to dredging for scenario six. Arrows represent the reduction in residual velocity. Image to the right shows scenario six and the modelled bed level change produced by the sand transport model.

Modelled results show that there are no large-scale disturbances to hydrodynamics in the estuary. However, the localised circulation in the region of the proposed approach channel indicates there are minor changes to the residual flow with tidal residuals reducing. This reduction results in the normal ebb domination weakening as the current velocities in the channels decrease.

Table 7.2 represents an assessment on the likely sedimentation rates calculated from the STM results. The accumulation rates are extrapolated from the 30-day period accumulation, to represent an annual volume. Sedimentation results calculated here assume that conditions remain the same and that the infilling remains constant. Taking this into consideration, the results shown in Table 7.2 are likely to be an over estimate.

Table 7.2: Volume of sediment indicated as accumulating in the channel over a period of one year from the sediment transport modelling.

Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
2100 m^3/yr	4300 m^3/yr	3400 m^3/yr	5100 m^3/yr	4300 m^3/yr	5700 m^3/yr

A significant finding is that the more complicated the channel design, the more significant the disruption to the residual circulation becomes, and the higher the annual sedimentation rate appears to be.

7.5.4 Shields Parameter Analysis

Deposition of sediment within a channel can occur as a result of a slowing of the current velocity as it moves into the channel. It can generally be assumed that in the "freestream" zone of the flow (i.e. the area where flow is unaffected by channels), the concentration of total suspended sediment (TSS) in the water column remains relatively constant. This is because turbulence within the water column replaces the sediment deposited on the bed with the sediment in suspension. Therefore, so long as the current velocity remains higher than that of the velocity necessary to entrain a particle of a given size and density from the bed, then the particle will remain in suspension within the water column (Dean & Dalrymple, 2002).

Where particles have a similar density (i.e. sand, silt, and clay), a greater flow speed will be required for the initial movement of coarser particles than what would be required for smaller particles. Whether or not deposition will occur in a channel is dependant upon the maximum grain size particle that will remain in suspension in the channel in relation to the reduced flow speed.

Dean & Dalrymple (2002) have shown that if $\Psi > 0.03$ sediment is likely to be moving, and if $\Psi > 0.1$, then it is almost certain that bottom sediments are moving with the flow. Given this finding, it can be assumed that a $\Psi < 0.03$ will mean that sediments will not be suspended into the water column and will therefore accumulate.

Table 7.3: Summary of sediment transport results as calculated using Shields parameter values shown in red indicate a likelihood of settling.

Current Velocities (m/s)	Grain-size (mm)				
	0.2	**0.18**	**0.12**	**0.1**	**0.07**
0.5	0.043	0.047	0.057	0.087	0.1215
0.4	0.034	0.038	0.045	0.068	0.097
0.3	0.026	0.028	0.034	0.051	0.07
0.2	0.017	0.019	0.023	0.034	0.049
0.1	0.008	0.009	0.01	0.017	0.024

Results shown in Table 7.3 suggest that for current velocities less than 0.3 m/s, there is a high probability that there will be an accumulation of sand sediments.

7.6 Discussion

Determining the sedimentation rate within a dredged channel is very difficult. This is due to the complex nature of sediment transport processes. Headland et al. (2000) define hydrodynamics such as velocity, tidal fluctuations, and salinity, and sediment features such as particle size fall velocity, suspended sediment concentration, and particle type (i.e., clay, silt, sand, etc) as being the most important variables to consider. Discussed are hydrodynamics and sediment transport, in particular changes in the tidal flat morphology due to dredging effects and the localised hydrodynamics and large-scale hydrodynamics.

Results from the numerical simulations imply that dredging of the proposed boat-ramp on the intertidal flats will induce a decrease in current velocity in the vicinity of the dredged channels. It is likely that the reduced current velocities at this site would be more prone to an increased accumulation of finer sediments, escalating the suggested higher sedimentation rates. It has long been known that as tidal currents slacken, fine sediments will accumulate and build up (French, 1997; Headland et al., 2000). At present the flood and ebb velocities, extracted from midway across the intertidal sand flat, are 0.5 m/s during ebb flows and 0.21 m/s during flood flows. Sediment traps deployed by Steeghs (2007) collected suspended sediment in the entrance and upper harbour of Whitianga Estuary. Sediment was found to be comprised of moderately sorted sediments that were near symmetrical with a mean grain size of 2.52 phi (~0.18 mm) and a particle fall velocity of about 0.026 m/s. Given that the sediment Steeghs (2007) measured to be in suspension was at locations adjacent to the current proposed boat-ramp, this sediment could be assumed to be representative of sediments in suspension at the boat-ramp site, which suggests sedimentation could occur if velocities are reduced.

Rapid sediment transport modelling suggests some bedload sediment transport on the intertidal sand flats at the proposed location of the navigation channel. The largest changes in bed level occur in the entrance to the harbour. Patterns of alternating scour and deposition are evident, suggestive of the formation of sand waves at the harbour entrance. The configuration and alignment of these sand waves present a method of determining the direction of net bedload sediment transport (FitzGerald et al., 2005). As a result, the rapid sediment transport model results imply that there is net movement of sediment into Buffalo Bay. There is some validation for the suggested model results in the fact that the formation of a sand bar in Buffalo Bay has become a navigational issue for boats entering the harbour (Steeghs, 2007).

To address the concern of whether sediment might accumulate in the channel because of the reduced current speeds, the Shields parameter analysis was applied. The Shields parameter was used to determine the threshold current speeds for initial motion for the range of sediment sizes likely to occur at the proposed location for the boat-ramp facility. The results imply that there is a high likelihood of increased sedimentation due to the reduction in velocity brought about by dredging the navigation boat-ramp access channel.

The assessment of the stability of the proposed new boat-ramp approach channel shows that all designs will likely require maintenance dredging. Modelled rapid sediment and STM results show that bedload transport does occur on the intertidal sandflats. Changes to the tidal flows due to the dredging of any of the approach channel designs, result in localised changes in the residual circulation, consequentially creating complex morphodynamic responses. In most cases, the results indicate that there is accumulation of sediment upstream of the dominant residual flow, and erosion of sediment in the downstream portions of the proposed dredged channel.

Residual circulation results suggest the more complicated the channel design, the more sizeable the disruption to the circulation becomes, and the higher the modelled annual sedimentation rate appears to be. Sedimentation appears minimised for the simple designs, which require the least possible removal of sediment (such as that in scenario two and three). Therefore, scenario two would be the best scenario for this situation. However, STM results show that for the modelled scenarios there is accumulation occurring due to the indicated changes to the residual circulation. This suggests that the dredged channel may migrate and need constant maintenance. Furthermore, for each of the proposed designs the uppermost dredged portion of the channel shows a large reduction in velocity and significant change to the residual circulation. Although the dredged channels for scenario two and three initially require the smallest removal of sediment, the sedimentation rates are higher than that of scenario one.

Taking all the findings into consideration the recommendation for this area would be to extent the existing concrete boat-ramp into the estuary tidal flat a distance of 10 m so as to reduce the dredging required for the upper channel. This would further alleviate the sedimentation problem in the upper dredged channel. It would then only be necessary to dredge to a simple design shape such as that modelled in scenario one, which showed the lowest sedimentation rates yet still maintains reasonable flow velocities.

7.7 Conclusion

Predicted changes to the localised morphology of relevant locations within the study area associated with the proposed new boat-ramp and navigation channel works are summarised below:

- No significant changes to large-scale hydrodynamics of the estuary;
- No significant changes to large-scale Morphodynamics of the estuary;
- Changes to localised tidal currents result in changes to the residual circulation around various scenario dredged navigation channels to the boat-ramp;
- Small scale morphological effects are predicted to occur due to the formation of the approach channel, resulting in channel sedimentation and the expectation of maintenance dredging.

One possible benefit of the channel establishment is that some of the sand from the initial dredging of the channel, or subsequent maintenance dredging operations, can be used to recharge beaches within the Mercury Bay area, which have lost sand over the last few decades.

The recommendation for this boat-ramp development would be to extend the existing concrete boat-ramp to alleviate the build up of sediment close to the shore. A navigation channel such as that modelled for scenario one, which showed the lowest annual sedimentation rates 2100 m^3/yr, would be most suitable for the proposed new boat-ramp and associated approach channel.

CHAPTER EIGHT: SUMMARY AND RECOMMENDATIONS

8.0 General Summary

Whitianga Estuary catchment is comprised of rugged steep topography. The regional geology is dominated by the Whitianga group, which consists of deep valleys and steep sided head walls. The soft erodible tertiary sediments and tephras combined with the localised high rainfalls result in a considerable sediment input to the Whitianga Estuary.

Whitianga Estuary and the surrounding catchment have undergone many changes since human settlement. In some areas of the catchment land use has changed from native forest to pasture. Much of the decrease in estaurine area occurred during the period of 1966 to 1984. Changes to the estuary include reclamation of land for agricultural purposes, the development of a marina, and the creation of a large waterway canal. All of these changes have led to changes in the estuarine tidal prism.

Mangrove expansion within Whitianga cannot be attributed solely to increased sedimentation rates. Expansion has been observed to be occurring decades after original deforestation of the surrounding catchment. Therefore, other alternative explanations for this increase in mangroves may link to climate change, and an increase in nutrients associated with agricultural activities in the catchment.

Raw heavy metal analysis from 4 cores collected within the estuary show that there has been an increase in heavy metal concentrations in the sediments at sites D and E, with these sites corresponding to the areas closest to development and likely polluting sources. These can be attributed to development in the area and can be dated to give an approximate sedimentation rate of 4.5 mm/yr.

^{210}Pb results indicate that prior to the 1950s sedimentation rates were as high as 30 mm/yr. Findings for the upper core suggest that there has been a significant reduction in recent sedimentation rate, with current findings indicating sedimentation rates since the 1950s of 5 - 9 mm/yr for the upper estuary. Recent sedimentation rates are still high, promoting the need for increased catchment management awareness.

The 3DD numerical model was used to simulate estuarine hydrodynamics of tidal flows and current velocities. The modelled results showed good performance for elevation and velocity with an average BBS of approximately 0.9. Although overall calibration was good there were some model limitations. These include (i) lack of full hydrographic data for the entire estuary; (ii) model resolution limitations due to computational time restrictions; and (iii) a lack of local weather data.

The 3 km tidal inlet entrance to the estuary is seen to have the most complicated flow hydrodynamics. Ebb tidal currents exiting the harbour converge on the Whitianga Rock and result in the development of a large scour hole at this location.

Applying the particle tracking model shows that the sediment accumulation that occurs in each of the sub estuaries is a function of sediment inputs from the two major rivers, the Waiwawa and Whangamoro. Sediment entrained and transported by the Whangamoro River is deposited on the intertidal flats and in the entrance to the waterway canal development. Inputs from the Waiwawa River accumulate in the area of the upper estuary sand bar and on the intertidal flats of the lower harbour.

Findings from modelling the effect of a variety of designs for a proposed new boat-ramp navigation show a large reduction in velocity due to the approach channel dredging. Furthermore, sediment transport modelling shows that dredging will be an ongoing necessity, as zones of sediment accumulation in the channels are a result of the reduction in residual flow. Taking into consideration that these areas are zones of sediment accumulation, the recommendation for this area would be to extend the concrete boat ramp into the estuary tidal flat a distance of 10 m so as to reduce the dredging required for the upper channel. Modelling indicates this would also alleviate the sedimentation problem in the upper channel. All approach channel design scenarios induced a localised effect on sediment transport and residual circulation. Large-scale hydrodynamics and morphological effects were negligible. Sediment transport modelling implied that scenario one would have the lowest annual sediment accumulation rate. A simple design shape such as that modelled in scenario one combined with an extended boat-loading ramp would seem to have the advantage of the least initial dredging volume and subsequent maintenance dredging.

8.1 Point Summary

- Heavy metal concentrations can be seen to have increased within surface samples from the cores collected closest to the developed area of Whitianga. This is likely associated with storm water and sewage inputs.

- ^{210}Pb-dating results provide evidence that sedimentation rates have slowed down since the mid 20th century. The sedimentation rates were calculated to be between 5-9 mm/yr post 1950s and as high as 30 mm/yr pre 1950s.

- Ebb tidal currents exiting the harbour converge on Whitianga Rock and result in the development of a large scour hole at this location.

- Residual circulation in Whitianga Estuary appears to be in near balance, but weakly ebb dominated.

- Six scenarios were modelled using a 10 m nested grid for a proposed boat-ramp and approach channel adjacent to the marina. Results from the hydrodynamic models show that dredging of the intertidal flat at this location resulted in reductions in flow velocities indicating a likely increase in the sedimentation, especially of fine sediments in the channel. The implication is that occasional maintenance dredging will be required.

- A simple dredged access channel and extended boat-loading ramp would be the best design for this estuarine environment.

8.2 Recommendations for Future Research

Black et al. (1998) highlight the importance of waves in estuarine sediment transport. Therefore, future studies are encouraged to deploy weather stations within Whitianga. This data could then be applied to future numerical models.

Sedimentation is going to be an ongoing concern for Whitianga Marina. The locality of the marina is such that it constrains a large residual eddy formation in the entrance to the harbour. There is a very high likelihood that sedimentation of the entrance is in part due to this eddy. Future research focused on preventing this sedimentation is required.

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APPENDIX I

Grain Size Analysis

(Refer to CD ROM- Back Cover)

MASTERSIZER 2000

Result Analysis Report

Sample Name:
980_1000a

Sample Source & type:
4o

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 19 June 2007 12:41:35 p.m.

Analysed:
Tuesday, 19 June 2007 12:41:36 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.855 %

Sensitivity:
Enhanced

Obscuration:
15.20 %

Result Emulation:
Off

Concentration:
0.1535 %Vol

Specific Surface Area:
0.0809 m²/g

Span :
2.482

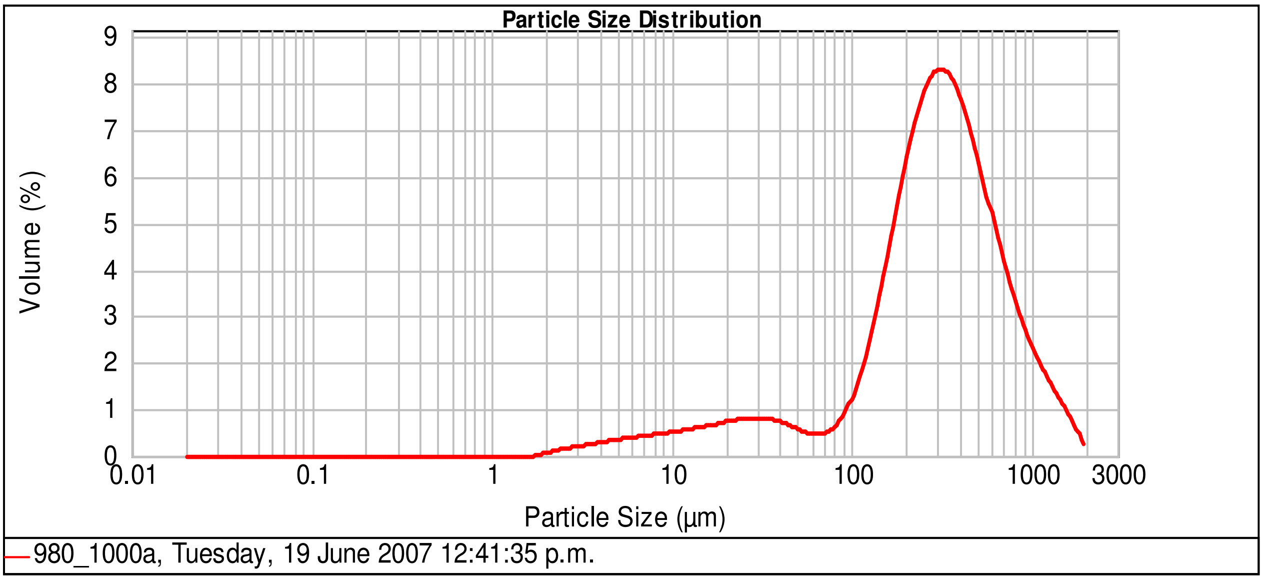
Surface Weighted Mean D[3,2]:
74.149 um

Uniformity:
0.732

Vol. Weighted Mean D[4,3]:
382.928 um

Result units:
Volume

d(0.1): 43.071 um **d(0.5): 302.238 um** **d(0.9): 793.150 um**



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.02
2.000	
	0.79
3.900	

Size (μm)	Volume In %
3.900	
	1.69
7.800	
	2.45
15.600	
	3.39
31.000	
	0.93
37.000	
	0.83
44.000	
	0.74
53.000	

Size (μm)	Volume In %
53.000	
	0.56
63.000	
	0.49
74.000	
	0.71
88.000	
	1.26
105.000	
	2.20
125.000	
	3.61
149.000	

Size (μm)	Volume In %
149.000	
	5.17
177.000	
	6.77
210.000	
	8.32
250.000	
	9.66
300.000	
	8.36
350.000	
	9.41
420.000	

Size (μm)	Volume In %
420.000	
	7.97
500.000	
	6.34
590.000	
	5.63
710.000	
	3.90
840.000	
	3.08
1000.000	
	5.70
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

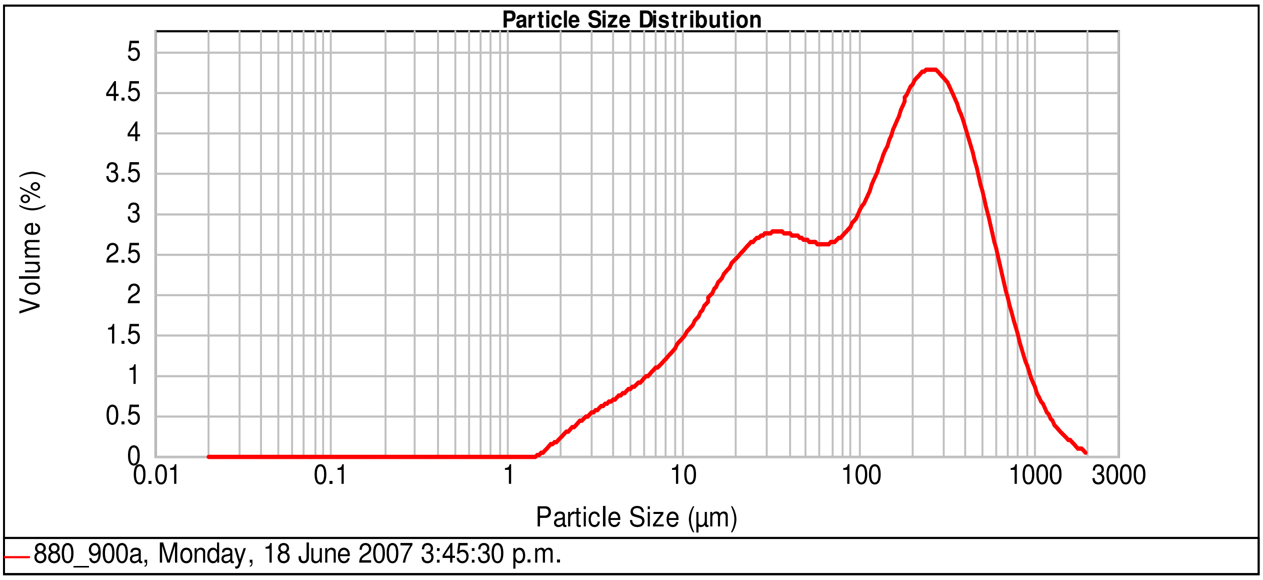
Result Analysis Report

Sample Name: 880_900a	**SOP Name:** Marine Sediment	**Measured:** Monday, 18 June 2007 3:45:30 p.m.
Sample Source & type: 30	**Measured by:** gmdr1	**Analysed:** Monday, 18 June 2007 3:45:31 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 13.02 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.333 %	**Result Emulation:** Off

Concentration: 0.0487 %Vol	**Span :** 4.109	**Uniformity:** 1.35	**Result units:** Volume
Specific Surface Area: 0.199 m²/g	**Surface Weighted Mean D[3,2]:** 30.182 um	**Vol. Weighted Mean D[4,3]:** 207.472 um	

d(0.1): 11.660 um **d(0.5): 123.150 um** **d(0.9): 517.652 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.18
2.000	2.01
3.900	

Size (µm)	Volume In %
3.900	4.10
7.800	7.28
15.600	11.20
31.000	3.20
37.000	3.12
44.000	3.28
53.000	

Size (µm)	Volume In %
53.000	2.98
63.000	2.77
74.000	3.09
88.000	3.39
105.000	3.73
125.000	4.24
149.000	

Size (µm)	Volume In %
149.000	4.64
177.000	5.02
210.000	5.39
250.000	5.70
300.000	4.66
350.000	5.07
420.000	

Size (µm)	Volume In %
420.000	4.20
500.000	3.28
590.000	2.82
710.000	1.82
840.000	1.26
1000.000	1.57
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
780_800a

Sample Source & type:
a7

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 19 June 2007 12:30:00 p.m.

Analysed:
Tuesday, 19 June 2007 12:30:01 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.730 %

Sensitivity:
Enhanced

Obscuration:
12.48 %

Result Emulation:
Off

Concentration:
0.1078 %Vol

Specific Surface Area:
0.0935 m²/g

Span :
2.686

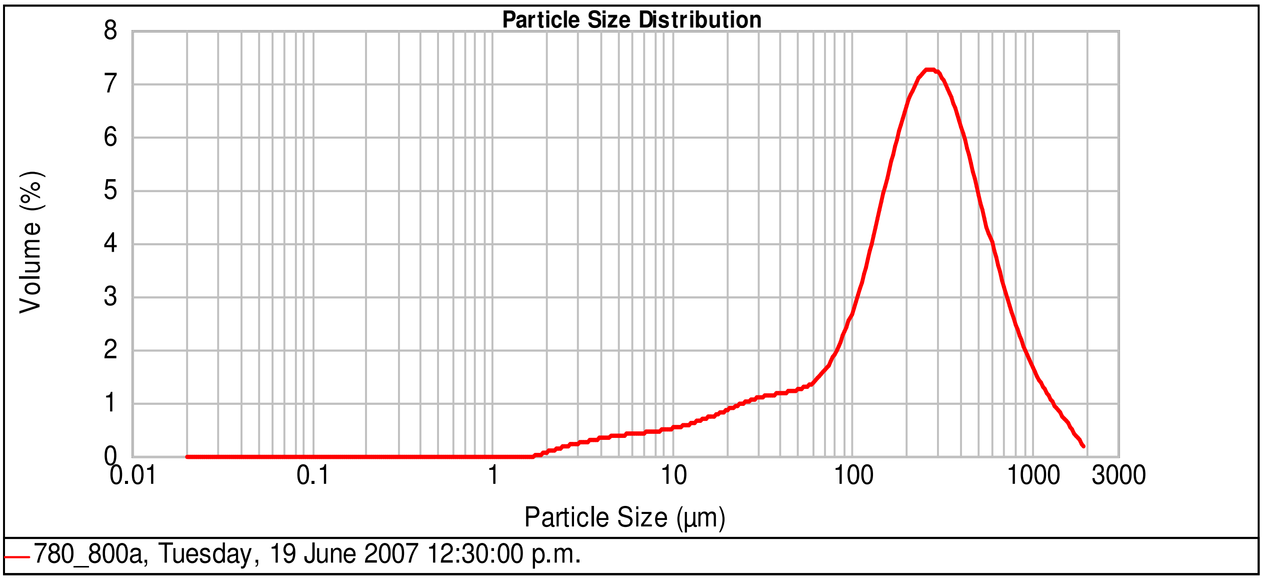
Surface Weighted Mean D[3,2]:
64.189 um

Uniformity:
0.833

Vol. Weighted Mean D[4,3]:
317.408 um

Result units:
Volume

d(0.1): 33.892 um **d(0.5): 240.481 um** **d(0.9): 679.799 um**



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.02
2.000	
	0.90
3.900	

Size (µm)	Volume In %
3.900	
	1.79
7.800	
	2.53
15.600	
	4.10
31.000	
	1.31
37.000	
	1.34
44.000	
	1.49
53.000	

Size (µm)	Volume In %
53.000	
	1.50
63.000	
	1.61
74.000	
	2.15
88.000	
	2.91
105.000	
	3.84
125.000	
	5.04
149.000	

Size (µm)	Volume In %
149.000	
	6.14
177.000	
	7.13
210.000	
	8.01
250.000	
	8.67
300.000	
	7.12
350.000	
	7.72
420.000	

Size (µm)	Volume In %
420.000	
	6.34
500.000	
	4.93
590.000	
	4.30
710.000	
	2.93
840.000	
	2.25
1000.000	
	3.92
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
600_620a

Sample Source & type:
14

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Monday, 18 June 2007 3:11:52 p.m.

Analysed:
Monday, 18 June 2007 3:11:53 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.278 %

Sensitivity:
Enhanced

Obscuration:
13.37 %

Result Emulation:
Off

Concentration:
0.0381 %Vol

Specific Surface Area:
0.263 m²/g

Span :
6.732

Surface Weighted Mean D[3,2]:
22.778 um

Uniformity:
2.48

Vol. Weighted Mean D[4,3]:
131.930 um

Result units:
Volume

d(0.1): 10.207 um **d(0.5):** 44.276 um **d(0.9):** 308.278 um

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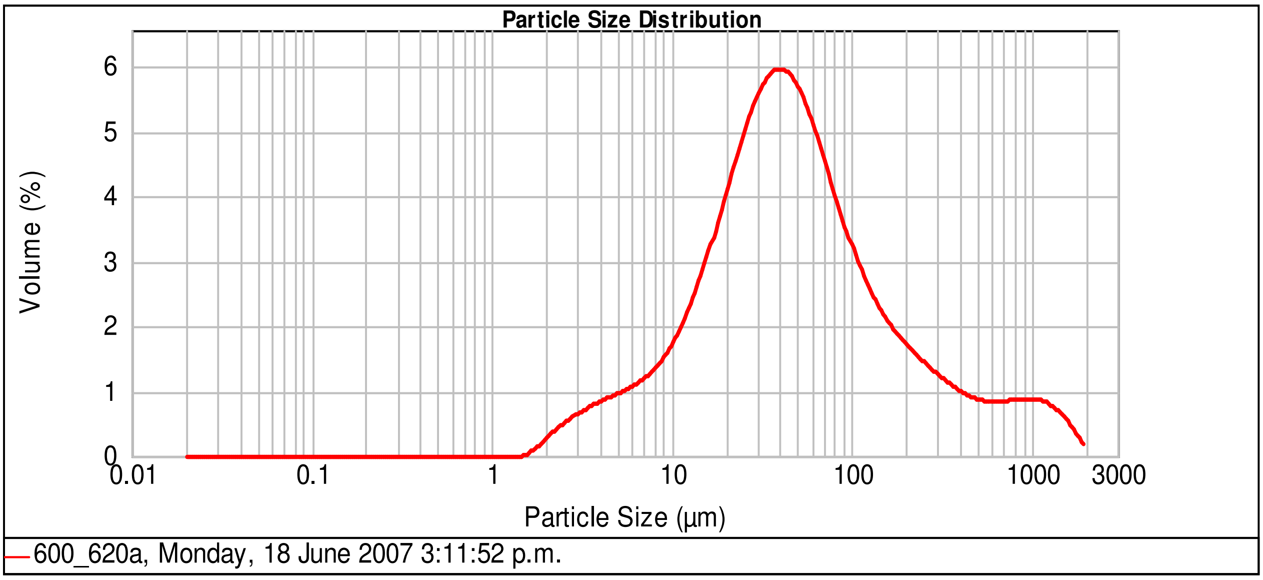


Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.19
2.000	2.51
3.900	

Size (µm)	Volume In %
3.900	4.67
7.800	9.06
15.600	19.85
31.000	6.73
37.000	6.74
44.000	7.02
53.000	

Size (µm)	Volume In %
53.000	6.00
63.000	4.96
74.000	4.59
88.000	3.90
105.000	3.20
125.000	2.71
149.000	

Size (µm)	Volume In %
149.000	2.28
177.000	1.97
210.000	1.77
250.000	1.62
300.000	1.20
350.000	1.24
420.000	

Size (µm)	Volume In %
420.000	1.05
500.000	0.93
590.000	1.01
710.000	0.94
840.000	1.00
1000.000	2.85
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
580_600a

Sample Source & type:
28

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Monday, 18 June 2007 3:00:13 p.m.

Analysed:
Monday, 18 June 2007 3:00:14 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.609 %

Sensitivity:
Enhanced

Obscuration:
15.20 %

Result Emulation:
Off

Concentration:
0.0358 %Vol

Specific Surface Area:
0.322 m²/g

Span :
2.302

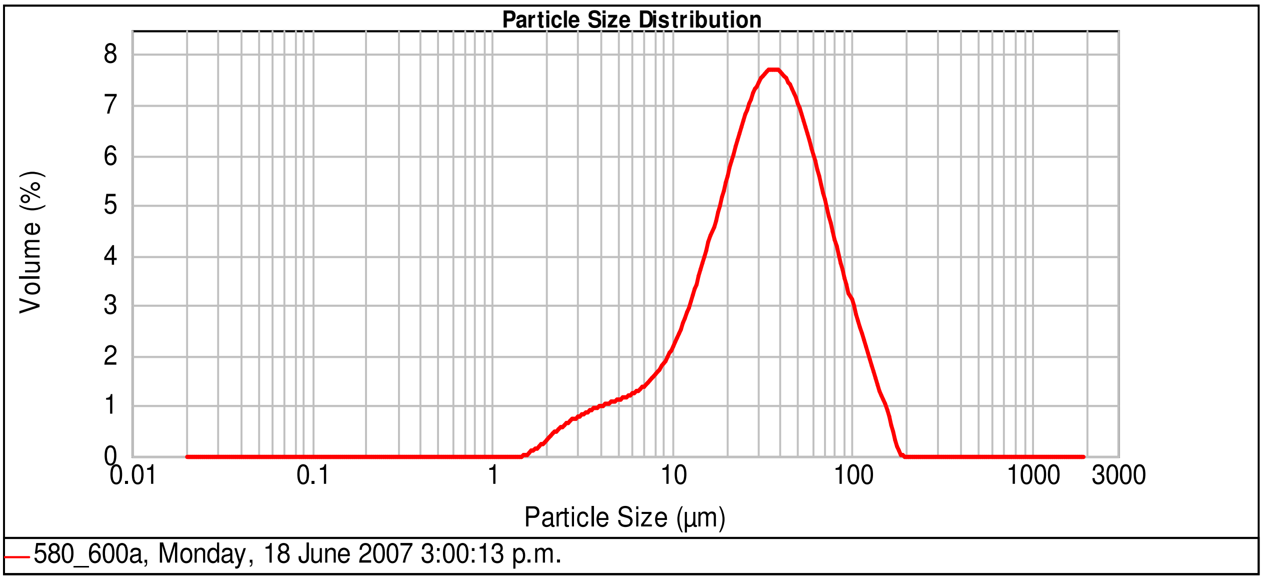
Surface Weighted Mean D[3,2]:
18.618 um

Uniformity:
0.703

Vol. Weighted Mean D[4,3]:
40.962 um

Result units:
Volume

d(0.1): 8.800 um **d(0.5): 32.913 um** **d(0.9): 84.549 um**



Size (µm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.23
3.900	3.01

Size (µm)	Volume In %
3.900	
7.800	5.45
15.600	11.59
31.000	26.75
37.000	8.85
44.000	8.65
53.000	8.73

Size (µm)	Volume In %
53.000	
63.000	7.17
74.000	5.66
88.000	4.92
105.000	3.81
125.000	2.68
149.000	1.69

Size (µm)	Volume In %
149.000	
177.000	0.79
210.000	0.00
250.000	0.00
300.000	0.00
350.000	0.00
420.000	0.00

Size (µm)	Volume In %
420.000	
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	0.00

Size (µm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
560_580a

Sample Source & type:
13

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Monday, 18 June 2007 2:15:02 p.m.

Analysed:
Monday, 18 June 2007 2:15:03 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.291 %

Sensitivity:
Enhanced

Obscuration:
12.87 %

Result Emulation:
Off

Concentration:
0.0353 %Vol

Specific Surface Area:
0.279 m²/g

Span :
2.648

Surface Weighted Mean D[3,2]:
21.543 um

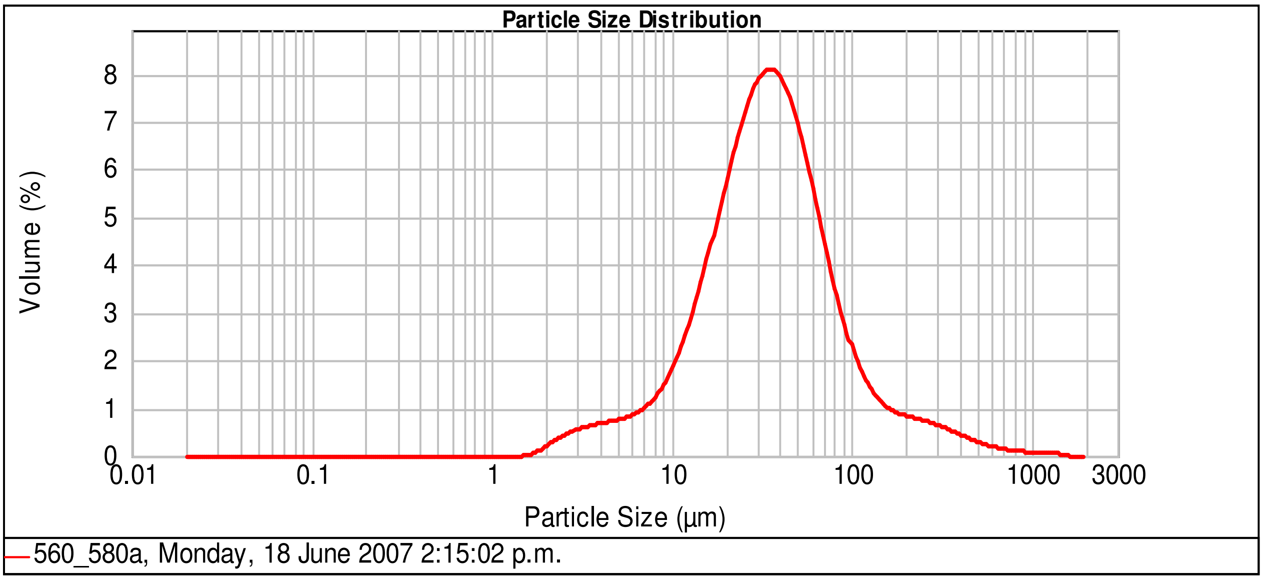
Uniformity:
1.1

Vol. Weighted Mean D[4,3]:
57.555 um

Result units:
Volume

d(0.1): 11.318 um **d(0.5):** 34.389 um **d(0.9):** 102.376 um

---



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.13
2.000	
	2.12
3.900	

Size (µm)	Volume In %
3.900	
	3.79
7.800	
	10.44
15.600	
	28.05
31.000	
	9.35
37.000	
	8.97
44.000	
	8.74
53.000	

Size (µm)	Volume In %
53.000	
	6.82
63.000	
	5.03
74.000	
	4.04
88.000	
	2.88
105.000	
	1.96
125.000	
	1.42
149.000	

Size (µm)	Volume In %
149.000	
	1.11
177.000	
	0.96
210.000	
	0.89
250.000	
	0.84
300.000	
	0.61
350.000	
	0.58
420.000	

Size (µm)	Volume In %
420.000	
	0.41
500.000	
	0.27
590.000	
	0.20
710.000	
	0.12
840.000	
	0.10
1000.000	
	0.18
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
540_560a

SOP Name:
Marine Sediment

Measured:
Monday, 18 June 2007 2:48:55 p.m.

Sample Source & type:
58

Measured by:
gmdr1

Analysed:
Monday, 18 June 2007 2:48:56 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
13.18 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.301 %

Result Emulation:
Off

Concentration:
0.0370 %Vol

Span :
5.934

Uniformity:
2.63

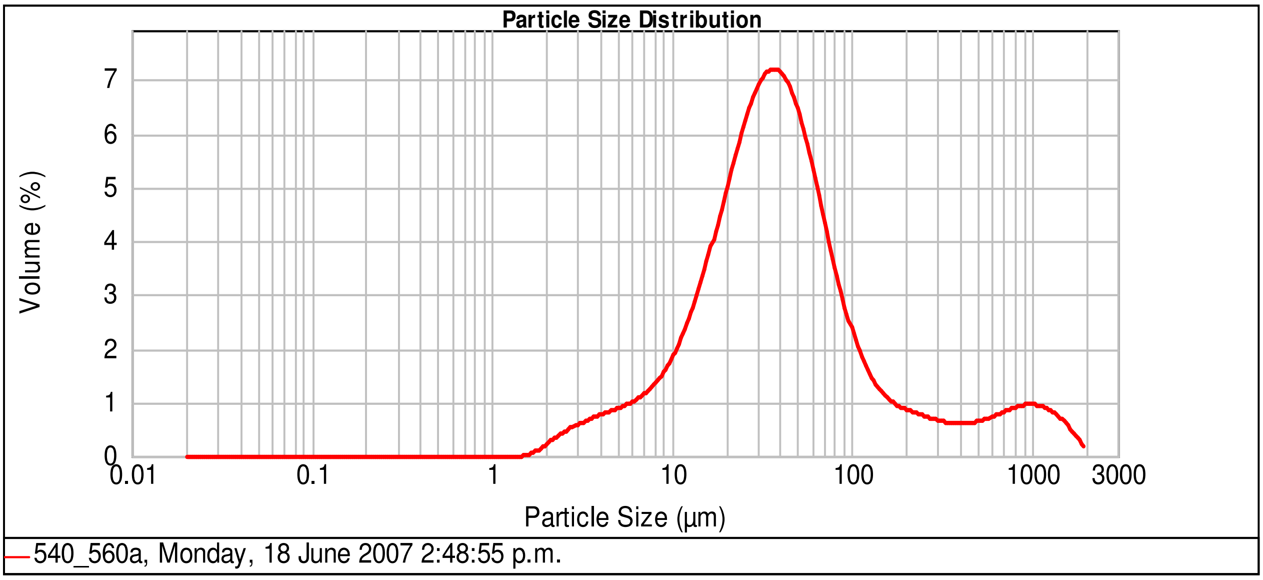
Result units:
Volume

Specific Surface Area:
0.271 m²/g

Surface Weighted Mean D[3,2]:
22.106 um

Vol. Weighted Mean D[4,3]:
119.075 um

d(0.1): 10.662 um **d(0.5): 37.563 um** **d(0.9): 233.576 um**



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.14
2.000	
	2.23
3.900	

Size (μm)	Volume In %
3.900	
	4.38
7.800	
	9.96
15.600	
	24.32
31.000	
	8.26
37.000	
	8.08
44.000	
	8.06
53.000	

Size (μm)	Volume In %
53.000	
	6.45
63.000	
	4.88
74.000	
	4.02
88.000	
	2.94
105.000	
	2.05
125.000	
	1.50
149.000	

Size (μm)	Volume In %
149.000	
	1.17
177.000	
	0.99
210.000	
	0.90
250.000	
	0.84
300.000	
	0.64
350.000	
	0.72
420.000	

Size (μm)	Volume In %
420.000	
	0.70
500.000	
	0.73
590.000	
	0.94
710.000	
	0.97
840.000	
	1.08
1000.000	
	3.04
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

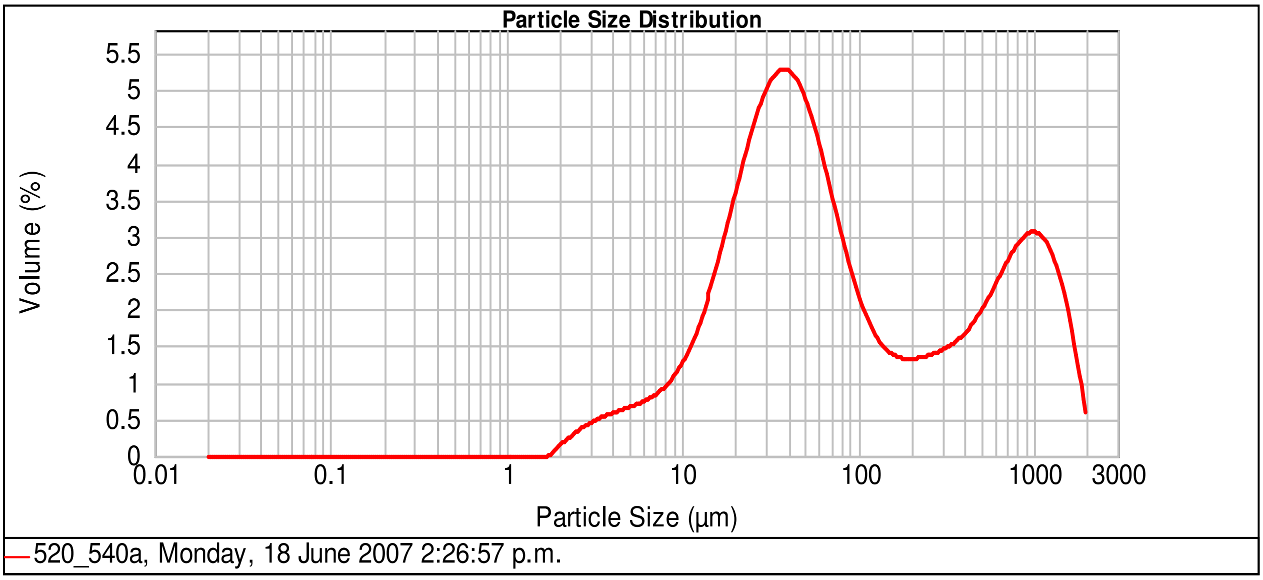
Result Analysis Report

Sample Name: 520_540a	**SOP Name:** Marine Sediment	**Measured:** Monday, 18 June 2007 2:26:57 p.m.
Sample Source & type: 50	**Measured by:** gmdr1	**Analysed:** Monday, 18 June 2007 2:26:58 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 11.49 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.541 %	**Result Emulation:** Off

Concentration: 0.0431 %Vol	**Span :** 17.154	**Uniformity:** 4.48	**Result units:** Volume
Specific Surface Area: 0.202 m²/g	**Surface Weighted Mean D[3,2]:** 29.745 um	**Vol. Weighted Mean D[4,3]:** 284.571 um	

d(0.1): 13.530 um **d(0.5): 57.283 um** **d(0.9): 996.181 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.05
2.000	1.70
3.900	

Size (μm)	Volume In %
3.900	3.27
7.800	7.11
15.600	17.49
31.000	6.02
37.000	5.97
44.000	6.06
53.000	

Size (μm)	Volume In %
53.000	4.98
63.000	3.91
74.000	3.39
88.000	2.69
105.000	2.08
125.000	1.74
149.000	

Size (μm)	Volume In %
149.000	1.54
177.000	1.48
210.000	1.53
250.000	1.67
300.000	1.50
350.000	1.93
420.000	

Size (μm)	Volume In %
420.000	2.09
500.000	2.30
590.000	3.00
710.000	3.10
840.000	3.45
1000.000	9.92
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
500_520a repeat

SOP Name:
Marine Sediment

Measured:
Monday, 18 June 2007 12:12:21 p.m.

Sample Source & type:
9

Measured by:
gmdr1

Analysed:
Monday, 18 June 2007 12:12:22 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
15.75 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.328 %

Result Emulation:
Off

Concentration:
0.0570 %Vol

Span :
7.032

Uniformity:
2.08

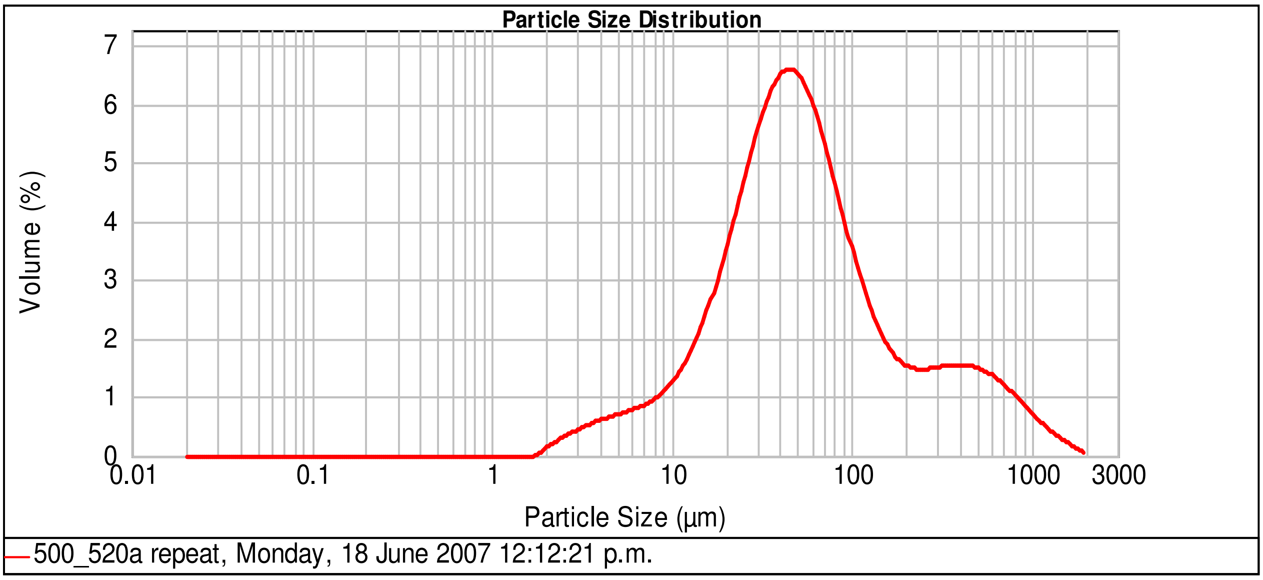
Result units:
Volume

Specific Surface Area:
0.216 m²/g

Surface Weighted Mean D[3,2]:
27.814 um

Vol. Weighted Mean D[4,3]:
130.477 um

d(0.1): 13.583 um **d(0.5): 50.031 um** **d(0.9): 365.384 um**



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060		3.900		53.000		149.000		420.000		2000.000	
	0.00		3.42		6.99		2.04		1.75		0.00
0.120		7.800		63.000		177.000		500.000		4000.000	
	0.00		6.80		5.81		1.76		1.57		
0.241		15.600		74.000		210.000		590.000			
	0.00		18.14		5.30		1.69		1.57		
0.490		31.000		88.000		250.000		710.000			
	0.00		7.01		4.33		1.78		1.18		
0.980		37.000		105.000		300.000		840.000			
	0.04		7.36		3.31		1.54		0.96		
2.000		44.000		125.000		350.000		1000.000			
	1.70		7.97		2.58		1.85		1.56		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
500_520a

Sample Source & type:
9

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Monday, 18 June 2007 12:01:08 p.m.

Analysed:
Monday, 18 June 2007 12:01:09 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.655 %

Sensitivity:
Enhanced

Obscuration:
12.62 %

Result Emulation:
Off

Concentration:
0.0626 %Vol

Specific Surface Area:
0.156 m²/g

Span :
9.244

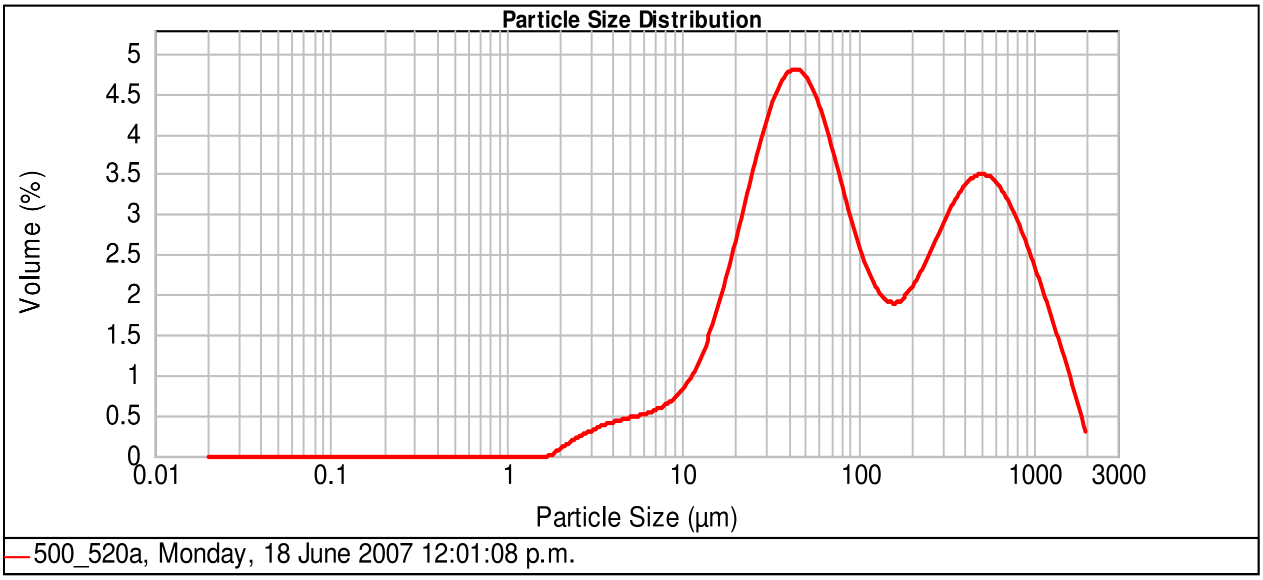
Surface Weighted Mean D[3,2]:
38.551 um

Uniformity:
2.79

Vol. Weighted Mean D[4,3]:
272.932 um

Result units:
Volume

d(0.1): 17.991 um **d(0.5): 84.431 um** **d(0.9): 798.458 um**



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.03
2.000	
	1.16
3.900	

Size (µm)	Volume In %
3.900	
	2.27
7.800	
	4.70
15.600	
	13.38
31.000	
	5.17
37.000	
	5.39
44.000	
	5.78
53.000	

Size (µm)	Volume In %
53.000	
	5.02
63.000	
	4.15
74.000	
	3.80
88.000	
	3.17
105.000	
	2.58
125.000	
	2.27
149.000	

Size (µm)	Volume In %
149.000	
	2.14
177.000	
	2.26
210.000	
	2.60
250.000	
	3.14
300.000	
	3.01
350.000	
	3.90
420.000	

Size (µm)	Volume In %
420.000	
	3.94
500.000	
	3.76
590.000	
	4.02
710.000	
	3.31
840.000	
	2.96
1000.000	
	6.08
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

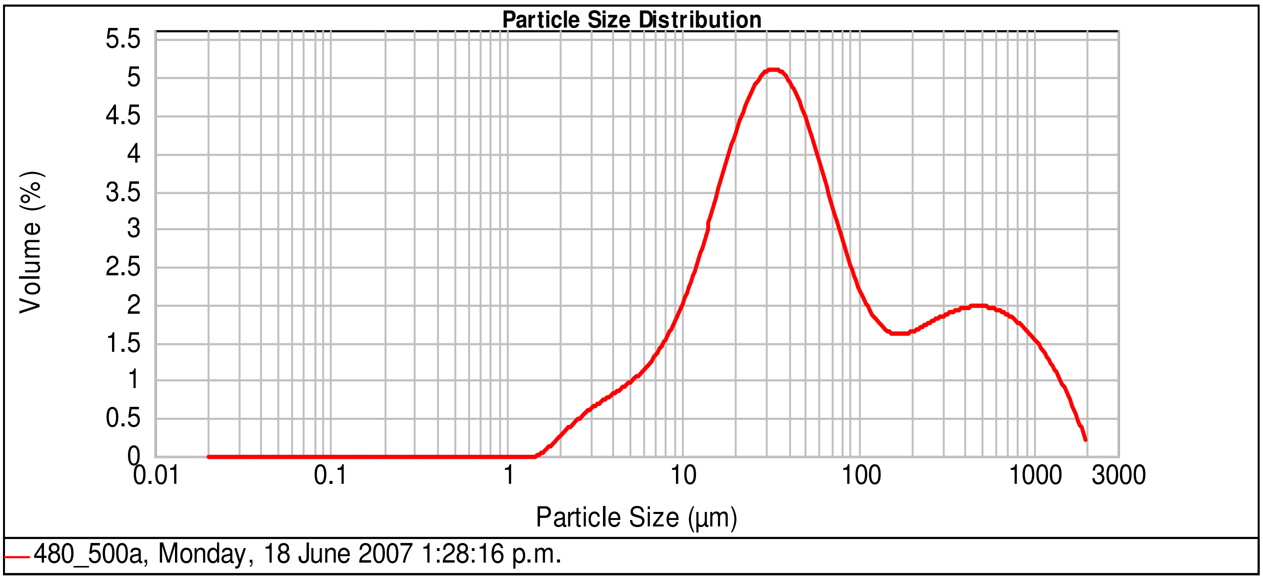
Result Analysis Report

Sample Name: 480_500a	**SOP Name:** Marine Sediment	**Measured:** Monday, 18 June 2007 1:28:16 p.m.
Sample Source & type: 20	**Measured by:** gmdr1	**Analysed:** Monday, 18 June 2007 1:28:17 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 13.33 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.330 %	**Result Emulation:** Off

Concentration: 0.0382 %Vol	**Span :** 13.442	**Uniformity:** 3.69	**Result units:** Volume
Specific Surface Area: 0.262 m^2/g	**Surface Weighted Mean D[3,2]:** 22.883 um	**Vol. Weighted Mean D[4,3]:** 186.625 um	

d(0.1): 9.765 um **d(0.5): 44.811 um** **d(0.9): 612.116 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.19
2.000	2.39
3.900	

Size (μm)	Volume In %
3.900	4.91
7.800	10.60
15.600	19.83
31.000	5.90
37.000	5.61
44.000	5.57
53.000	

Size (μm)	Volume In %
53.000	4.55
63.000	3.62
74.000	3.24
88.000	2.70
105.000	2.21
125.000	1.96
149.000	

Size (μm)	Volume In %
149.000	1.81
177.000	1.81
210.000	1.93
250.000	2.13
300.000	1.89
350.000	2.31
420.000	

Size (μm)	Volume In %
420.000	2.25
500.000	2.13
590.000	2.31
710.000	1.98
840.000	1.88
1000.000	4.30
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
460_480a

Sample Source & type:
36

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Monday, 18 June 2007 1:52:52 p.m.

Analysed:
Monday, 18 June 2007 1:52:53 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.297 %

Sensitivity:
Enhanced

Obscuration:
15.08 %

Result Emulation:
Off

Concentration:
0.0476 %Vol

Specific Surface Area:
0.247 m²/g

Span :
6.576

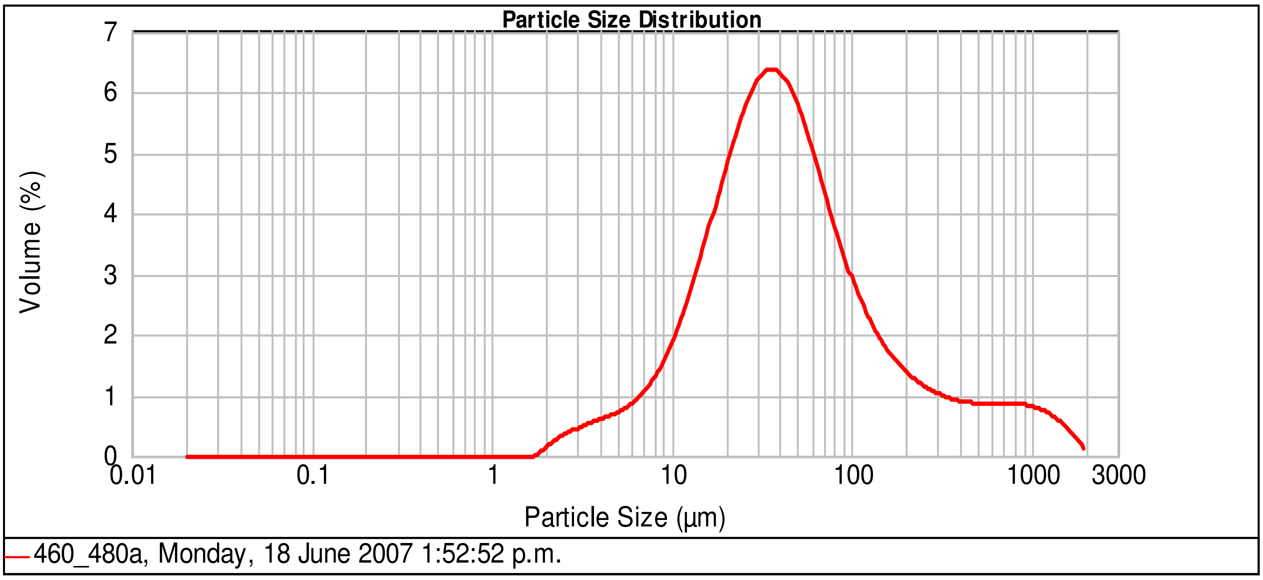
Surface Weighted Mean D[3,2]:
24.304 um

Uniformity:
2.47

Vol. Weighted Mean D[4,3]:
122.019 um

Result units:
Volume

d(0.1): 11.563 um **d(0.5): 40.598 um** **d(0.9): 278.553 um**



Size (µm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.05
3.900	1.75

Size (µm)	Volume In %
3.900	
7.800	3.78
15.600	10.18
31.000	23.02
37.000	7.37
44.000	7.15
53.000	7.21

Size (µm)	Volume In %
53.000	
63.000	5.97
74.000	4.78
88.000	4.30
105.000	3.56
125.000	2.84
149.000	2.33

Size (µm)	Volume In %
149.000	
177.000	1.90
210.000	1.61
250.000	1.42
300.000	1.31
350.000	1.00
420.000	1.10

Size (µm)	Volume In %
420.000	
500.000	1.00
590.000	0.94
710.000	1.05
840.000	0.95
1000.000	0.96
2000.000	2.48

Size (µm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

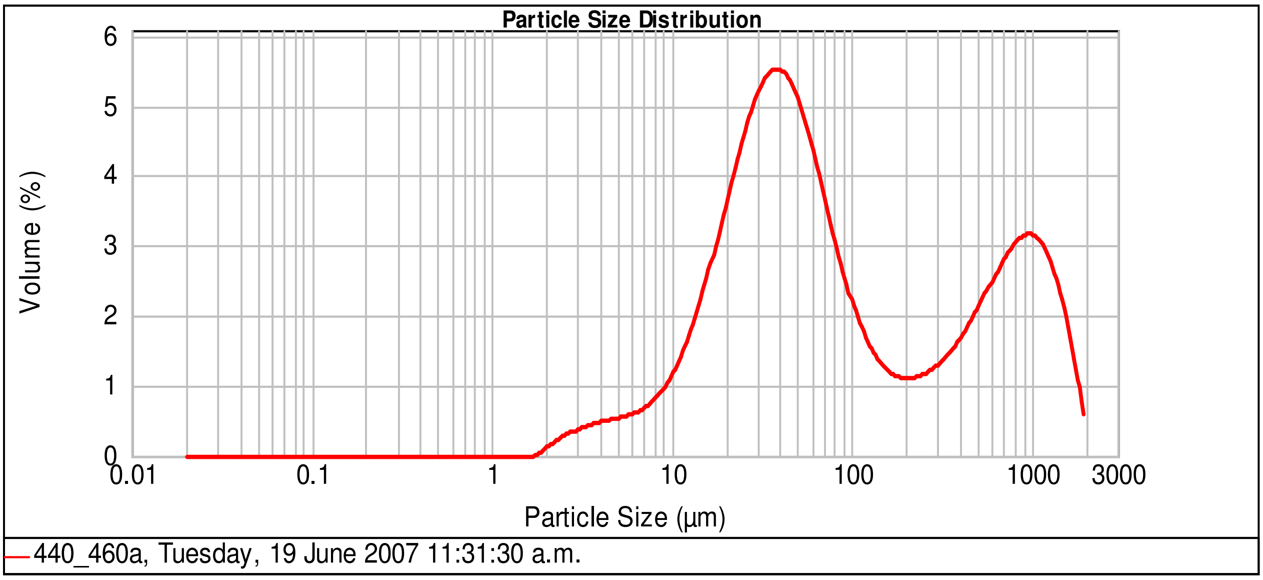
Result Analysis Report

Sample Name: 440_460a	**SOP Name:** Marine Sediment	**Measured:** Tuesday, 19 June 2007 11:31:30 a.m.
Sample Source & type: a9	**Measured by:** gmdr1	**Analysed:** Tuesday, 19 June 2007 11:31:31 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 14.65 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.512 %	**Result Emulation:** Off

Concentration: 0.0643 %Vol	**Span :** 17.147	**Uniformity:** 4.53	**Result units:** Volume
Specific Surface Area: 0.188 m²/g	**Surface Weighted Mean D[3,2]:** 31.856 um	**Vol. Weighted Mean D[4,3]:** 289.082 um	

d(0.1): 14.949 um **d(0.5): 57.516 um** **d(0.9): 1001.173 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	1.43
3.900	

Size (µm)	Volume In %
3.900	2.65
7.800	6.56
15.600	17.90
31.000	6.28
37.000	6.24
44.000	6.34
53.000	

Size (µm)	Volume In %
53.000	5.21
63.000	4.08
74.000	3.51
88.000	2.73
105.000	2.04
125.000	1.61
149.000	

Size (µm)	Volume In %
149.000	1.34
177.000	1.24
210.000	1.29
250.000	1.46
300.000	1.39
350.000	1.91
420.000	

Size (µm)	Volume In %
420.000	2.18
500.000	2.46
590.000	3.21
710.000	3.28
840.000	3.59
1000.000	10.02
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
420_440a

Sample Source & type:
46

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Monday, 18 June 2007 1:40:26 p.m.

Analysed:
Monday, 18 June 2007 1:40:27 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.393 %

Sensitivity:
Enhanced

Obscuration:
16.26 %

Result Emulation:
Off

Concentration:
0.0549 %Vol

Specific Surface Area:
0.232 m²/g

Span :
20.173

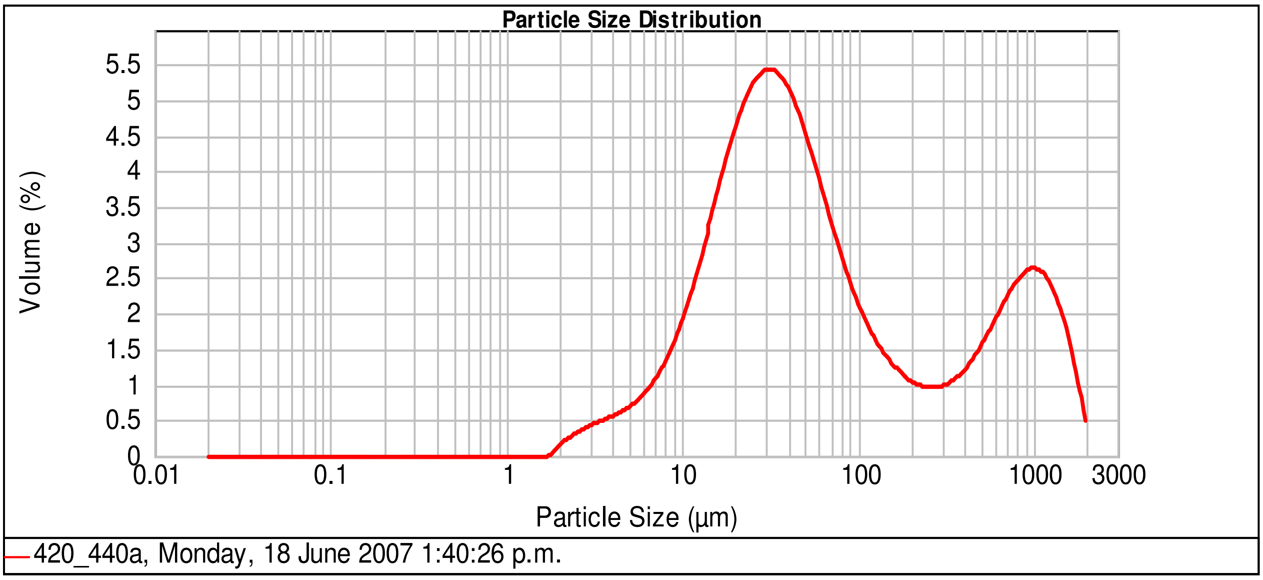
Surface Weighted Mean D[3,2]:
25.874 um

Uniformity:
4.91

Vol. Weighted Mean D[4,3]:
242.357 um

Result units:
Volume

d(0.1): 11.524 um **d(0.5): 44.804 um** **d(0.9): 915.382 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.05
2.000	1.64
3.900	

Size (µm)	Volume In %
3.900	3.72
7.800	10.53
15.600	21.38
31.000	6.25
37.000	5.84
44.000	5.68
53.000	

Size (µm)	Volume In %
53.000	4.56
63.000	3.57
74.000	3.15
88.000	2.58
105.000	2.05
125.000	1.69
149.000	

Size (µm)	Volume In %
149.000	1.40
177.000	1.21
210.000	1.13
250.000	1.15
300.000	1.02
350.000	1.37
420.000	

Size (µm)	Volume In %
420.000	1.58
500.000	1.84
590.000	2.50
710.000	2.64
840.000	2.97
1000.000	8.48
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
400_420a

Sample Source & type:
a8

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 19 June 2007 12:18:34 p.m.

Analysed:
Tuesday, 19 June 2007 12:18:35 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.535 %

Sensitivity:
Enhanced

Obscuration:
14.45 %

Result Emulation:
Off

Concentration:
0.0680 %Vol

Specific Surface Area:
0.174 m²/g

Span :
13.250

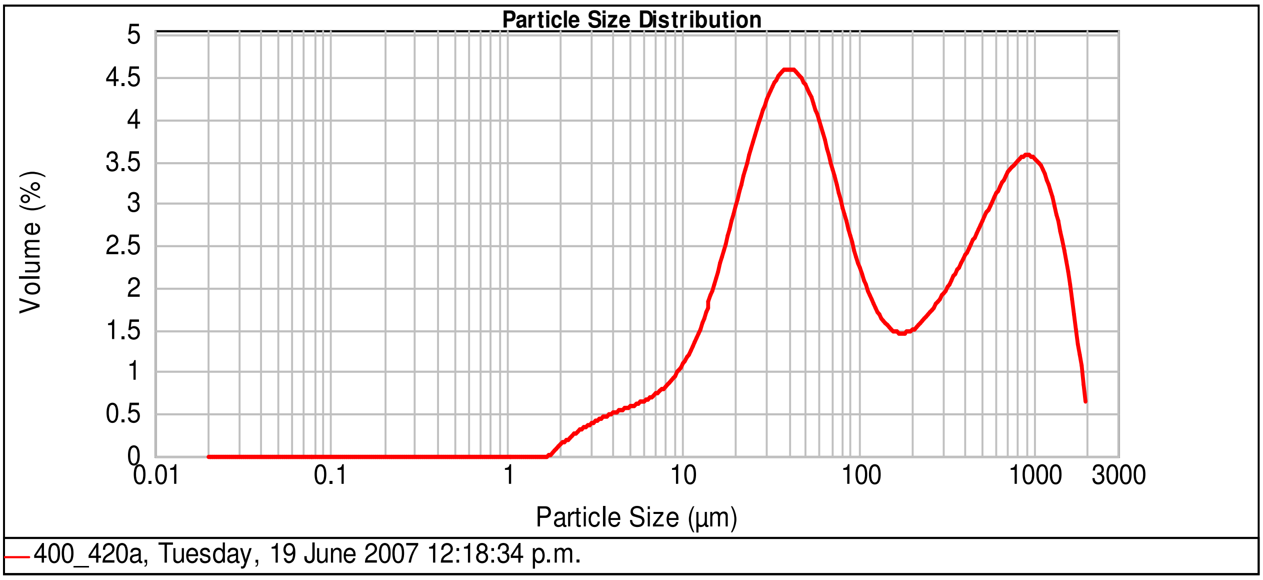
Surface Weighted Mean D[3,2]:
34.401 um

Uniformity:
3.81

Vol. Weighted Mean D[4,3]:
330.308 um

Result units:
Volume

d(0.1): 15.274 um **d(0.5):** 77.941 um **d(0.9):** 1048.030 um



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	2.85	53.000	4.61	149.000	1.66	420.000	2.95	2000.000	0.00
0.120	0.00	7.800	5.97	63.000	3.75	177.000	1.64	500.000	3.14	4000.000	
0.241	0.00	15.600	14.49	74.000	3.37	210.000	1.80	590.000	3.89		
0.490	0.00	31.000	5.14	88.000	2.77	250.000	2.11	710.000	3.81		
0.980	0.04	37.000	5.20	105.000	2.20	300.000	2.02	840.000	4.07		
2.000	1.43	44.000	5.44	125.000	1.86	350.000	2.71	1000.000	11.08		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
380_400a

Sample Source & type:
a6

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 19 June 2007 11:19:28 a.m.

Analysed:
Tuesday, 19 June 2007 11:19:29 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.334 %

Sensitivity:
Enhanced

Obscuration:
14.86 %

Result Emulation:
Off

Concentration:
0.0424 %Vol

Specific Surface Area:
0.288 m²/g

Span :
2.333

Surface Weighted Mean D[3,2]:
20.799 um

Uniformity:
0.866

Vol. Weighted Mean D[4,3]:
50.395 um

Result units:
Volume

d(0.1): 10.005 um **d(0.5):** 35.563 um **d(0.9):** 92.964 um

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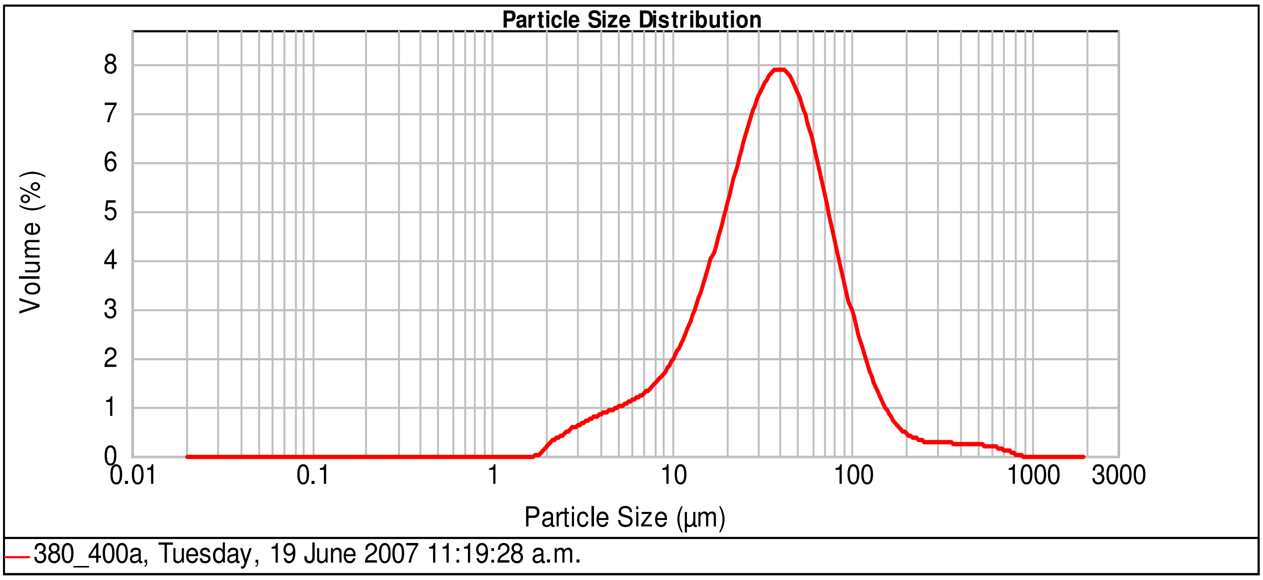


Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	2.38
3.900	

Size (µm)	Volume In %
3.900	4.91
7.800	10.47
15.600	25.32
31.000	8.90
37.000	8.93
44.000	9.18
53.000	

Size (µm)	Volume In %
53.000	7.60
63.000	5.94
74.000	5.02
88.000	3.69
105.000	2.45
125.000	1.56
149.000	

Size (µm)	Volume In %
149.000	0.93
177.000	0.57
210.000	0.40
250.000	0.34
300.000	0.27
350.000	0.31
420.000	

Size (µm)	Volume In %
420.000	0.28
500.000	0.23
590.000	0.19
710.000	0.08
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

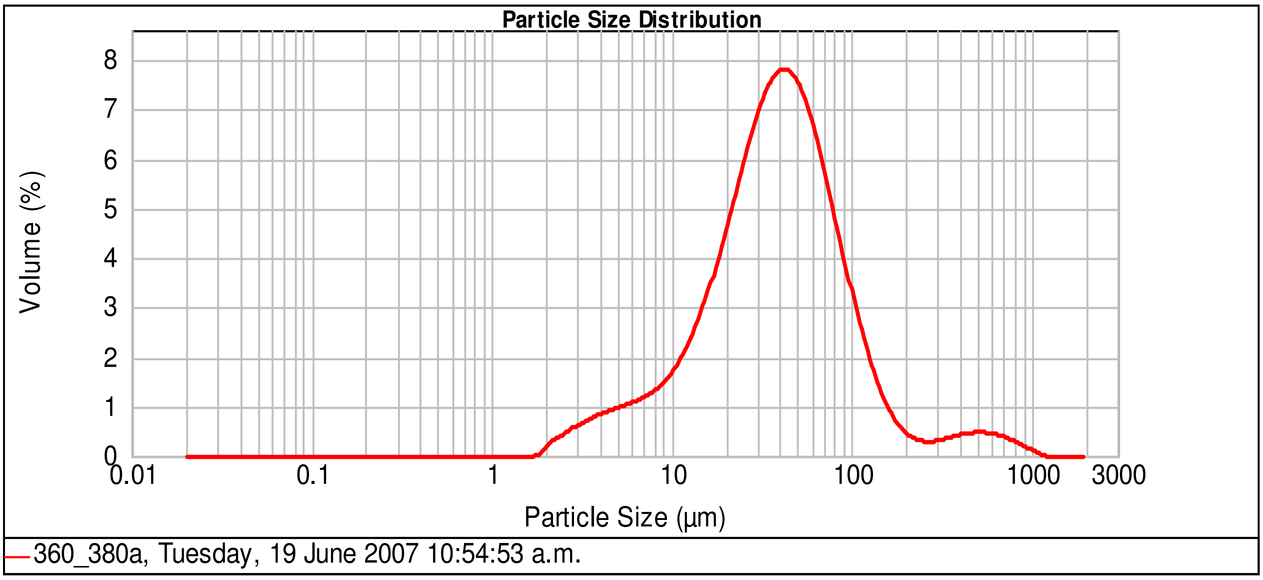
Result Analysis Report

Sample Name: 360_380a	**SOP Name:** Marine Sediment	**Measured:** Tuesday, 19 June 2007 10:54:53 a.m.
Sample Source & type: a5	**Measured by:** gmdr1	**Analysed:** Tuesday, 19 June 2007 10:54:54 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 14.61 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.320 %	**Result Emulation:** Off

Concentration: 0.0436 %Vol	**Span :** 2.443	**Uniformity:** 1.07	**Result units:** Volume
Specific Surface Area: 0.275 m²/g	**Surface Weighted Mean D[3,2]:** 21.844 um	**Vol. Weighted Mean D[4,3]:** 62.144 um	

d(0.1): 10.469 um **d(0.5):** 38.456 um **d(0.9):** 104.405 um



Size (µm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.04
3.900	2.37

Size (µm)	Volume In %
3.900	
7.800	4.71
15.600	9.14
31.000	23.19
37.000	8.60
44.000	8.83
53.000	9.32

Size (µm)	Volume In %
53.000	
63.000	7.92
74.000	6.35
88.000	5.50
105.000	4.15
125.000	2.79
149.000	1.77

Size (µm)	Volume In %
149.000	
177.000	1.01
210.000	0.58
250.000	0.38
300.000	0.35
350.000	0.34
420.000	0.48

Size (µm)	Volume In %
420.000	
500.000	0.53
590.000	0.52
710.000	0.51
840.000	0.35
1000.000	0.21
2000.000	0.06

Size (µm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
320_340

Sample Source & type:
a3

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 19 June 2007 12:05:19 p.m.

Analysed:
Tuesday, 19 June 2007 12:05:20 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.303 %

Sensitivity:
Enhanced

Obscuration:
17.25 %

Result Emulation:
Off

Concentration:
0.0500 %Vol

Specific Surface Area:
0.285 m²/g

Span :
2.383

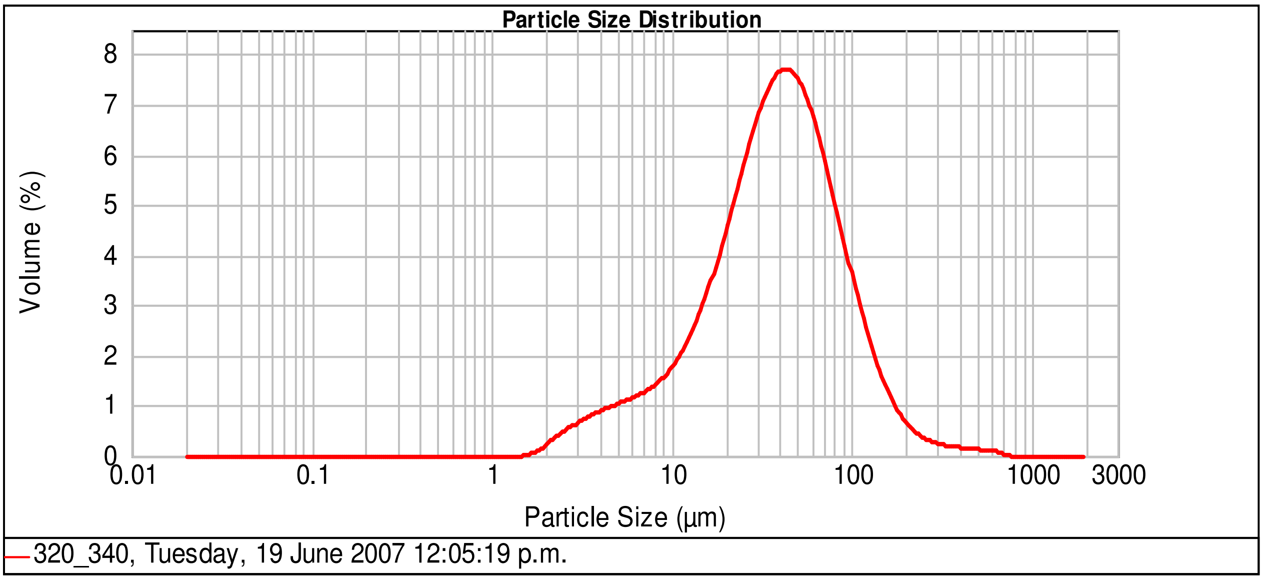
Surface Weighted Mean D[3,2]:
21.038 um

Uniformity:
0.808

Vol. Weighted Mean D[4,3]:
51.574 um

Result units:
Volume

d(0.1): 9.837 um   **d(0.5):** 38.339 um   **d(0.9):** 101.189 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.13
2.000	2.54
3.900	

Size (μm)	Volume In %
3.900	5.02
7.800	9.39
15.600	22.75
31.000	8.41
37.000	8.69
44.000	9.24
53.000	

Size (μm)	Volume In %
53.000	7.95
63.000	6.48
74.000	5.75
88.000	4.48
105.000	3.17
125.000	2.15
149.000	

Size (μm)	Volume In %
149.000	1.34
177.000	0.82
210.000	0.52
250.000	0.35
300.000	0.22
350.000	0.21
420.000	

Size (μm)	Volume In %
420.000	0.17
500.000	0.13
590.000	0.09
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
300_320a

SOP Name:
Marine Sediment

Measured:
Friday, 15 June 2007 2:39:52 p.m.

Sample Source & type:
15

Measured by:
gmdr1

Analysed:
Friday, 15 June 2007 2:39:53 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
15.41 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.332 %

Result Emulation:
Off

Concentration:
0.0426 %Vol

Span :
1.949

Uniformity:
0.608

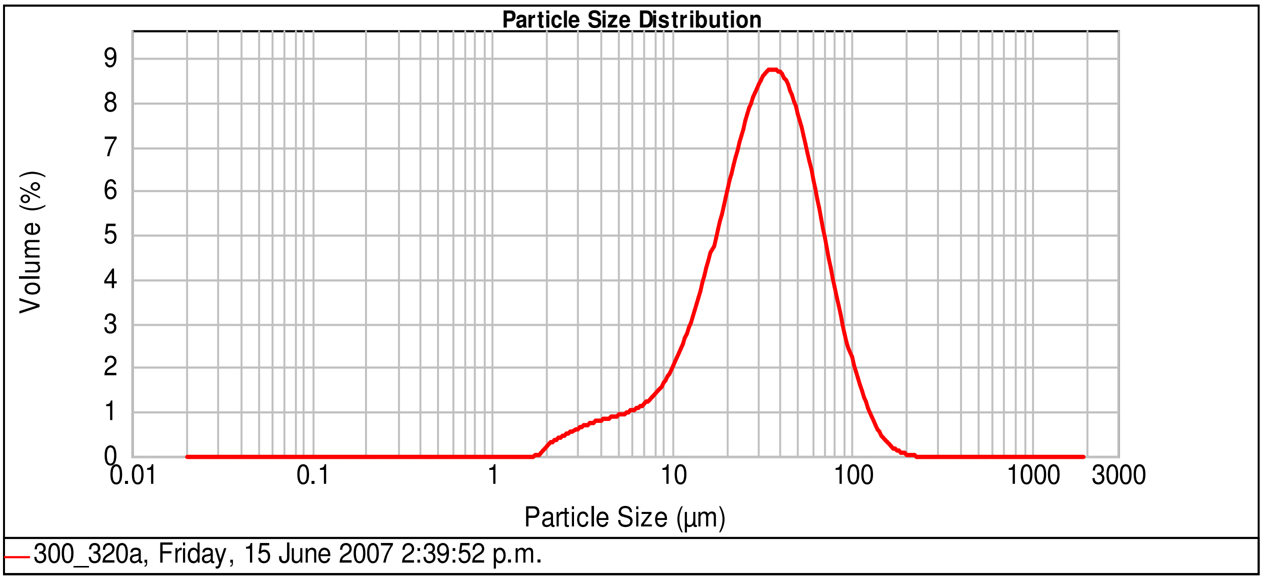
Result units:
Volume

Specific Surface Area:
0.299 m²/g

Surface Weighted Mean D[3,2]:
20.087 um

Vol. Weighted Mean D[4,3]:
38.411 um

d(0.1): 10.365 um **d(0.5): 32.520 um** **d(0.9): 73.741 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	2.37
3.900	

Size (µm)	Volume In %
3.900	4.52
7.800	11.11
15.600	29.28
31.000	10.04
37.000	9.79
44.000	9.70
53.000	

Size (µm)	Volume In %
53.000	7.64
63.000	5.62
74.000	4.38
88.000	2.85
105.000	1.57
125.000	0.74
149.000	

Size (µm)	Volume In %
149.000	0.27
177.000	0.08
210.000	0.00
250.000	0.00
300.000	0.00
350.000	0.00
420.000	

Size (µm)	Volume In %
420.000	0.00
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

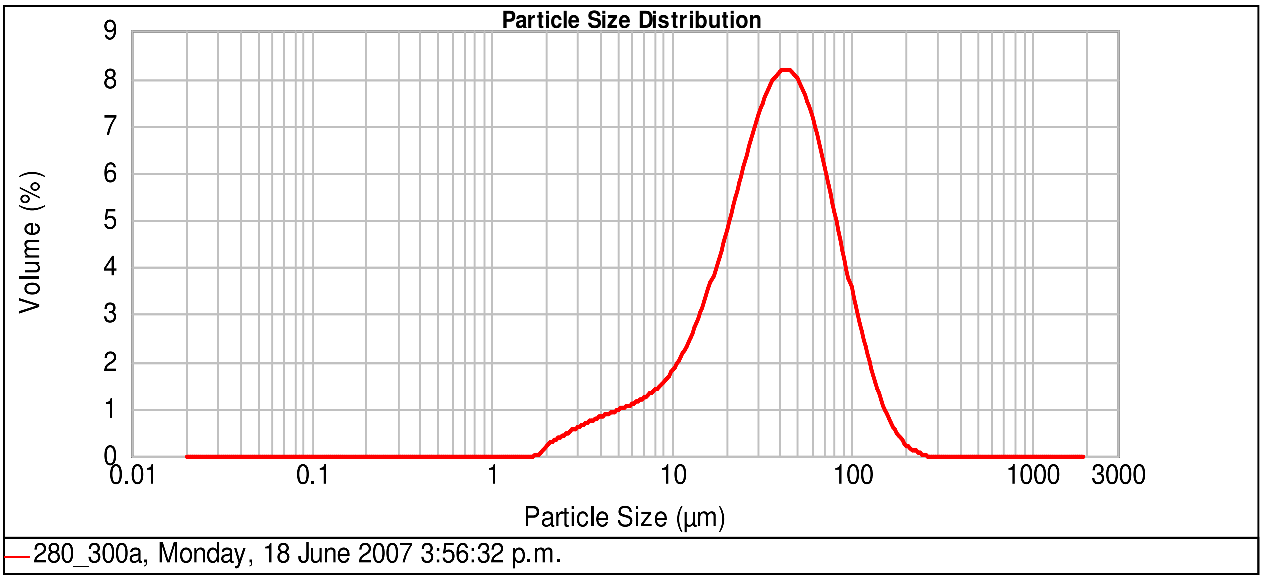
Result Analysis Report

Sample Name: 280_300a	**SOP Name:** Marine Sediment	**Measured:** Monday, 18 June 2007 3:56:32 p.m.
Sample Source & type: d2	**Measured by:** gmdr1	**Analysed:** Monday, 18 June 2007 3:56:33 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 14.51 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.293 %	**Result Emulation:** Off

Concentration: 0.0400 %Vol	**Span :** 2.104	**Uniformity:** 0.653	**Result units:** Volume
Specific Surface Area: 0.28 m²/g	**Surface Weighted Mean D[3,2]:** 21.416 um	**Vol. Weighted Mean D[4,3]:** 44.920 um	

d(0.1): 10.381 um **d(0.5):** 37.312 um **d(0.9):** 88.874 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	2.29
3.900	

Size (μm)	Volume In %
3.900	4.74
7.800	9.60
15.600	23.97
31.000	8.92
37.000	9.23
44.000	9.82
53.000	

Size (μm)	Volume In %
53.000	8.42
63.000	6.79
74.000	5.90
88.000	4.41
105.000	2.89
125.000	1.71
149.000	

Size (μm)	Volume In %
149.000	0.84
177.000	0.34
210.000	0.10
250.000	0.00
300.000	0.00
350.000	0.00
420.000	

Size (μm)	Volume In %
420.000	0.00
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
260_280a

Sample Source & type:
b2

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Monday, 18 June 2007 3:23:46 p.m.

Analysed:
Monday, 18 June 2007 3:23:47 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.306 %

Sensitivity:
Enhanced

Obscuration:
13.86 %

Result Emulation:
Off

Concentration:
0.0367 %Vol

Specific Surface Area:
0.29 m²/g

Span :
2.094

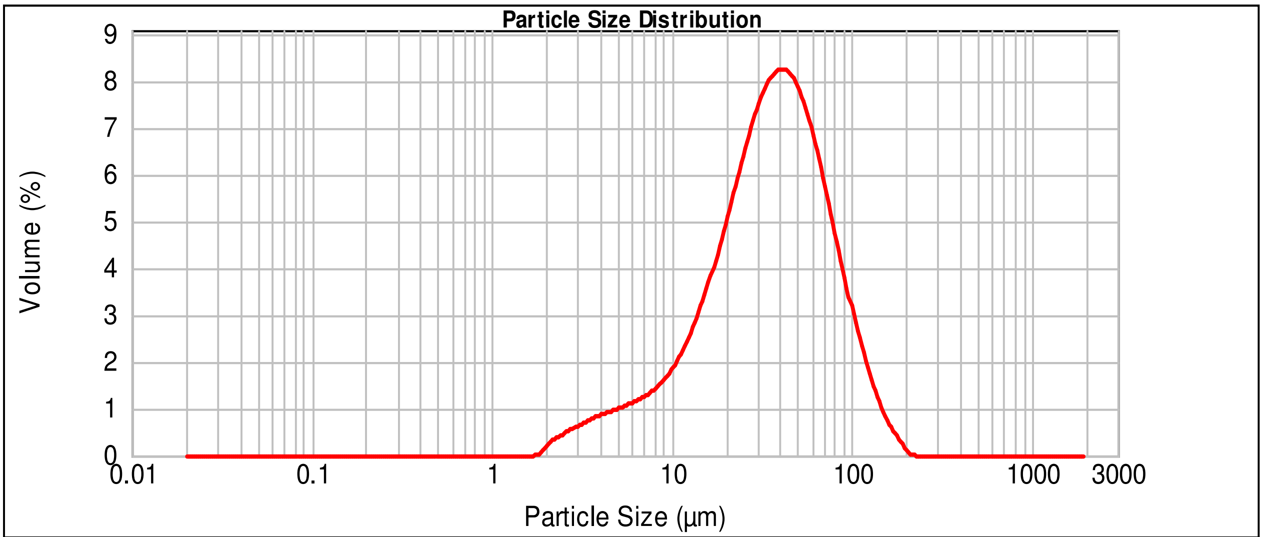
Surface Weighted Mean D[3,2]:
20.706 um

Uniformity:
0.647

Vol. Weighted Mean D[4,3]:
42.970 um

Result units:
Volume

d(0.1): 10.057 um **d(0.5): 35.757 um** **d(0.9): 84.940 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	2.44
3.900	

Size (µm)	Volume In %
3.900	4.90
7.800	9.99
15.600	25.25
31.000	9.20
37.000	9.36
44.000	9.75
53.000	

Size (µm)	Volume In %
53.000	8.16
63.000	6.43
74.000	5.46
88.000	3.99
105.000	2.57
125.000	1.50
149.000	

Size (µm)	Volume In %
149.000	0.71
177.000	0.24
210.000	0.00
250.000	0.00
300.000	0.00
350.000	0.00
420.000	

Size (µm)	Volume In %
420.000	0.00
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
240_260a

Sample Source & type:
a2

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 19 June 2007 11:53:05 a.m.

Analysed:
Tuesday, 19 June 2007 11:53:06 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.353 %

Sensitivity:
Enhanced

Obscuration:
15.44 %

Result Emulation:
Off

Concentration:
0.0456 %Vol

Specific Surface Area:
0.281 m²/g

Span :
1.962

Surface Weighted Mean D[3,2]:
21.337 um

Uniformity:
0.608

Vol. Weighted Mean D[4,3]:
41.803 um

Result units:
Volume

d(0.1): 10.867 um **d(0.5):** 35.535 um **d(0.9):** 80.576 um

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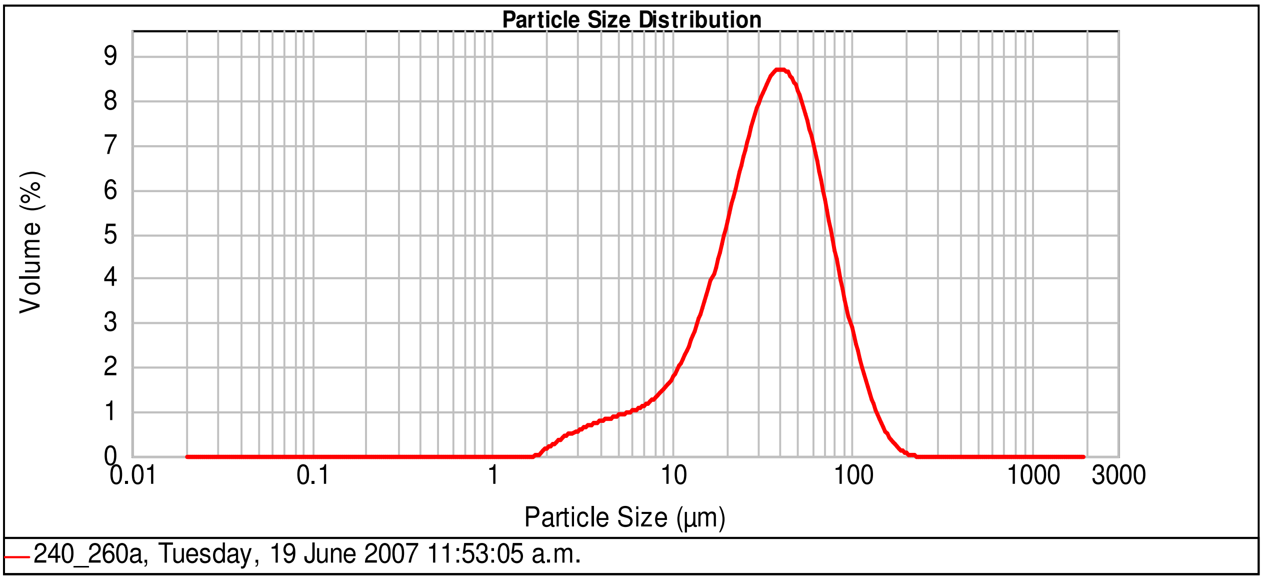


Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.05
2.000	
	2.18
3.900	

Size (µm)	Volume In %
3.900	
	4.41
7.800	
	9.67
15.600	
	26.26
31.000	
	9.70
37.000	
	9.84
44.000	
	10.18
53.000	

Size (µm)	Volume In %
53.000	
	8.40
63.000	
	6.47
74.000	
	5.31
88.000	
	3.67
105.000	
	2.17
125.000	
	1.12
149.000	

Size (µm)	Volume In %
149.000	
	0.44
177.000	
	0.11
210.000	
	0.00
250.000	
	0.00
300.000	
	0.00
350.000	
	0.00
420.000	

Size (µm)	Volume In %
420.000	
	0.00
500.000	
	0.00
590.000	
	0.00
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

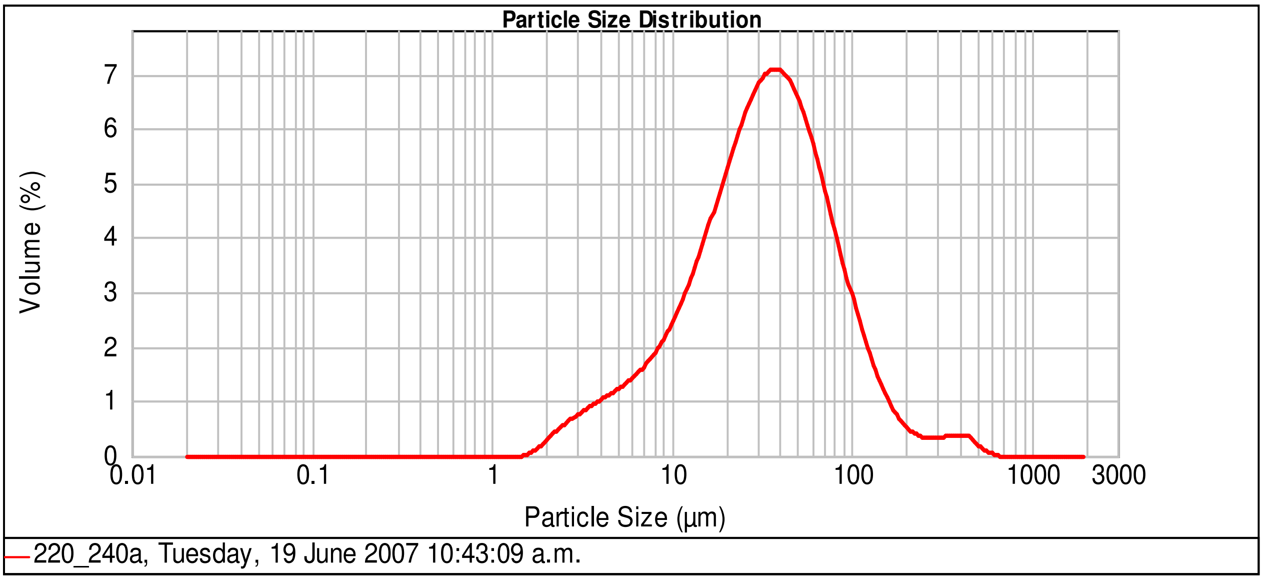
Result Analysis Report

Sample Name: 220_240a	**SOP Name:** Marine Sediment	**Measured:** Tuesday, 19 June 2007 10:43:09 a.m.
Sample Source & type: a1	**Measured by:** gmdr1	**Analysed:** Tuesday, 19 June 2007 10:43:10 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 19.04 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.945 %	**Result Emulation:** Off

Concentration: 0.0488 %Vol	**Span :** 2.635	**Uniformity:** 0.934	**Result units:** Volume
Specific Surface Area: 0.324 m²/g	**Surface Weighted Mean D[3,2]:** 18.515 um	**Vol. Weighted Mean D[4,3]:** 48.334 um	

d(0.1): 8.304 um **d(0.5): 33.128 um** **d(0.9): 95.592 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.19
2.000	2.92
3.900	

Size (µm)	Volume In %
3.900	6.12
7.800	12.58
15.600	25.17
31.000	8.12
37.000	7.99
44.000	8.15
53.000	

Size (µm)	Volume In %
53.000	6.79
63.000	5.40
74.000	4.72
88.000	3.65
105.000	2.57
125.000	1.74
149.000	

Size (µm)	Volume In %
149.000	1.08
177.000	0.66
210.000	0.44
250.000	0.39
300.000	0.35
350.000	0.44
420.000	

Size (µm)	Volume In %
420.000	0.39
500.000	0.14
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

Result Analysis Report

Sample Name:
200_220a

Sample Source & type:
b1

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 19 June 2007 11:07:29 a.m.

Analysed:
Tuesday, 19 June 2007 11:07:31 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.481 %

Sensitivity:
Enhanced

Obscuration:
11.72 %

Result Emulation:
Off

Concentration:
0.0254 %Vol

Specific Surface Area:
0.365 m²/g

Span :
2.056

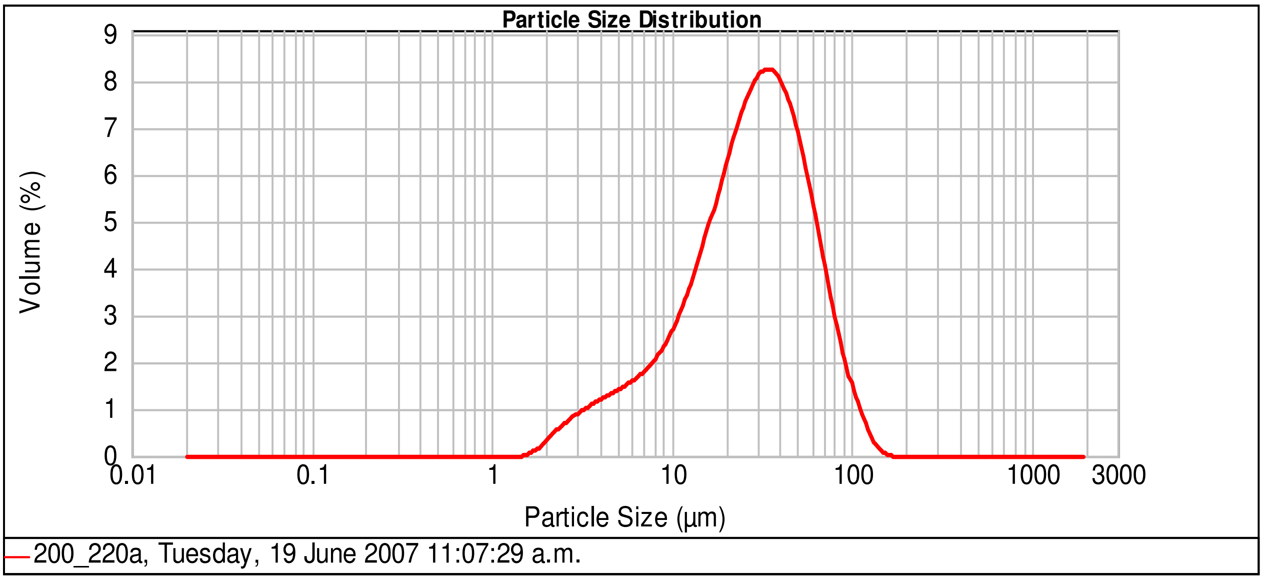
Surface Weighted Mean D[3,2]:
16.426 um

Uniformity:
0.634

Vol. Weighted Mean D[4,3]:
33.353 um

Result units:
Volume

d(0.1): 7.434 um **d(0.5):** 28.343 um **d(0.9):** 65.703 um



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.21
2.000	
	3.47
3.900	

Size (μm)	Volume In %
3.900	
	6.93
7.800	
	14.09
15.600	
	30.04
31.000	
	9.54
37.000	
	9.04
44.000	
	8.70
53.000	

Size (μm)	Volume In %
53.000	
	6.62
63.000	
	4.68
74.000	
	3.45
88.000	
	2.03
105.000	
	0.95
125.000	
	0.25
149.000	

Size (μm)	Volume In %
149.000	
	0.01
177.000	
	0.00
210.000	
	0.00
250.000	
	0.00
300.000	
	0.00
350.000	
	0.00
420.000	

Size (μm)	Volume In %
420.000	
	0.00
500.000	
	0.00
590.000	
	0.00
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
190_200a repeat

Sample Source & type:
17

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 15 June 2007 3:26:55 p.m.

Analysed:
Friday, 15 June 2007 3:26:57 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.355 %

Sensitivity:
Enhanced

Obscuration:
11.67 %

Result Emulation:
Off

Concentration:
0.0234 %Vol

Specific Surface Area:
0.392 m²/g

Span :
2.002

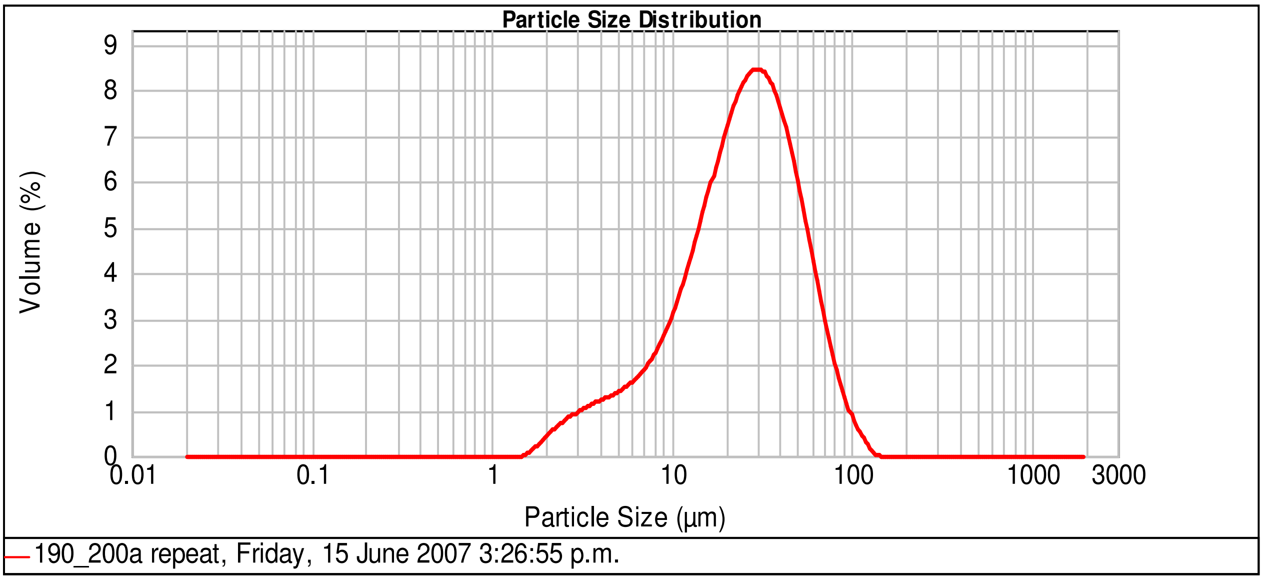
Surface Weighted Mean D[3,2]:
15.287 um

Uniformity:
0.618

Vol. Weighted Mean D[4,3]:
29.779 um

Result units:
Volume

d(0.1): 7.166 um **d(0.5):** 25.384 um **d(0.9):** 57.979 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.32
2.000	3.75
3.900	

Size (μm)	Volume In %
3.900	7.06
7.800	16.38
15.600	33.50
31.000	9.61
37.000	8.60
44.000	7.73
53.000	

Size (μm)	Volume In %
53.000	5.45
63.000	3.54
74.000	2.36
88.000	1.21
105.000	0.46
125.000	0.03
149.000	

Size (μm)	Volume In %
149.000	0.00
177.000	0.00
210.000	0.00
250.000	0.00
300.000	0.00
350.000	0.00
420.000	

Size (μm)	Volume In %
420.000	0.00
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
180_190a

SOP Name:
Marine Sediment

Measured:
Friday, 15 June 2007 1:46:08 p.m.

Sample Source & type:
1

Measured by:
gmdr1

Analysed:
Friday, 15 June 2007 1:46:09 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
12.09 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
2.918 %

Result Emulation:
Off

Concentration:
0.0332 %Vol

Span :
1.783

Uniformity:
0.558

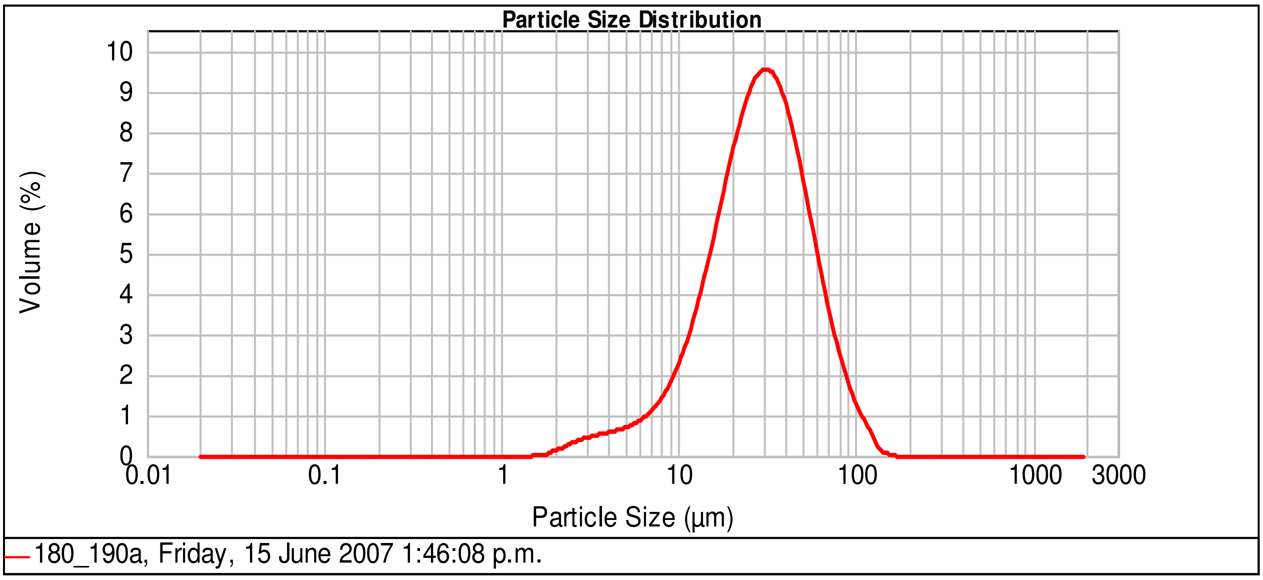
Result units:
Volume

Specific Surface Area:
0.301 m²/g

Surface Weighted Mean D[3,2]:
19.911 um

Vol. Weighted Mean D[4,3]:
33.381 um

d(0.1): 11.003 um **d(0.5): 28.609 um** **d(0.9): 62.014 um**



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.07
2.000	
	1.66
3.900	

Size (μm)	Volume In %
3.900	
	3.80
7.800	
	13.61
15.600	
	35.87
31.000	
	10.91
37.000	
	9.76
44.000	
	8.71
53.000	

Size (μm)	Volume In %
53.000	
	6.09
63.000	
	3.99
74.000	
	2.80
88.000	
	1.67
105.000	
	0.86
125.000	
	0.19
149.000	

Size (μm)	Volume In %
149.000	
	0.01
177.000	
	0.00
210.000	
	0.00
250.000	
	0.00
300.000	
	0.00
350.000	
	0.00
420.000	

Size (μm)	Volume In %
420.000	
	0.00
500.000	
	0.00
590.000	
	0.00
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
170_180a

Sample Source & type:
b3

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

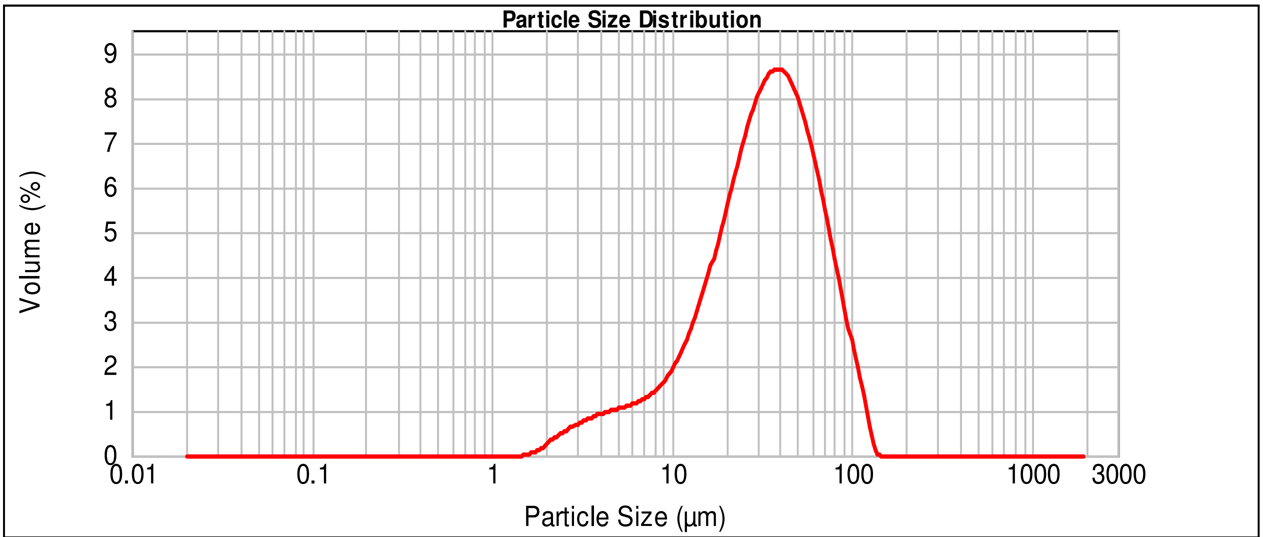
Measured:
Monday, 18 June 2007 1:08:22 p.m.

Analysed:
Monday, 18 June 2007 1:08:23 p.m.

Particle Name:	**Accessory Name:**	**Analysis model:**	**Sensitivity:**
Marine Sediment	None	General purpose	Enhanced
Particle RI:	**Absorption:**	**Size range:**	**Obscuration:**
1.500	0	0.020 to 2000.000 um	13.89 %
Dispersant Name:	**Dispersant RI:**	**Weighted Residual:**	**Result Emulation:**
Water	1.330	4.306 %	Off

Concentration:	**Span :**	**Uniformity:**	**Result units:**
0.0342 %Vol	1.941	0.59	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.309 m²/g	19.394 um	38.290 um	

d(0.1): 9.582 um **d(0.5): 33.301 um** **d(0.9): 74.204 um**



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.15
2.000	
	2.71
3.900	

Size (μm)	Volume In %
3.900	
	5.04
7.800	
	10.61
15.600	
	27.60
31.000	
	9.79
37.000	
	9.76
44.000	
	9.94
53.000	

Size (μm)	Volume In %
53.000	
	8.11
63.000	
	6.21
74.000	
	5.04
88.000	
	3.32
105.000	
	1.61
125.000	
	0.11
149.000	

Size (μm)	Volume In %
149.000	
	0.00
177.000	
	0.00
210.000	
	0.00
250.000	
	0.00
300.000	
	0.00
350.000	
	0.00
420.000	

Size (μm)	Volume In %
420.000	
	0.00
500.000	
	0.00
590.000	
	0.00
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

MALVERN INSTRUMENTS

Result Analysis Report

Sample Name: 160
SOP Name: Marine Sediment
Measured: Friday, 15 June 2007 2:27:24 p.m.

Sample Source & type: b0
Measured by: gmdr1
Analysed: Friday, 15 June 2007 2:27:25 p.m.

Sample bulk lot ref:
Result Source: Measurement

Particle Name: Marine Sediment
Accessory Name: Hydro 2000G (A)
Analysis model: General purpose
Sensitivity: Enhanced

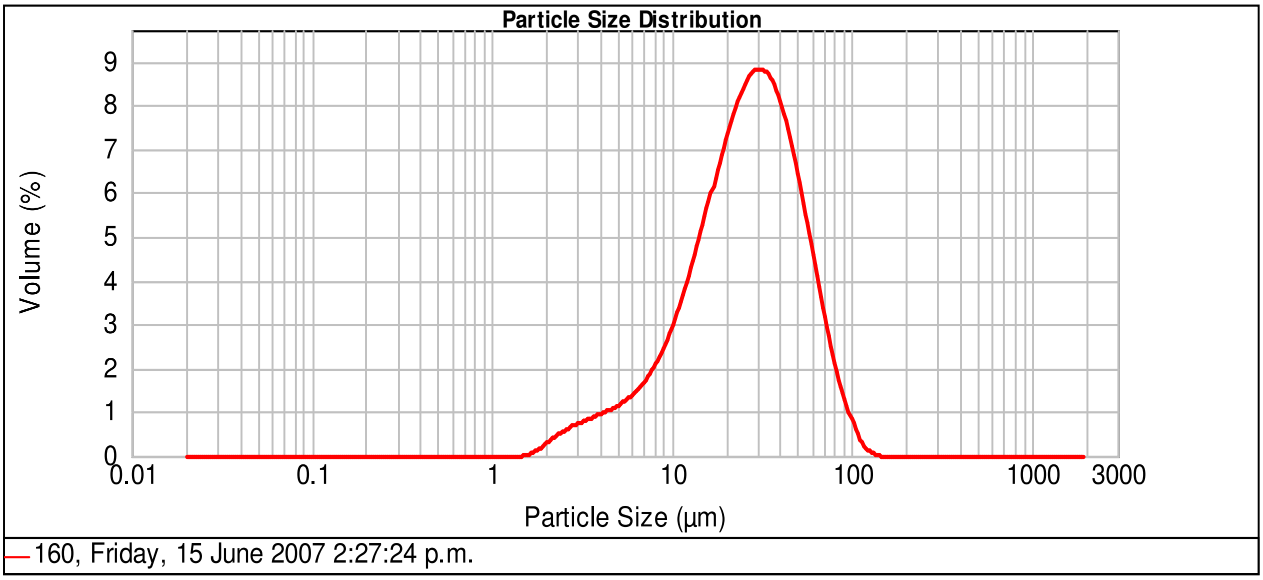
Particle RI: 1.500
Absorption: 0
Size range: 0.020 to 2000.000 um
Obscuration: 11.72 %

Dispersant Name: Water
Dispersant RI: 1.330
Weighted Residual: 0.389 %
Result Emulation: Off

Concentration: 0.0263 %Vol
Span : 1.891
Uniformity: 0.582
Result units: Volume

Specific Surface Area: 0.358 m²/g
Surface Weighted Mean D[3,2]: 16.779 um
Vol. Weighted Mean D[4,3]: 30.653 um

d(0.1): 8.406 um **d(0.5): 26.486 um** **d(0.9): 58.498 um**



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.19
2.000	
	2.82
3.900	

Size (μm)	Volume In %
3.900	
	5.99
7.800	
	15.84
15.600	
	34.18
31.000	
	10.07
37.000	
	9.11
44.000	
	8.25
53.000	

Size (μm)	Volume In %
53.000	
	5.83
63.000	
	3.76
74.000	
	2.44
88.000	
	1.20
105.000	
	0.30
125.000	
	0.03
149.000	

Size (μm)	Volume In %
149.000	
	0.00
177.000	
	0.00
210.000	
	0.00
250.000	
	0.00
300.000	
	0.00
350.000	
	0.00
420.000	

Size (μm)	Volume In %
420.000	
	0.00
500.000	
	0.00
590.000	
	0.00
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
150_160a

SOP Name:
Marine Sediment

Measured:
Friday, 15 June 2007 2:54:40 p.m.

Sample Source & type:
18

Measured by:
gmdr1

Analysed:
Friday, 15 June 2007 2:54:41 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
14.63 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.374 %

Result Emulation:
Off

Concentration:
0.0340 %Vol

Span :
1.825

Uniformity:
0.561

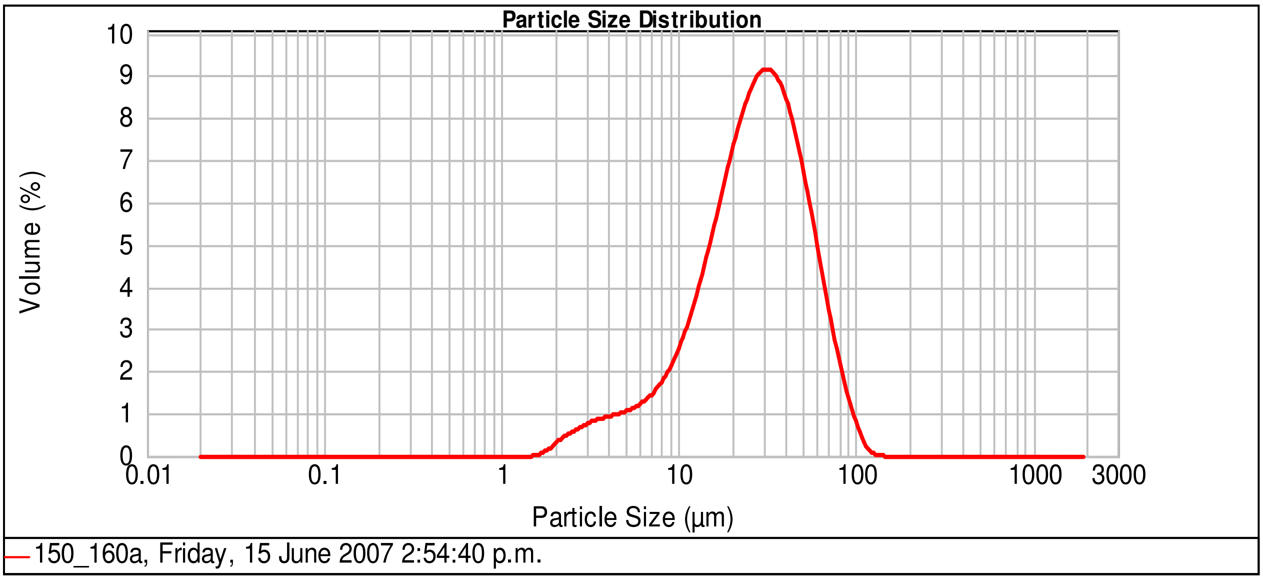
Result units:
Volume

Specific Surface Area:
0.349 m²/g

Surface Weighted Mean D[3,2]:
17.173 um

Vol. Weighted Mean D[4,3]:
31.160 um

d(0.1): 8.837 um **d(0.5):** 27.287 um **d(0.9):** 58.638 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.21
2.000	2.89
3.900	

Size (μm)	Volume In %
3.900	5.38
7.800	14.54
15.600	34.57
31.000	10.49
37.000	9.52
44.000	8.62
53.000	

Size (μm)	Volume In %
53.000	6.06
63.000	3.86
74.000	2.46
88.000	1.15
105.000	0.23
125.000	0.01
149.000	

Size (μm)	Volume In %
149.000	0.00
177.000	0.00
210.000	0.00
250.000	0.00
300.000	0.00
350.000	0.00
420.000	

Size (μm)	Volume In %
420.000	0.00
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

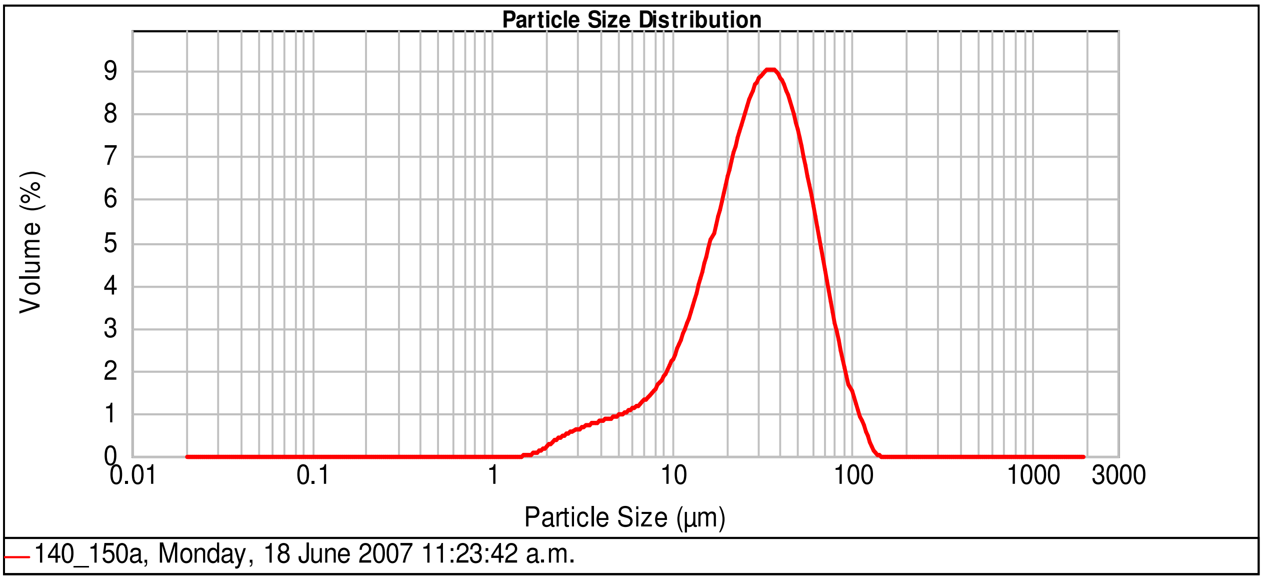
Result Analysis Report

Sample Name: 140_150a	**SOP Name:** Marine Sediment	**Measured:** Monday, 18 June 2007 11:23:42 a.m.
Sample Source & type: 8N	**Measured by:** gmdr1	**Analysed:** Monday, 18 June 2007 11:23:43 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 18.11 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.361 %	**Result Emulation:** Off

Concentration: 0.0453 %Vol	**Span :** 1.844	**Uniformity:** 0.567	**Result units:** Volume
Specific Surface Area: 0.315 m²/g	**Surface Weighted Mean D[3,2]:** 19.043 um	**Vol. Weighted Mean D[4,3]:** 34.858 um	

d(0.1): 9.844 um **d(0.5):** 30.412 um **d(0.9):** 65.917 um



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	4.80	53.000	7.27	149.000	0.00	420.000	0.00	2000.000	0.00
0.120	0.00	7.800	12.40	63.000	5.05	177.000	0.00	500.000	0.00	4000.000	
0.241	0.00	15.600	31.40	74.000	3.61	210.000	0.00	590.000	0.00		
0.490	0.00	31.000	10.44	88.000	2.01	250.000	0.00	710.000	0.00		
0.980	0.12	37.000	9.98	105.000	0.85	300.000	0.00	840.000	0.00		
2.000	2.38	44.000	9.61	125.000	0.06	350.000	0.00	1000.000	0.00		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

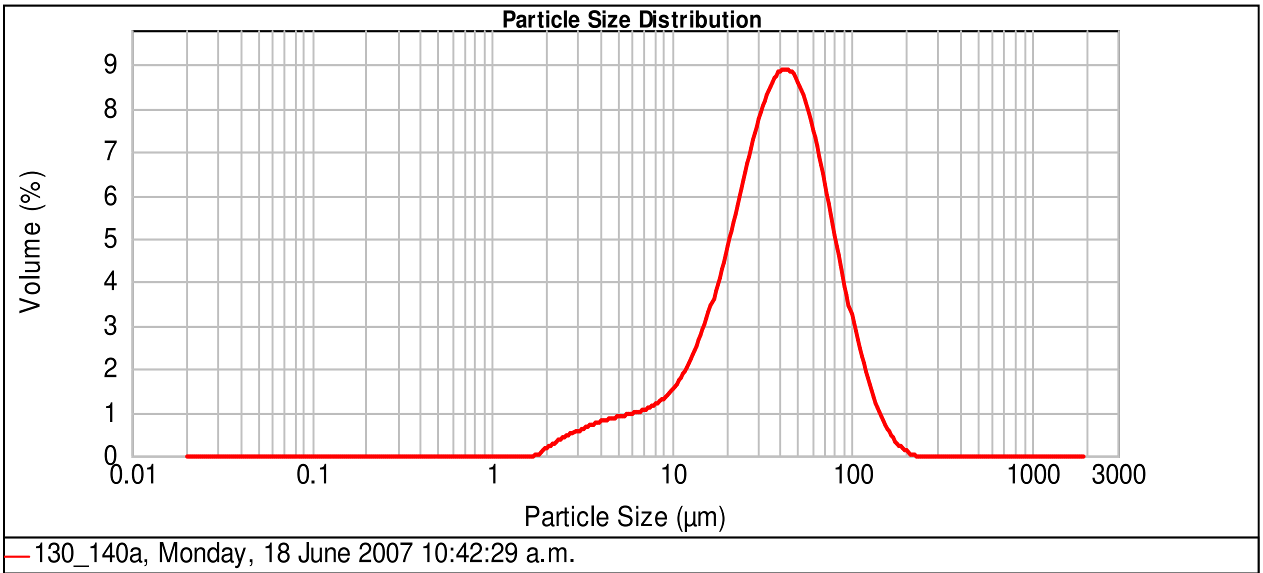
Result Analysis Report

Sample Name: 130_140a	**SOP Name:** Marine Sediment	**Measured:** Monday, 18 June 2007 10:42:29 a.m.
Sample Source & type: 8	**Measured by:** gmdr1	**Analysed:** Monday, 18 June 2007 10:42:31 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 14.86 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 1.184 %	**Result Emulation:** Off

Concentration: 0.0427 %Vol	**Span :** 1.927	**Uniformity:** 0.597	**Result units:** Volume
Specific Surface Area: 0.27 m²/g	**Surface Weighted Mean D[3,2]:** 22.214 um	**Vol. Weighted Mean D[4,3]:** 43.973 um	

d(0.1): 11.450 um **d(0.5):** 37.685 um **d(0.9):** 84.080 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.05
2.000	2.15
3.900	

Size (μm)	Volume In %
3.900	4.25
7.800	8.39
15.600	24.47
31.000	9.64
37.000	10.04
44.000	10.62
53.000	

Size (μm)	Volume In %
53.000	8.94
63.000	6.99
74.000	5.81
88.000	4.09
105.000	2.47
125.000	1.33
149.000	

Size (μm)	Volume In %
149.000	0.58
177.000	0.18
210.000	0.00
250.000	0.00
300.000	0.00
350.000	0.00
420.000	

Size (μm)	Volume In %
420.000	0.00
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
120_130a

Sample Source & type:
19

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 15 June 2007 5:29:12 p.m.

Analysed:
Friday, 15 June 2007 5:29:13 p.m.

Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 15.40 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.350 %	**Result Emulation:** Off

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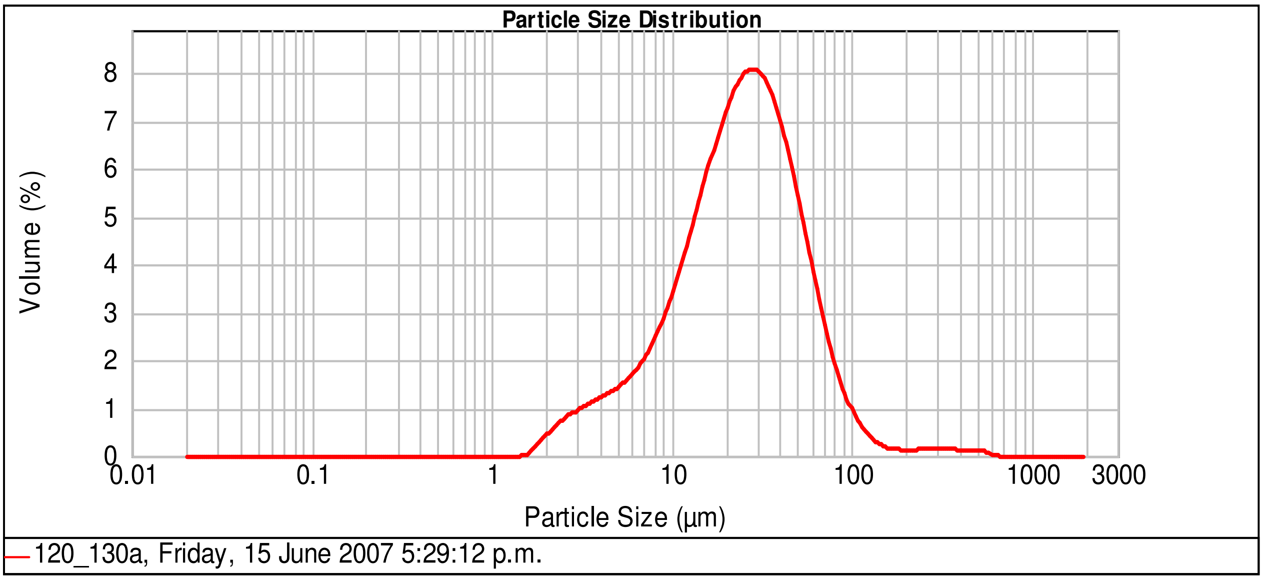
Concentration: 0.0310 %Vol	**Span :** 2.173	**Uniformity:** 0.78	**Result units:** Volume
Specific Surface Area: 0.4 m²/g	**Surface Weighted Mean D[3,2]:** 15.016 um	**Vol. Weighted Mean D[4,3]:** 32.685 um	

d(0.1): 7.035 um **d(0.5):** 24.519 um **d(0.9):** 60.321 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.35
2.000	3.75
3.900	

Size (μm)	Volume In %
3.900	7.38
7.800	17.70
15.600	33.17
31.000	8.97
37.000	7.88
44.000	6.99
53.000	

Size (μm)	Volume In %
53.000	4.91
63.000	3.22
74.000	2.24
88.000	1.29
105.000	0.65
125.000	0.32
149.000	

Size (μm)	Volume In %
149.000	0.18
177.000	0.15
210.000	0.15
250.000	0.17
300.000	0.14
350.000	0.16
420.000	

Size (μm)	Volume In %
420.000	0.14
500.000	0.10
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
110_120a

Sample Source & type:
48

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 15 June 2007 2:07:45 p.m.

Analysed:
Friday, 15 June 2007 2:07:46 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.752 %

Sensitivity:
Enhanced

Obscuration:
14.54 %

Result Emulation:
Off

Concentration:
0.0267 %Vol

Specific Surface Area:
0.432 m²/g

Span :
2.228

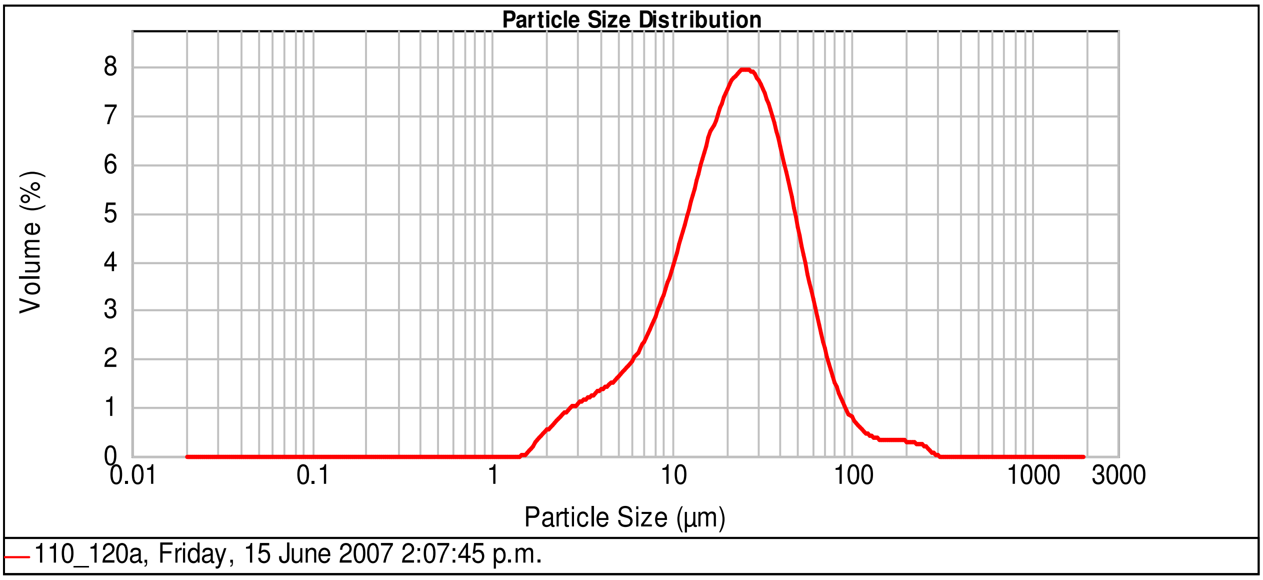
Surface Weighted Mean D[3,2]:
13.877 um

Uniformity:
0.755

Vol. Weighted Mean D[4,3]:
29.347 um

Result units:
Volume

d(0.1): 6.411 um **d(0.5): 22.444 um** **d(0.9): 56.417 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.45
2.000	4.20
3.900	

Size (μm)	Volume In %
3.900	8.39
7.800	19.86
15.600	33.74
31.000	8.44
37.000	7.15
44.000	6.11
53.000	

Size (μm)	Volume In %
53.000	4.13
63.000	2.62
74.000	1.77
88.000	1.03
105.000	0.58
125.000	0.41
149.000	

Size (μm)	Volume In %
149.000	0.36
177.000	0.35
210.000	0.29
250.000	0.13
300.000	0.00
350.000	0.00
420.000	

Size (μm)	Volume In %
420.000	0.00
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
100_110a

SOP Name:
Marine Sediment

Measured:
Monday, 18 June 2007 11:36:50 a.m.

Sample Source & type:
57

Measured by:
gmdr1

Analysed:
Monday, 18 June 2007 11:36:51 a.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
12.80 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.417 %

Result Emulation:
Off

Concentration:
0.0349 %Vol

Span :
2.182

Uniformity:
0.843

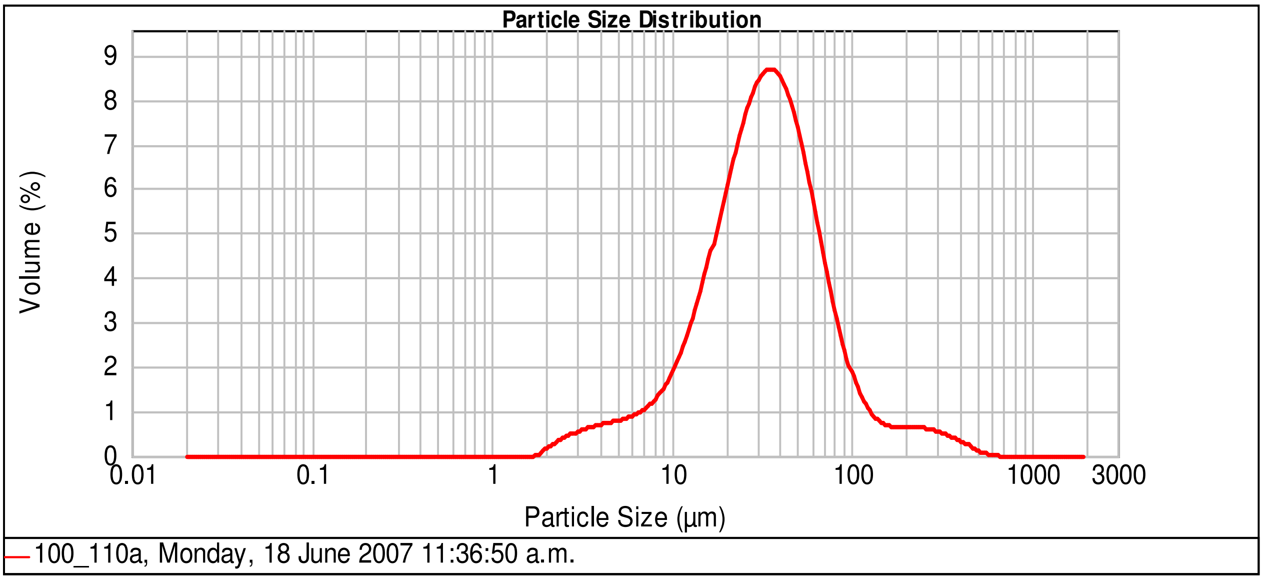
Result units:
Volume

Specific Surface Area:
0.282 m²/g

Surface Weighted Mean D[3,2]:
21.251 um

Vol. Weighted Mean D[4,3]:
47.175 um

d(0.1): 11.237 um **d(0.5): 33.118 um** **d(0.9): 83.502 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.05
2.000	2.05
3.900	

Size (μm)	Volume In %
3.900	3.95
7.800	10.70
15.600	29.53
31.000	10.01
37.000	9.60
44.000	9.27
53.000	

Size (μm)	Volume In %
53.000	7.06
63.000	5.00
74.000	3.76
88.000	2.42
105.000	1.45
125.000	0.96
149.000	

Size (μm)	Volume In %
149.000	0.76
177.000	0.72
210.000	0.73
250.000	0.71
300.000	0.51
350.000	0.44
420.000	

Size (μm)	Volume In %
420.000	0.26
500.000	0.08
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

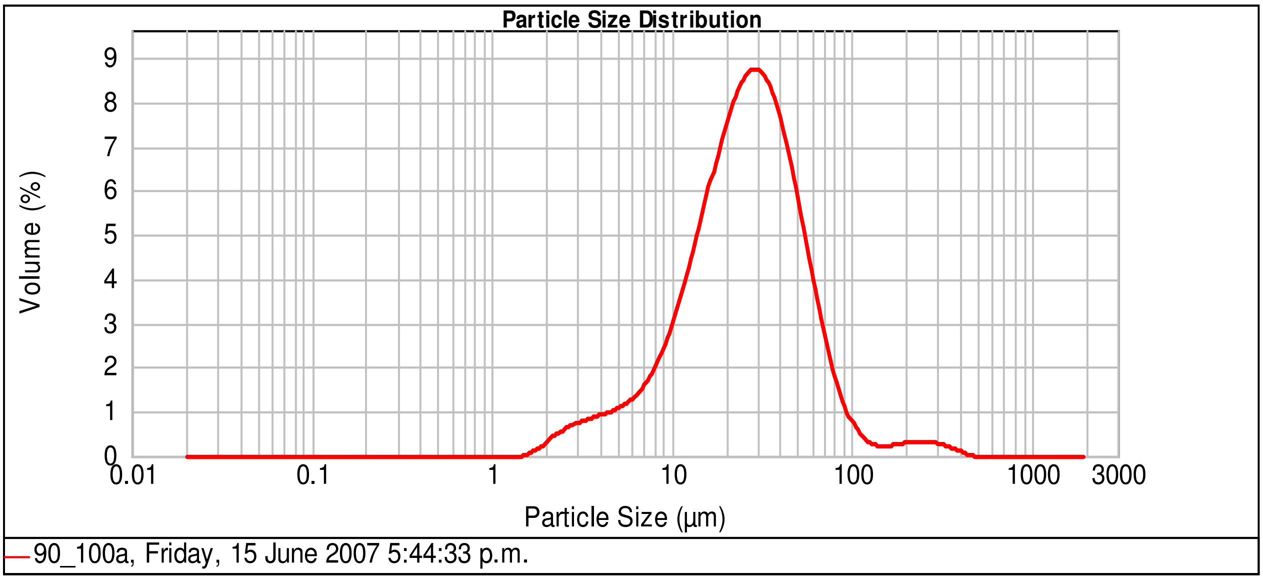
Result Analysis Report

Sample Name: 90_100a	**SOP Name:** Marine Sediment	**Measured:** Friday, 15 June 2007 5:44:33 p.m.
Sample Source & type: 37	**Measured by:** gmdr1	**Analysed:** Friday, 15 June 2007 5:44:34 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 13.32 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.444 %	**Result Emulation:** Off

Concentration: 0.0300 %Vol	**Span :** 1.994	**Uniformity:** 0.73	**Result units:** Volume
Specific Surface Area: 0.358 m²/g	**Surface Weighted Mean D[3,2]:** 16.773 um	**Vol. Weighted Mean D[4,3]:** 34.117 um	

d(0.1): 8.571 um **d(0.5): 26.052 um** **d(0.9): 60.513 um**



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	5.64	53.000	5.16	149.000	0.26	420.000	0.02	2000.000	0.00
0.120	0.00	7.800	16.24	63.000	3.24	177.000	0.32	500.000	0.00	4000.000	
0.241	0.00	15.600	34.95	74.000	2.09	210.000	0.37	590.000	0.00		
0.490	0.00	31.000	9.80	88.000	1.09	250.000	0.37	710.000	0.00		
0.980	0.21	37.000	8.61	105.000	0.49	300.000	0.26	840.000	0.00		
2.000	2.89	44.000	7.54	125.000	0.28	350.000	0.17	1000.000	0.00		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
80_90a

Sample Source & type:
42

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 15 June 2007 4:19:25 p.m.

Analysed:
Friday, 15 June 2007 4:19:26 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.421 %

Sensitivity:
Enhanced

Obscuration:
16.66 %

Result Emulation:
Off

Concentration:
0.0263 %Vol

Specific Surface Area:
0.503 m²/g

Span :
2.356

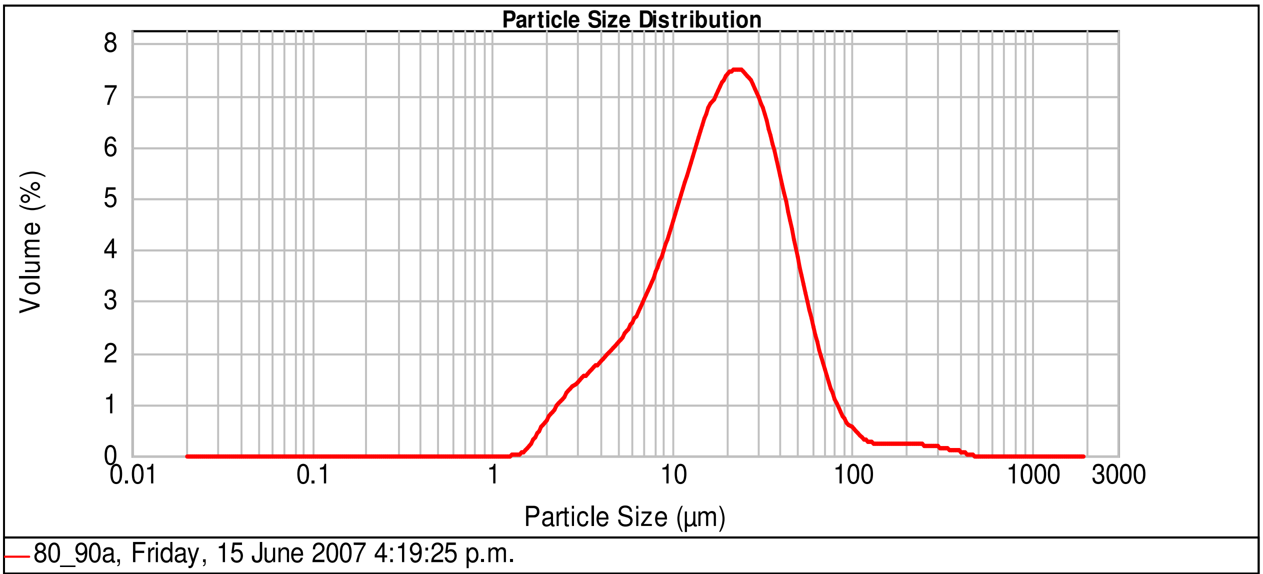
Surface Weighted Mean D[3,2]:
11.939 um

Uniformity:
0.844

Vol. Weighted Mean D[4,3]:
26.970 um

Result units:
Volume

d(0.1): 5.193 um **d(0.5):** 19.521 um **d(0.9):** 51.178 um



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.65
2.000	
	5.58
3.900	

Size (µm)	Volume In %
3.900	
	11.10
7.800	
	22.40
15.600	
	32.52
31.000	
	7.45
37.000	
	6.10
44.000	
	5.03
53.000	

Size (µm)	Volume In %
53.000	
	3.28
63.000	
	2.00
74.000	
	1.29
88.000	
	0.71
105.000	
	0.39
125.000	
	0.27
149.000	

Size (µm)	Volume In %
149.000	
	0.24
177.000	
	0.25
210.000	
	0.24
250.000	
	0.22
300.000	
	0.15
350.000	
	0.12
420.000	

Size (µm)	Volume In %
420.000	
	0.02
500.000	
	0.00
590.000	
	0.00
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
70_80a

Sample Source & type:
11

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Monday, 18 June 2007 10:55:40 a.m.

Analysed:
Monday, 18 June 2007 10:55:41 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.402 %

Sensitivity:
Enhanced

Obscuration:
21.37 %

Result Emulation:
Off

Concentration:
0.0444 %Vol

Specific Surface Area:
0.375 m²/g

Span :
2.077

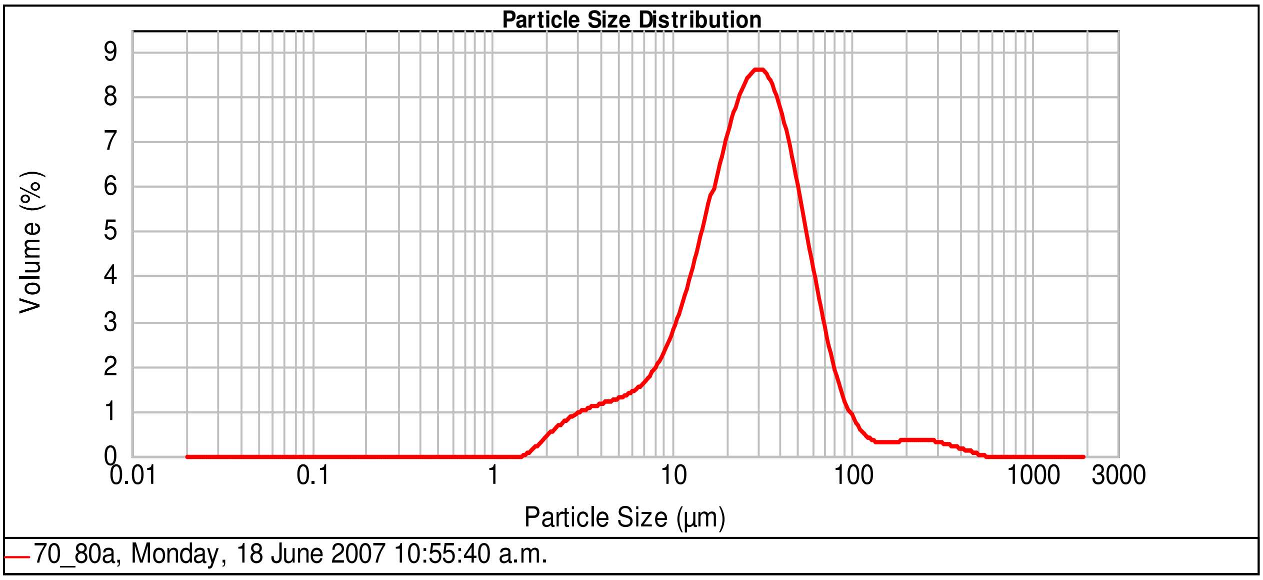
Surface Weighted Mean D[3,2]:
15.983 um

Uniformity:
0.78

Vol. Weighted Mean D[4,3]:
35.729 um

Result units:
Volume

d(0.1): 7.609 um **d(0.5): 26.613 um** **d(0.9): 62.895 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.32
2.000	3.68
3.900	

Size (μm)	Volume In %
3.900	6.29
7.800	14.94
15.600	33.31
31.000	9.75
37.000	8.69
44.000	7.72
53.000	

Size (μm)	Volume In %
53.000	5.34
63.000	3.39
74.000	2.23
88.000	1.20
105.000	0.58
125.000	0.36
149.000	

Size (μm)	Volume In %
149.000	0.33
177.000	0.38
210.000	0.42
250.000	0.41
300.000	0.29
350.000	0.24
420.000	

Size (μm)	Volume In %
420.000	0.12
500.000	0.01
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
60_70a

SOP Name:
Marine Sediment

Measured:
Friday, 15 June 2007 4:32:07 p.m.

Sample Source & type:
7

Measured by:
gmdr1

Analysed:
Friday, 15 June 2007 4:32:08 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
17.34 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.355 %

Result Emulation:
Off

Concentration:
0.0305 %Vol

Span :
3.180

Uniformity:
1.19

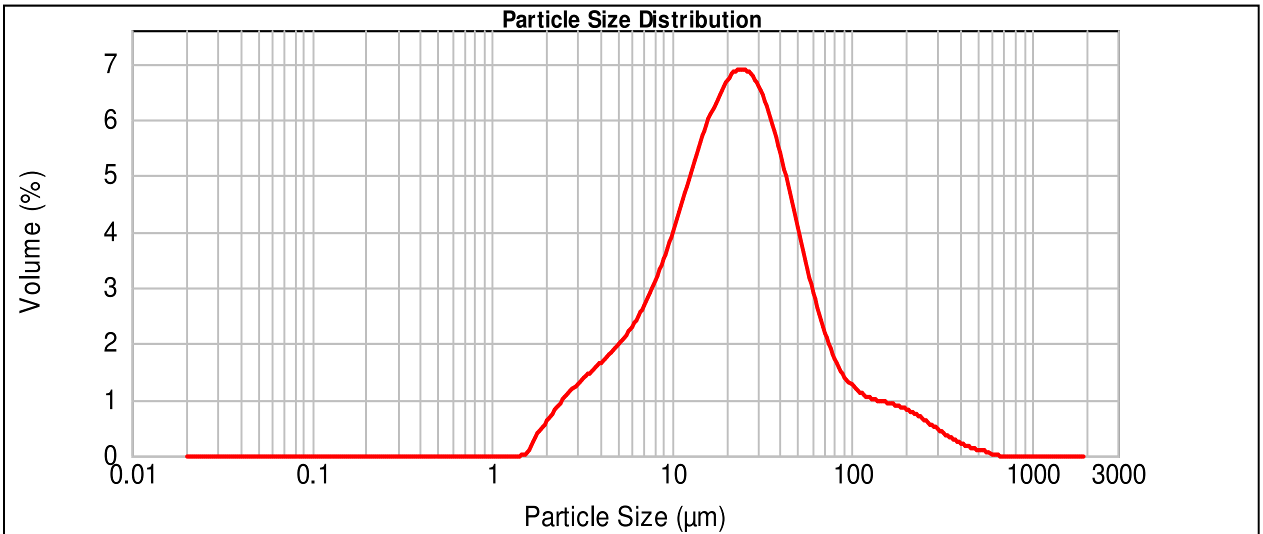
Result units:
Volume

Specific Surface Area:
0.454 m²/g

Surface Weighted Mean D[3,2]:
13.222 um

Vol. Weighted Mean D[4,3]:
38.116 um

d(0.1): 5.626 um **d(0.5): 22.167 um** **d(0.9): 76.117 um**



60_70a, Friday, 15 June 2007 4:32:07 p.m.

Size (μm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.50
3.900	5.00

Size (μm)	Volume In %
3.900	
7.800	9.92
15.600	19.75
31.000	29.76
37.000	7.17
44.000	6.07
53.000	5.25

Size (μm)	Volume In %
53.000	
63.000	3.68
74.000	2.52
88.000	1.99
105.000	1.52
125.000	1.24
149.000	1.14

Size (μm)	Volume In %
149.000	
177.000	1.05
210.000	0.95
250.000	0.83
300.000	0.67
350.000	0.41
420.000	0.31

Size (μm)	Volume In %
420.000	
500.000	0.18
590.000	0.09
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	0.00

Size (μm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
50_60a

Sample Source & type:
63

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Monday, 18 June 2007 11:08:45 a.m.

Analysed:
Monday, 18 June 2007 11:08:46 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.310 %

Sensitivity:
Enhanced

Obscuration:
14.57 %

Result Emulation:
Off

Concentration:
0.0405 %Vol

Specific Surface Area:
0.278 m²/g

Span :
2.177

Surface Weighted Mean D[3,2]:
21.601 um

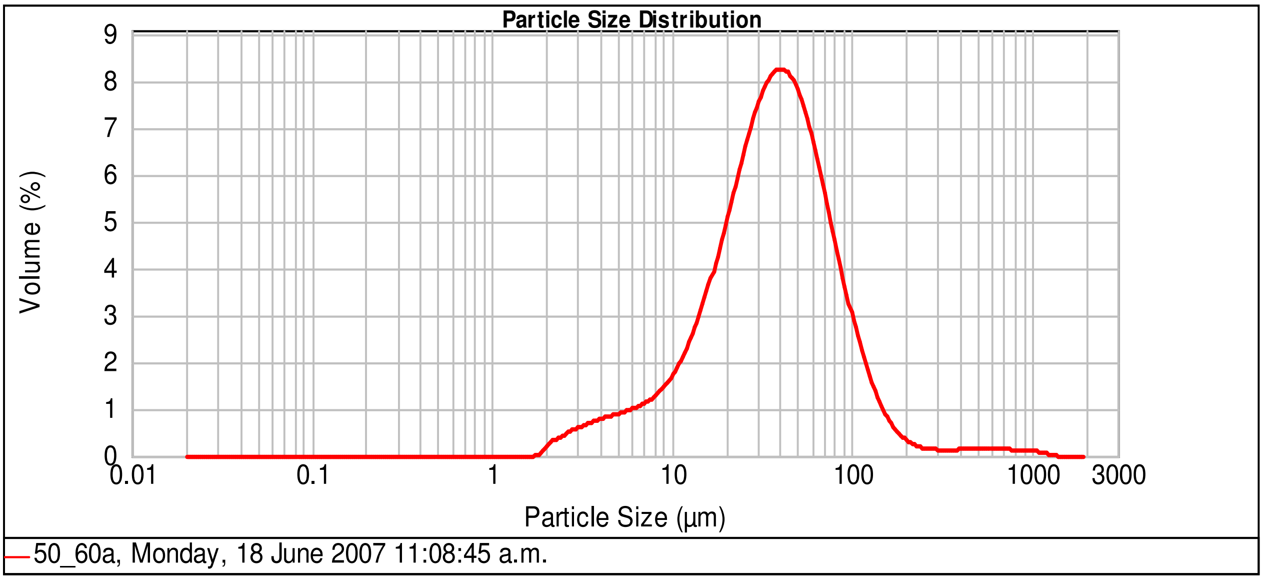
Uniformity:
0.846

Vol. Weighted Mean D[4,3]:
51.481 um

Result units:
Volume

d(0.1): 10.872 um **d(0.5):** 36.556 um **d(0.9):** 90.465 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	2.29
3.900	

Size (µm)	Volume In %
3.900	4.38
7.800	9.43
15.600	25.26
31.000	9.25
37.000	9.37
44.000	9.70
53.000	

Size (µm)	Volume In %
53.000	8.05
63.000	6.28
74.000	5.27
88.000	3.83
105.000	2.47
125.000	1.50
149.000	

Size (µm)	Volume In %
149.000	0.82
177.000	0.44
210.000	0.25
250.000	0.18
300.000	0.13
350.000	0.16
420.000	

Size (µm)	Volume In %
420.000	0.16
500.000	0.16
590.000	0.18
710.000	0.15
840.000	0.13
1000.000	0.13
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
40_50a

Sample Source & type:
44

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 15 June 2007 3:58:48 p.m.

Analysed:
Friday, 15 June 2007 3:58:49 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.437 %

Sensitivity:
Enhanced

Obscuration:
13.43 %

Result Emulation:
Off

Concentration:
0.0292 %Vol

Specific Surface Area:
0.364 m²/g

Span :
3.635

Surface Weighted Mean D[3,2]:
16.498 um

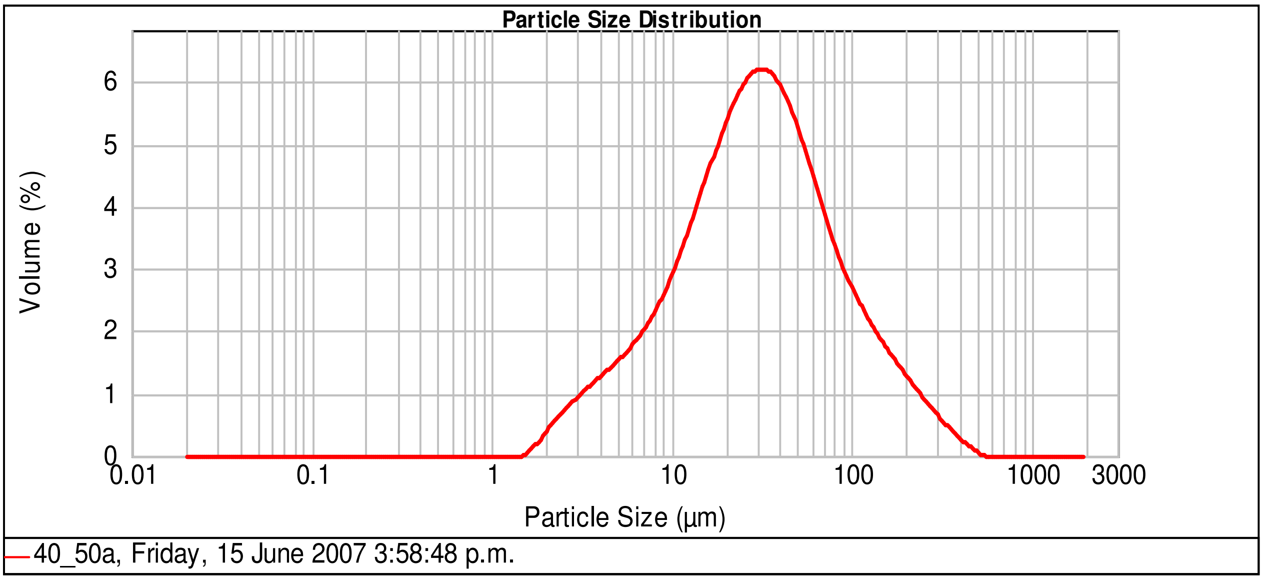
Uniformity:
1.16

Vol. Weighted Mean D[4,3]:
50.169 um

Result units:
Volume

d(0.1): 6.944 um **d(0.5):** 30.079 um **d(0.9):** 116.272 um

---



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.29
2.000	
	3.71
3.900	

Size (µm)	Volume In %
3.900	
	7.61
7.800	
	14.68
15.600	
	24.94
31.000	
	7.14
37.000	
	6.70
44.000	
	6.58
53.000	

Size (µm)	Volume In %
53.000	
	5.35
63.000	
	4.26
74.000	
	3.86
88.000	
	3.26
105.000	
	2.68
125.000	
	2.27
149.000	

Size (µm)	Volume In %
149.000	
	1.86
177.000	
	1.51
210.000	
	1.22
250.000	
	0.94
300.000	
	0.55
350.000	
	0.42
420.000	

Size (µm)	Volume In %
420.000	
	0.17
500.000	
	0.01
590.000	
	0.00
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

Result Analysis Report

Sample Name:
30_40a

Sample Source & type:
49

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 15 June 2007 6:12:24 p.m.

Analysed:
Friday, 15 June 2007 6:12:25 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.395 %

Sensitivity:
Enhanced

Obscuration:
12.18 %

Result Emulation:
Off

Concentration:
0.0242 %Vol

Span :
2.391

Uniformity:
0.978

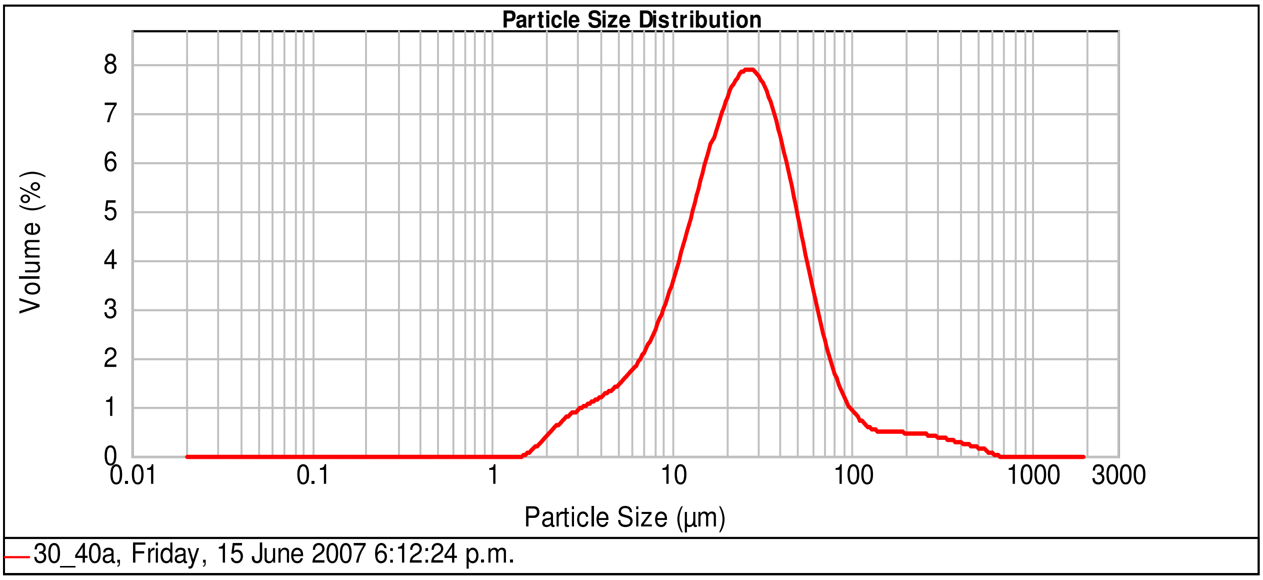
Result units:
Volume

Specific Surface Area:
0.398 m²/g

Surface Weighted Mean D[3,2]:
15.064 um

Vol. Weighted Mean D[4,3]:
36.963 um

d(0.1): 7.060 um **d(0.5):** 24.103 um **d(0.9):** 64.687 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.30
2.000	3.65
3.900	

Size (μm)	Volume In %
3.900	7.52
7.800	18.39
15.600	33.06
31.000	8.55
37.000	7.33
44.000	6.33
53.000	

Size (μm)	Volume In %
53.000	4.33
63.000	2.79
74.000	1.94
88.000	1.21
105.000	0.77
125.000	0.60
149.000	

Size (μm)	Volume In %
149.000	0.55
177.000	0.53
210.000	0.52
250.000	0.50
300.000	0.36
350.000	0.35
420.000	

Size (μm)	Volume In %
420.000	0.25
500.000	0.15
590.000	0.01
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
20_30a

SOP Name:
Marine Sediment

Measured:
Friday, 15 June 2007 5:16:29 p.m.

Sample Source & type:
4

Measured by:
gmdr1

Analysed:
Friday, 15 June 2007 5:16:30 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
13.47 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.331 %

Result Emulation:
Off

Concentration:
0.0285 %Vol

Span :
4.050

Uniformity:
1.35

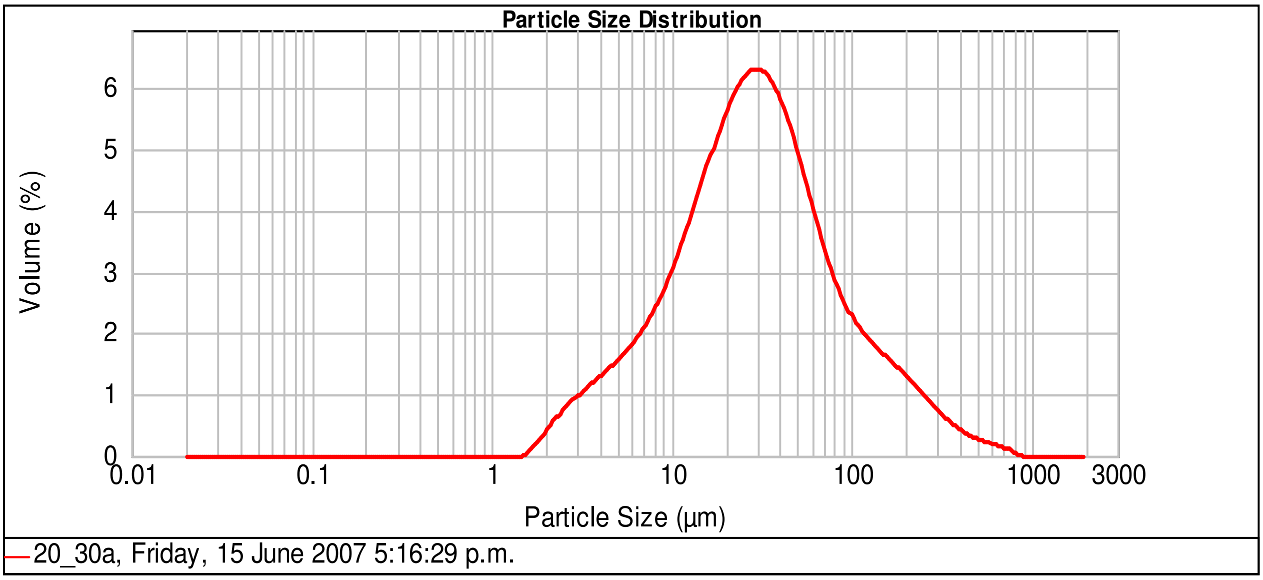
Result units:
Volume

Specific Surface Area:
0.373 m²/g

Surface Weighted Mean D[3,2]:
16.067 um

Vol. Weighted Mean D[4,3]:
53.391 um

d(0.1): 6.786 um **d(0.5): 28.647 um** **d(0.9): 122.797 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.31
2.000	3.82
3.900	

Size (μm)	Volume In %
3.900	7.85
7.800	15.39
15.600	25.90
31.000	7.18
37.000	6.58
44.000	6.24
53.000	

Size (μm)	Volume In %
53.000	4.88
63.000	3.74
74.000	3.29
88.000	2.74
105.000	2.30
125.000	2.03
149.000	

Size (μm)	Volume In %
149.000	1.76
177.000	1.51
210.000	1.28
250.000	1.04
300.000	0.66
350.000	0.57
420.000	

Size (μm)	Volume In %
420.000	0.38
500.000	0.26
590.000	0.20
710.000	0.08
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
10_20a

Sample Source & type:
42

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 15 June 2007 5:58:09 p.m.

Analysed:
Friday, 15 June 2007 5:58:10 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.418 %

Sensitivity:
Enhanced

Obscuration:
11.54 %

Result Emulation:
Off

Concentration:
0.0260 %Vol

Specific Surface Area:
0.351 m²/g

Span :
4.669

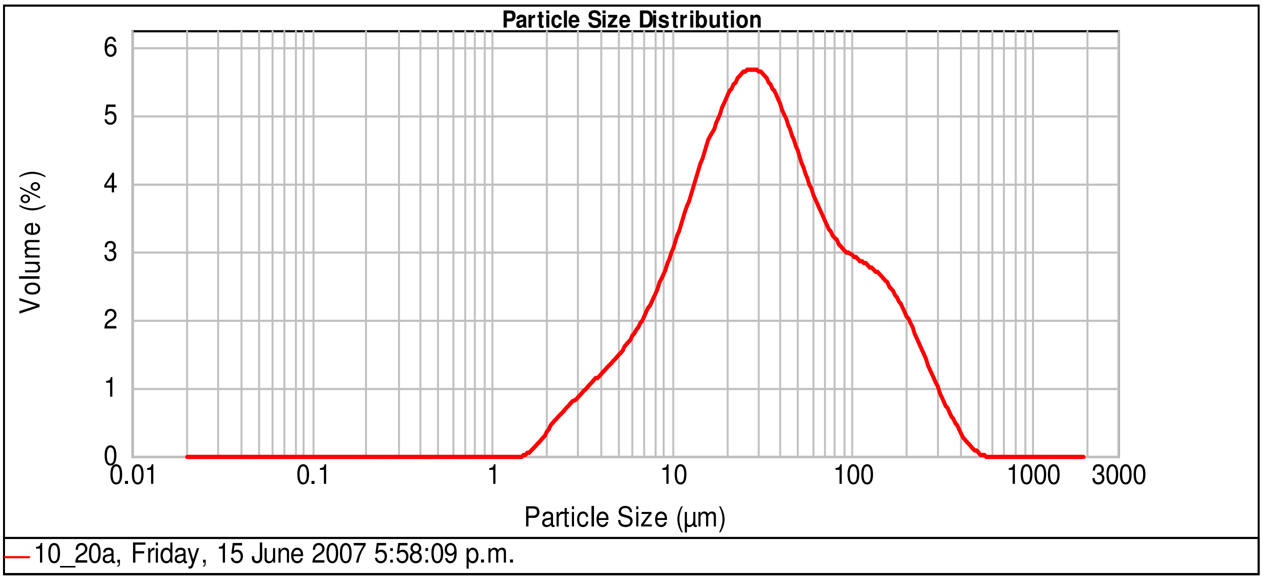
Surface Weighted Mean D[3,2]:
17.116 um

Uniformity:
1.37

Vol. Weighted Mean D[4,3]:
57.741 um

Result units:
Volume

d(0.1): 7.209 um **d(0.5): 30.817 um** **d(0.9): 151.101 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.24
2.000	3.40
3.900	

Size (μm)	Volume In %
3.900	7.49
7.800	15.12
15.600	23.97
31.000	6.39
37.000	5.83
44.000	5.60
53.000	

Size (μm)	Volume In %
53.000	4.56
63.000	3.75
74.000	3.64
88.000	3.45
105.000	3.24
125.000	3.10
149.000	

Size (μm)	Volume In %
149.000	2.79
177.000	2.41
210.000	1.98
250.000	1.50
300.000	0.83
350.000	0.55
420.000	

Size (μm)	Volume In %
420.000	0.17
500.000	0.01
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
0

Sample Source & type:
69

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 15 June 2007 4:47:04 p.m.

Analysed:
Friday, 15 June 2007 4:47:05 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
Hydro 2000G (A)

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.419 %

Sensitivity:
Enhanced

Obscuration:
11.15 %

Result Emulation:
Off

Concentration:
0.0201 %Vol

Specific Surface Area:
0.433 m²/g

Span :
3.510

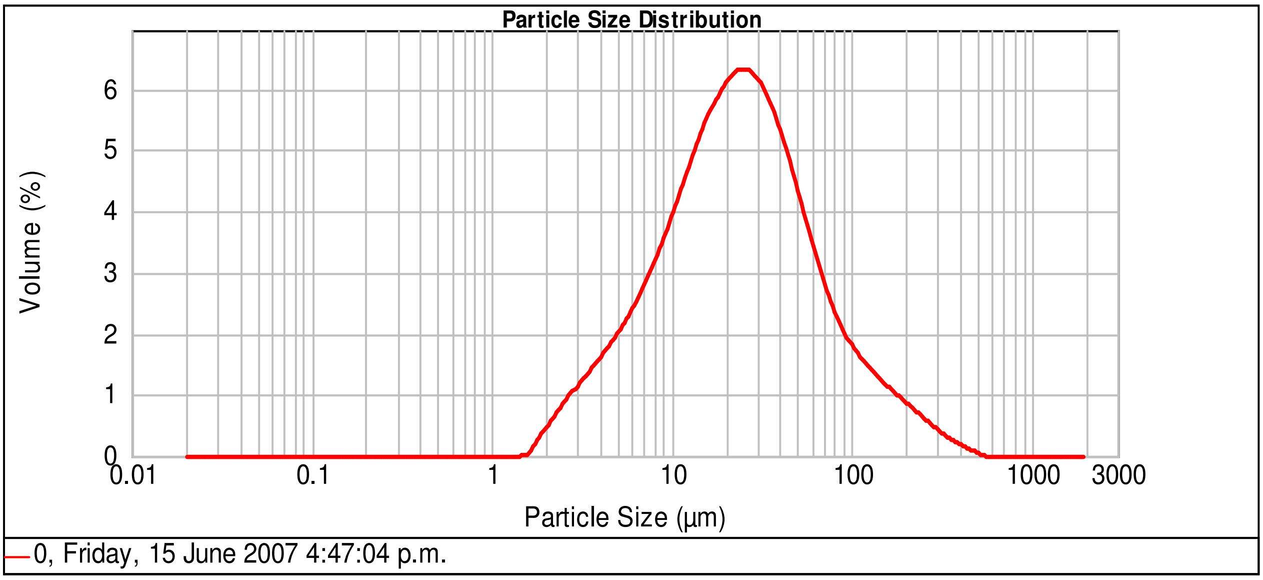
Surface Weighted Mean D[3,2]:
13.855 um

Uniformity:
1.19

Vol. Weighted Mean D[4,3]:
39.832 um

Result units:
Volume

d(0.1): 5.868 um **d(0.5):** 23.289 um **d(0.9):** 87.619 um



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.060	0.00	3.900	10.18	53.000	4.19	149.000	1.24	420.000	0.12	2000.000	0.00
0.120	0.00	7.800	19.31	63.000	3.14	177.000	1.02	500.000	0.01	4000.000	
0.241	0.00	15.600	27.40	74.000	2.70	210.000	0.82	590.000	0.00		
0.490	0.00	31.000	6.80	88.000	2.19	250.000	0.63	710.000	0.00		
0.980	0.35	37.000	6.00	105.000	1.77	300.000	0.36	840.000	0.00		
2.000	4.48	44.000	5.51	125.000	1.50	350.000	0.27	1000.000	0.00		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

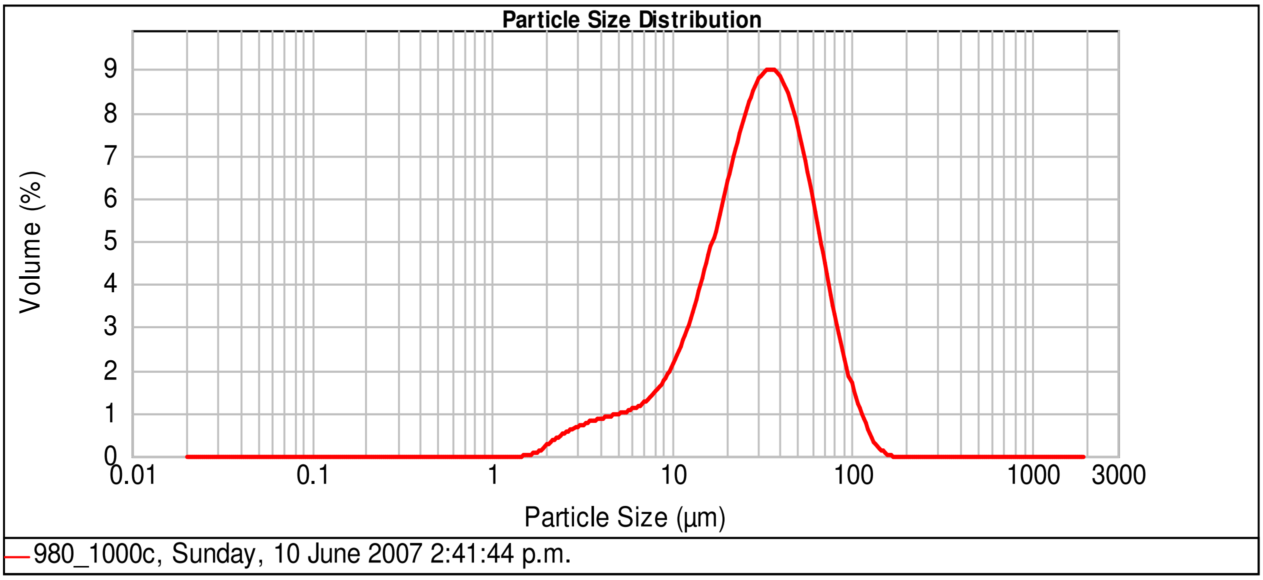
Result Analysis Report

Sample Name: 980_1000c	**SOP Name:** Marine Sediment	**Measured:** Sunday, 10 June 2007 2:41:44 p.m.
Sample Source & type: b3	**Measured by:** gmdr1	**Analysed:** Sunday, 10 June 2007 2:41:45 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 12.36 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.357 %	**Result Emulation:** Off

Concentration: 0.0296 %Vol	**Span :** 1.874	**Uniformity:** 0.576	**Result units:** Volume
Specific Surface Area: 0.317 m²/g	**Surface Weighted Mean D[3,2]:** 18.956 um	**Vol. Weighted Mean D[4,3]:** 35.646 um	

d(0.1): 9.778 um **d(0.5):** 30.898 um **d(0.9):** 67.670 um



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.15
2.000	2.60
3.900	

Size (µm)	Volume In %
3.900	4.81
7.800	11.75
15.600	30.88
31.000	10.38
37.000	9.96
44.000	9.63
53.000	

Size (µm)	Volume In %
53.000	7.34
63.000	5.17
74.000	3.78
88.000	2.22
105.000	1.03
125.000	0.28
149.000	

Size (µm)	Volume In %
149.000	0.02
177.000	0.00
210.000	0.00
250.000	0.00
300.000	0.00
350.000	0.00
420.000	

Size (µm)	Volume In %
420.000	0.00
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
880_900c

Sample Source & type:
b2

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Sunday, 10 June 2007 2:29:57 p.m.

Analysed:
Sunday, 10 June 2007 2:29:58 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.332 %

Sensitivity:
Enhanced

Obscuration:
19.94 %

Result Emulation:
Off

Concentration:
0.0494 %Vol

Specific Surface Area:
0.319 m²/g

Span :
1.894

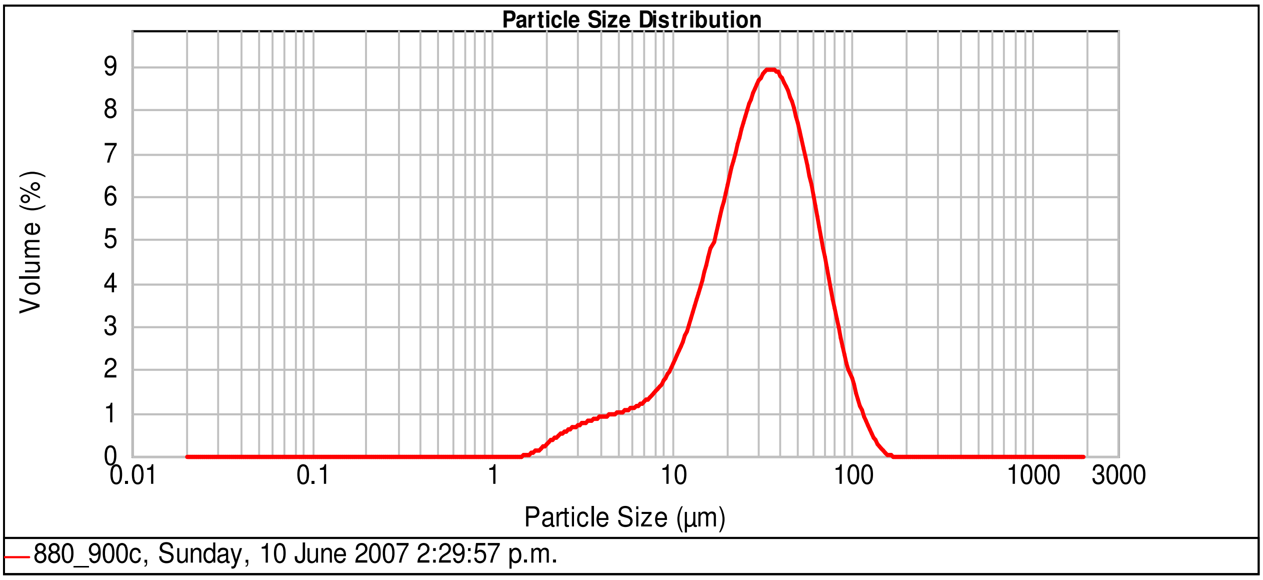
Surface Weighted Mean D[3,2]:
18.835 um

Uniformity:
0.582

Vol. Weighted Mean D[4,3]:
36.002 um

Result units:
Volume

d(0.1): 9.629 um **d(0.5):** 31.151 um **d(0.9):** 68.627 um



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.17
2.000	
	2.70
3.900	

Size (µm)	Volume In %
3.900	
	4.88
7.800	
	11.61
15.600	
	30.36
31.000	
	10.28
37.000	
	9.92
44.000	
	9.65
53.000	

Size (µm)	Volume In %
53.000	
	7.42
63.000	
	5.28
74.000	
	3.91
88.000	
	2.34
105.000	
	1.10
125.000	
	0.37
149.000	

Size (µm)	Volume In %
149.000	
	0.01
177.000	
	0.00
210.000	
	0.00
250.000	
	0.00
300.000	
	0.00
350.000	
	0.00
420.000	

Size (µm)	Volume In %
420.000	
	0.00
500.000	
	0.00
590.000	
	0.00
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
780_800c

Sample Source & type:
b1

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 7:30:08 p.m.

Analysed:
Thursday, 7 June 2007 7:30:09 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.324 %

Sensitivity:
Enhanced

Obscuration:
12.68 %

Result Emulation:
Off

Concentration:
0.0364 %Vol

Specific Surface Area:
0.27 m²/g

Span :
2.012

Surface Weighted Mean D[3,2]:
22.257 um

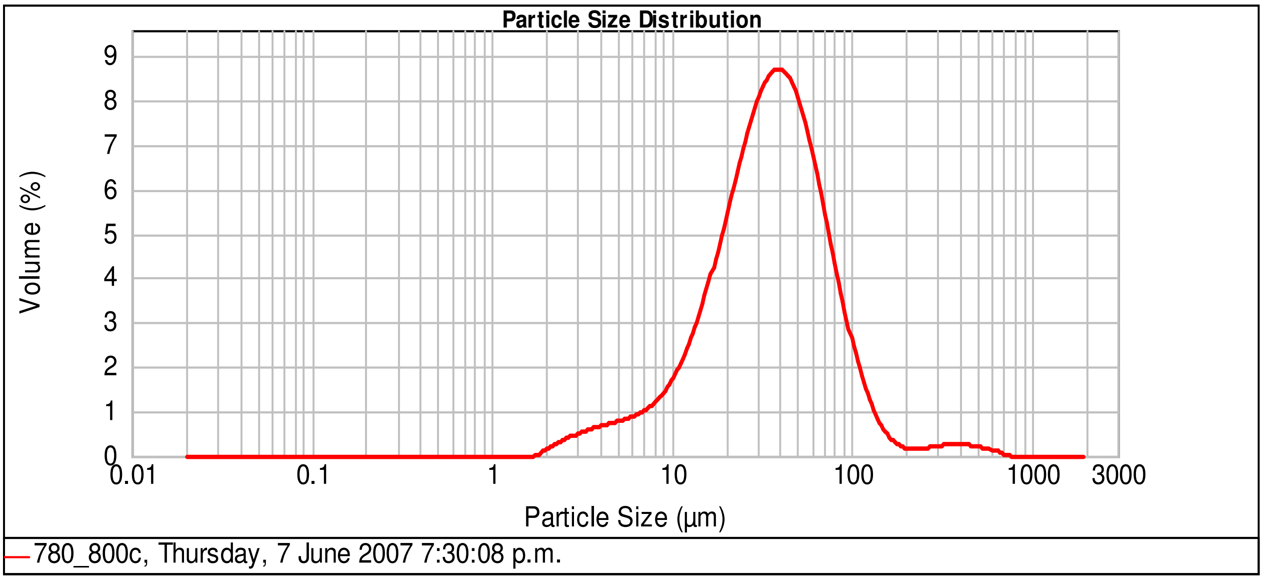
Uniformity:
0.74

Vol. Weighted Mean D[4,3]:
46.843 um

Result units:
Volume

d(0.1): 11.704 um **d(0.5):** 35.521 um **d(0.9):** 83.155 um

---



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.060	0.00	3.900	3.86	53.000	8.14	149.000	0.46	420.000	0.27	2000.000	0.00
0.120	0.00	7.800	9.66	63.000	6.16	177.000	0.22	500.000	0.19	4000.000	
0.241	0.00	15.600	27.06	74.000	4.96	210.000	0.18	590.000	0.11		
0.490	0.00	31.000	9.81	88.000	3.37	250.000	0.23	710.000	0.00		
0.980	0.05	37.000	9.84	105.000	1.96	300.000	0.24	840.000	0.00		
2.000	1.87	44.000	10.02	125.000	1.02	350.000	0.31	1000.000	0.00		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
560_580c

SOP Name:
Marine Sediment

Measured:
Sunday, 10 June 2007 2:18:00 p.m.

Sample Source & type:
a9

Measured by:
gmdr1

Analysed:
Sunday, 10 June 2007 2:18:02 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
11.68 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.282 %

Result Emulation:
Off

Concentration:
0.0581 %Vol

Span :
5.428

Uniformity:
1.71

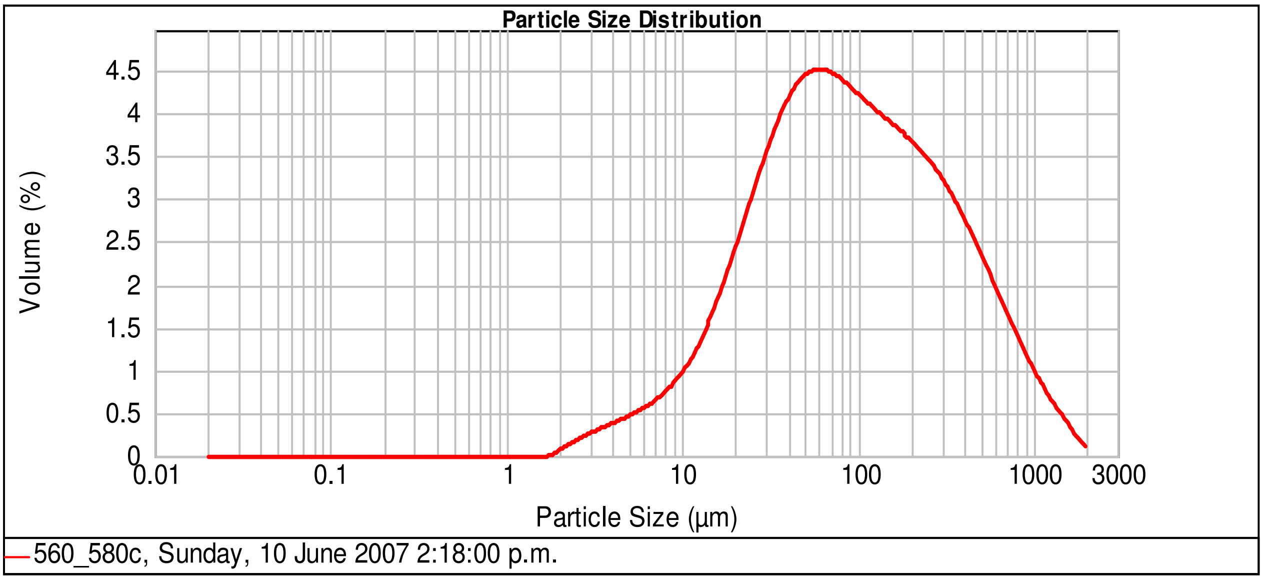
Result units:
Volume

Specific Surface Area:
0.156 m²/g

Surface Weighted Mean D[3,2]:
38.493 um

Vol. Weighted Mean D[4,3]:
189.842 um

d(0.1): 17.349 um **d(0.5): 88.005 um** **d(0.9): 495.080 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.02
2.000	1.00
3.900	

Size (μm)	Volume In %
3.900	2.39
7.800	5.27
15.600	11.99
31.000	4.43
37.000	4.74
44.000	5.37
53.000	

Size (μm)	Volume In %
53.000	5.09
63.000	4.72
74.000	4.97
88.000	4.91
105.000	4.68
125.000	4.55
149.000	

Size (μm)	Volume In %
149.000	4.32
177.000	4.15
210.000	4.06
250.000	4.02
300.000	3.16
350.000	3.41
420.000	

Size (μm)	Volume In %
420.000	2.89
500.000	2.38
590.000	2.22
710.000	1.63
840.000	1.32
1000.000	2.30
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

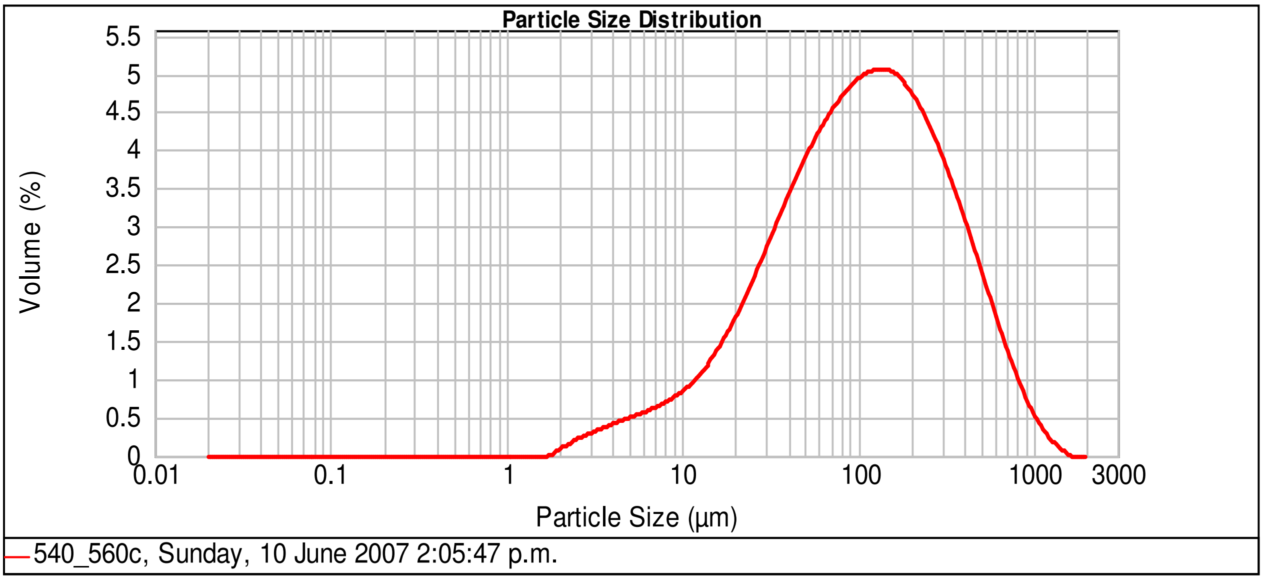
Result Analysis Report

Sample Name: 540_560c	**SOP Name:** Marine Sediment	**Measured:** Sunday, 10 June 2007 2:05:47 p.m.
Sample Source & type: a8	**Measured by:** gmdr1	**Analysed:** Sunday, 10 June 2007 2:05:48 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 11.40 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.332 %	**Result Emulation:** Off

Concentration: 0.0597 %Vol	**Span :** 3.793	**Uniformity:** 1.19	**Result units:** Volume
Specific Surface Area: 0.146 m²/g	**Surface Weighted Mean D[3,2]:** 41.093 um	**Vol. Weighted Mean D[4,3]:** 175.297 um	

d(0.1): 19.139 um **d(0.5): 107.021 um** **d(0.9): 425.047 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.03
2.000	1.12
3.900	

Size (µm)	Volume In %
3.900	2.45
7.800	4.37
15.600	9.02
31.000	3.47
37.000	3.87
44.000	4.65
53.000	

Size (µm)	Volume In %
53.000	4.72
63.000	4.70
74.000	5.33
88.000	5.65
105.000	5.72
125.000	5.81
149.000	

Size (µm)	Volume In %
149.000	5.62
177.000	5.39
210.000	5.19
250.000	4.98
300.000	3.78
350.000	3.90
420.000	

Size (µm)	Volume In %
420.000	3.11
500.000	2.37
590.000	2.00
710.000	1.25
840.000	0.82
1000.000	0.68
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
500_520c

Sample Source & type:
a6

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Sunday, 10 June 2007 1:53:24 p.m.

Analysed:
Sunday, 10 June 2007 1:53:25 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.294 %

Sensitivity:
Enhanced

Obscuration:
11.74 %

Result Emulation:
Off

Concentration:
0.0647 %Vol

Specific Surface Area:
0.14 m²/g

Span :
4.219

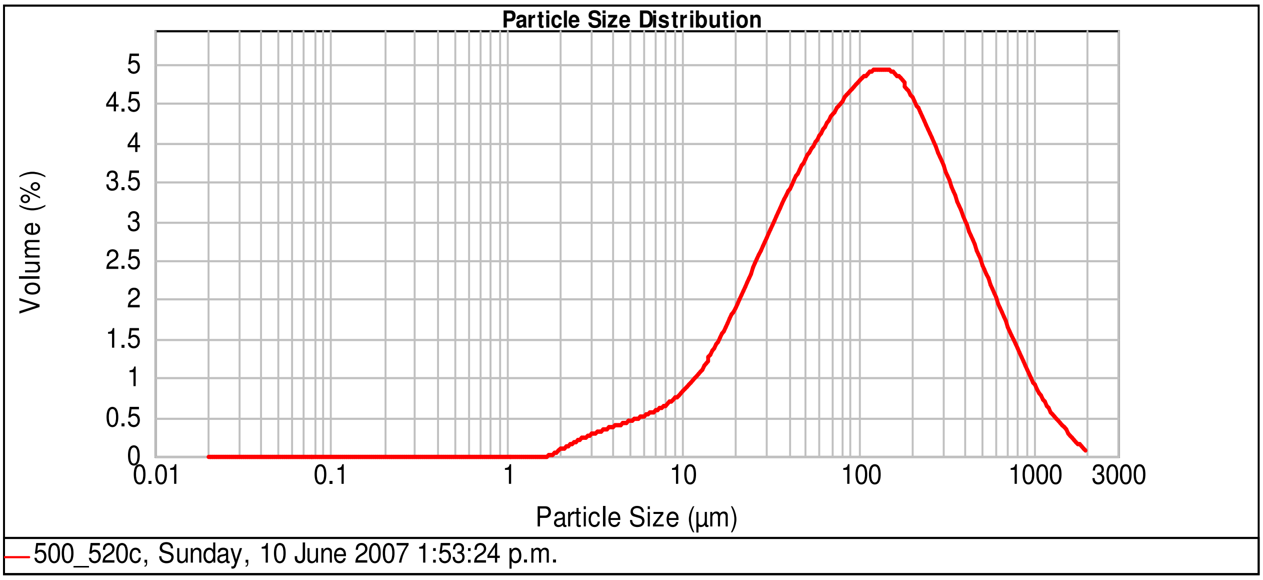
Surface Weighted Mean D[3,2]:
42.901 um

Uniformity:
1.34

Vol. Weighted Mean D[4,3]:
197.505 um

Result units:
Volume

d(0.1): 19.726 um **d(0.5): 110.585 um** **d(0.9): 486.301 um**



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.060	0.00	3.900	2.19	53.000	4.54	149.000	5.47	420.000	3.09	2000.000	0.00
0.120	0.00	7.800	4.31	63.000	4.51	177.000	5.22	500.000	2.48	4000.000	
0.241	0.00	15.600	9.36	74.000	5.12	210.000	4.98	590.000	2.27		
0.490	0.00	31.000	3.49	88.000	5.46	250.000	4.75	710.000	1.60		
0.980	0.02	37.000	3.83	105.000	5.56	300.000	3.60	840.000	1.25		
2.000	1.00	44.000	4.52	125.000	5.66	350.000	3.76	1000.000	1.94		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
480_500c

SOP Name:
Marine Sediment

Measured:
Sunday, 10 June 2007 1:39:11 p.m.

Sample Source & type:
a5

Measured by:
gmdr1

Analysed:
Sunday, 10 June 2007 1:39:12 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
13.24 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.263 %

Result Emulation:
Off

Concentration:
0.0648 %Vol

Span :
5.104

Uniformity:
1.61

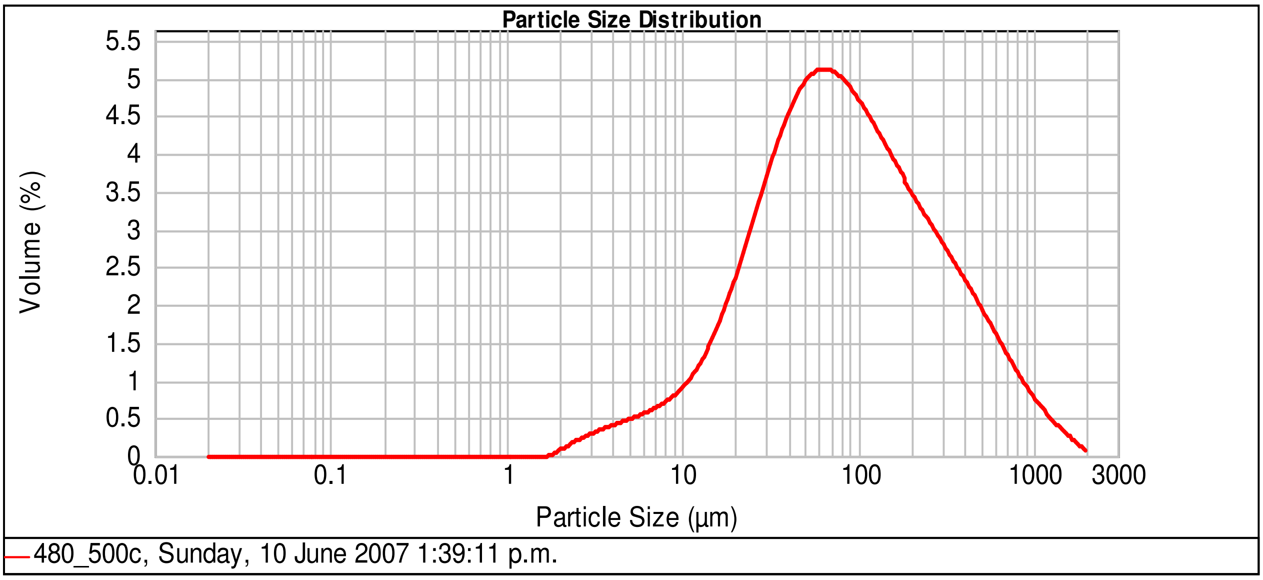
Result units:
Volume

Specific Surface Area:
0.159 m²/g

Surface Weighted Mean D[3,2]:
37.661 um

Vol. Weighted Mean D[4,3]:
168.225 um

d(0.1): 17.822 um **d(0.5): 80.426 um** **d(0.9): 428.319 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.02
2.000	1.08
3.900	

Size (µm)	Volume In %
3.900	2.41
7.800	4.90
15.600	11.91
31.000	4.69
37.000	5.15
44.000	5.97
53.000	

Size (µm)	Volume In %
53.000	5.75
63.000	5.38
74.000	5.66
88.000	5.52
105.000	5.13
125.000	4.81
149.000	

Size (µm)	Volume In %
149.000	4.36
177.000	4.00
210.000	3.75
250.000	3.57
300.000	2.74
350.000	2.91
420.000	

Size (µm)	Volume In %
420.000	2.43
500.000	1.97
590.000	1.82
710.000	1.30
840.000	1.03
1000.000	1.73
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
460_480c

Sample Source & type:
a4

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Sunday, 10 June 2007 1:24:10 p.m.

Analysed:
Sunday, 10 June 2007 1:24:11 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.364 %

Sensitivity:
Enhanced

Obscuration:
11.38 %

Result Emulation:
Off

Concentration:
0.0550 %Vol

Specific Surface Area:
0.159 m²/g

Span :
3.149

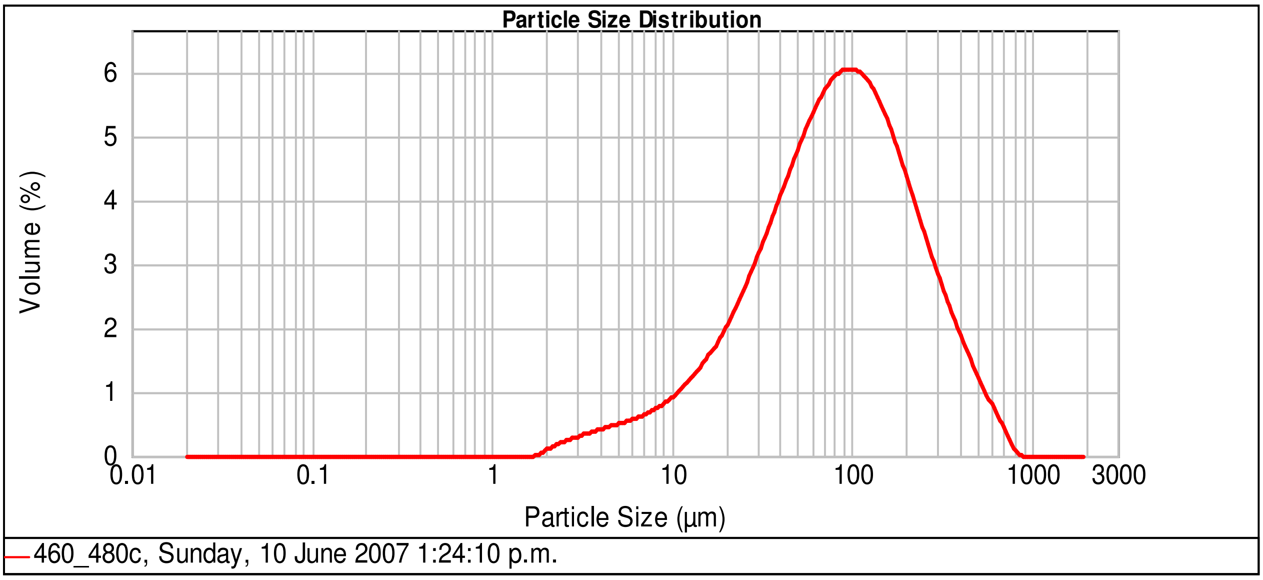
Surface Weighted Mean D[3,2]:
37.756 um

Uniformity:
0.977

Vol. Weighted Mean D[4,3]:
123.578 um

Result units:
Volume

d(0.1): 18.144 um **d(0.5): 84.328 um** **d(0.9): 283.681 um**



Size (µm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.03
3.900	1.15

Size (µm)	Volume In %
3.900	
7.800	2.46
15.600	4.72
31.000	10.35
37.000	4.08
44.000	4.64
53.000	5.69

Size (µm)	Volume In %
53.000	
63.000	5.90
74.000	5.94
88.000	6.72
105.000	7.00
125.000	6.80
149.000	6.49

Size (µm)	Volume In %
149.000	
177.000	5.80
210.000	5.07
250.000	4.42
300.000	3.82
350.000	2.63
420.000	2.46

Size (µm)	Volume In %
420.000	
500.000	1.75
590.000	1.15
710.000	0.74
840.000	0.19
1000.000	0.00
2000.000	0.00

Size (µm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

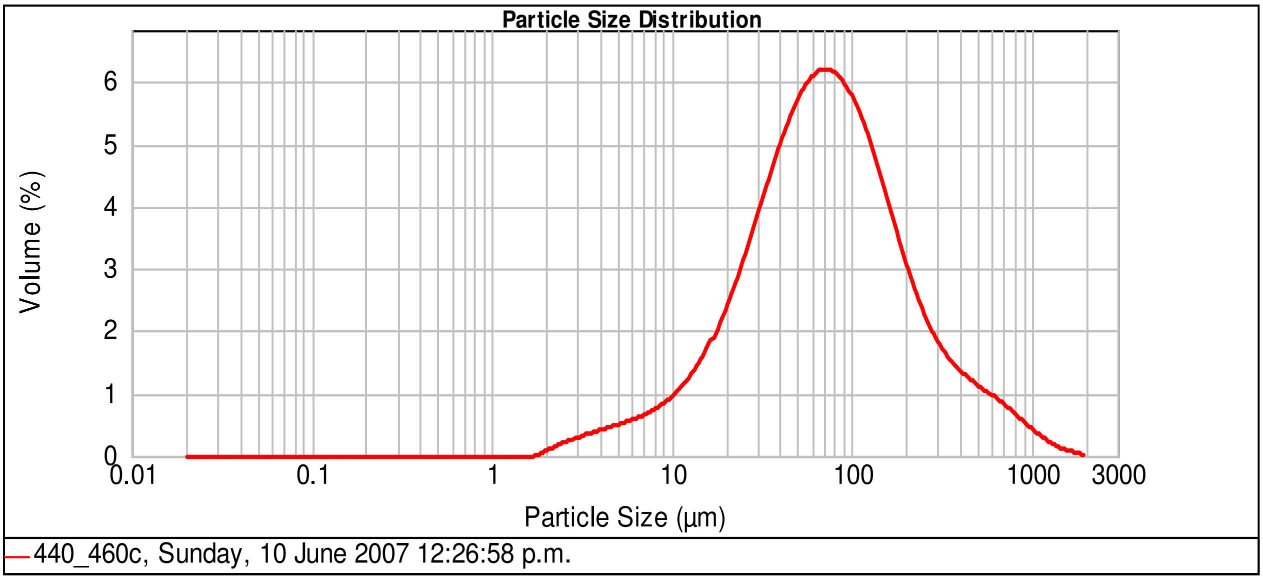
Result Analysis Report

Sample Name: 440_460c	**SOP Name:** Marine Sediment	**Measured:** Sunday, 10 June 2007 12:26:58 p.m.
Sample Source & type: a3	**Measured by:** gmdr1	**Analysed:** Sunday, 10 June 2007 12:26:59 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 11.33 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.337 %	**Result Emulation:** Off

Concentration: 0.0518 %Vol	**Span :** 3.759	**Uniformity:** 1.29	**Result units:** Volume
Specific Surface Area: 0.169 m²/g	**Surface Weighted Mean D[3,2]:** 35.499 um	**Vol. Weighted Mean D[4,3]:** 127.041 um	

d(0.1): 17.405 um **d(0.5):** 70.502 um **d(0.9):** 282.421 um



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.03
2.000	
	1.12
3.900	

Size (μm)	Volume In %
3.900	
	2.50
7.800	
	5.04
15.600	
	12.37
31.000	
	5.06
37.000	
	5.70
44.000	
	6.83
53.000	

Size (μm)	Volume In %
53.000	
	6.80
63.000	
	6.52
74.000	
	6.97
88.000	
	6.78
105.000	
	6.12
125.000	
	5.40
149.000	

Size (μm)	Volume In %
149.000	
	4.47
177.000	
	3.63
210.000	
	2.96
250.000	
	2.46
300.000	
	1.71
350.000	
	1.71
420.000	

Size (μm)	Volume In %
420.000	
	1.40
500.000	
	1.16
590.000	
	1.09
710.000	
	0.79
840.000	
	0.60
1000.000	
	0.79
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
420_440c

Sample Source & type:
a2

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Sunday, 10 June 2007 11:50:38 a.m.

Analysed:
Sunday, 10 June 2007 11:50:39 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.383 %

Sensitivity:
Enhanced

Obscuration:
13.07 %

Result Emulation:
Off

Concentration:
0.0568 %Vol

Specific Surface Area:
0.177 m²/g

Span :
3.927

Surface Weighted Mean D[3,2]:
33.954 um

Uniformity:
1.35

Vol. Weighted Mean D[4,3]:
147.793 um

Result units:
Volume

d(0.1): 15.175 um　**d(0.5):** 81.328 um　**d(0.9):** 334.577 um

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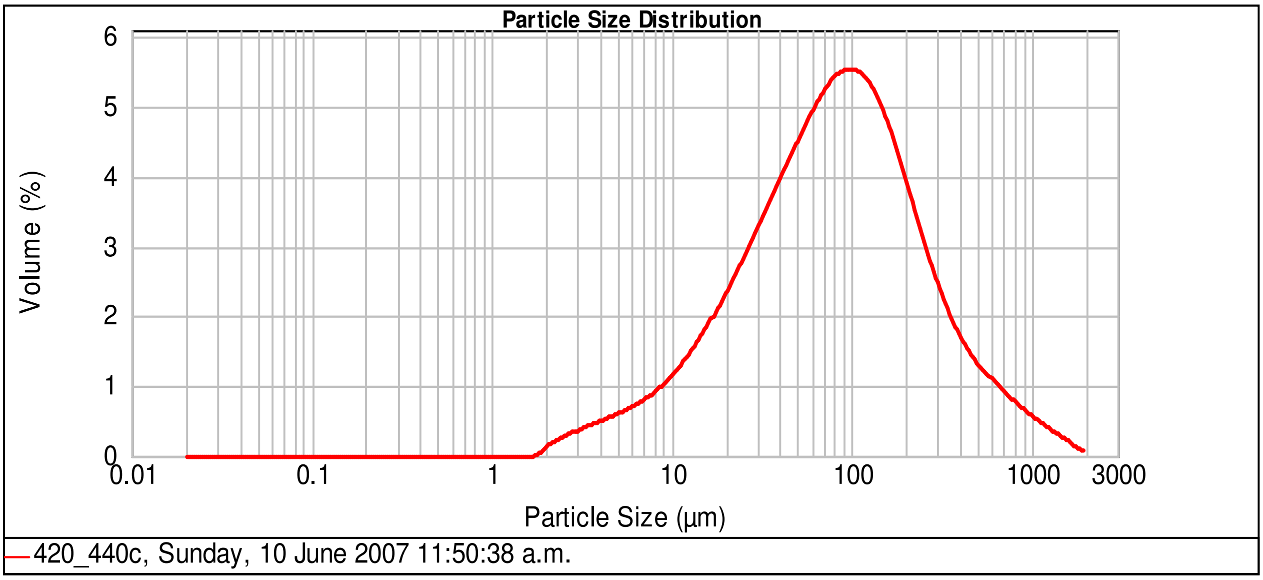


Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	1.41
3.900	

Size (μm)	Volume In %
3.900	3.01
7.800	5.87
15.600	11.50
31.000	4.12
37.000	4.51
44.000	5.36
53.000	

Size (μm)	Volume In %
53.000	5.45
63.000	5.43
74.000	6.13
88.000	6.38
105.000	6.21
125.000	5.92
149.000	

Size (μm)	Volume In %
149.000	5.26
177.000	4.55
210.000	3.90
250.000	3.31
300.000	2.27
350.000	2.17
420.000	

Size (μm)	Volume In %
420.000	1.68
500.000	1.31
590.000	1.21
710.000	0.89
840.000	0.74
1000.000	1.37
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
400_420c

SOP Name:
Marine Sediment

Measured:
Sunday, 10 June 2007 12:13:45 p.m.

Sample Source & type:
a1

Measured by:
gmdr1

Analysed:
Sunday, 10 June 2007 12:13:46 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
18.70 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.371 %

Result Emulation:
Off

Concentration:
0.1026 %Vol

Span :
3.292

Uniformity:
1.1

Result units:
Volume

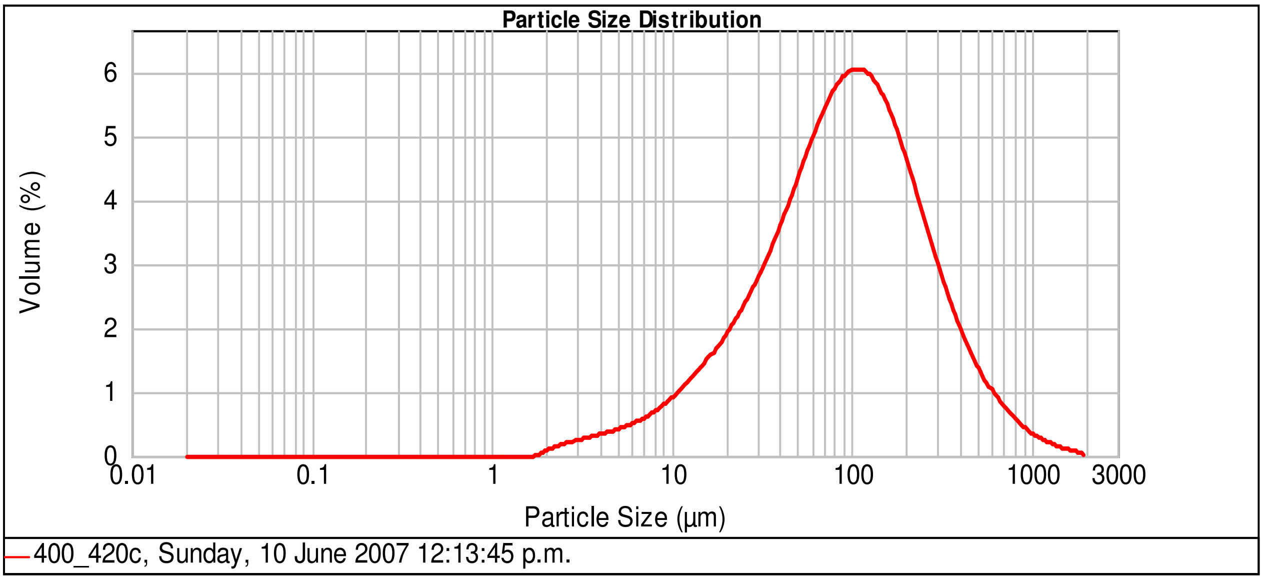
Specific Surface Area:
0.147 m²/g

Surface Weighted Mean D[3,2]:
40.906 um

Vol. Weighted Mean D[4,3]:
147.327 um

d(0.1): 19.088 um **d(0.5):** 93.246 um **d(0.9):** 326.097 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.03
2.000	0.96
3.900	

Size (µm)	Volume In %
3.900	2.15
7.800	4.68
15.600	9.53
31.000	3.60
37.000	4.12
44.000	5.13
53.000	

Size (µm)	Volume In %
53.000	5.44
63.000	5.61
74.000	6.51
88.000	6.94
105.000	6.89
125.000	6.69
149.000	

Size (µm)	Volume In %
149.000	6.07
177.000	5.37
210.000	4.69
250.000	4.04
300.000	2.77
350.000	2.58
420.000	

Size (µm)	Volume In %
420.000	1.88
500.000	1.34
590.000	1.08
710.000	0.69
840.000	0.49
1000.000	0.74
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
380_400c

Sample Source & type:
63

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 7:06:40 p.m.

Analysed:
Thursday, 7 June 2007 7:06:41 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.204 %

Sensitivity:
Enhanced

Obscuration:
16.11 %

Result Emulation:
Off

Concentration:
0.0802 %Vol

Specific Surface Area:
0.16 m²/g

Span :
2.898

Surface Weighted Mean D[3,2]:
37.574 um

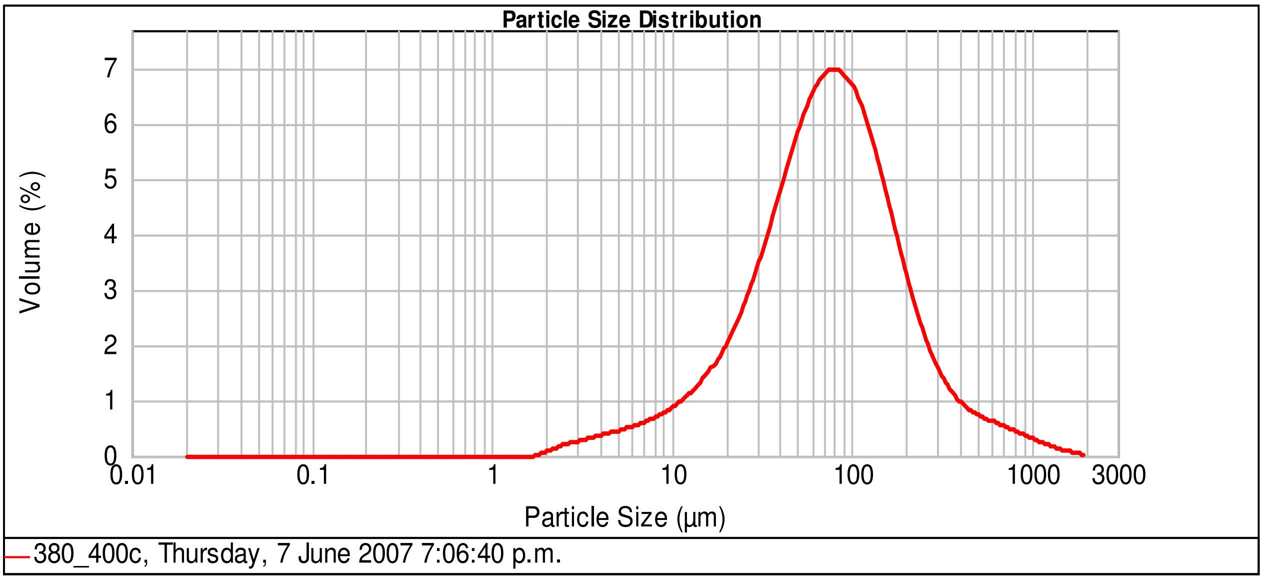
Uniformity:
1.06

Vol. Weighted Mean D[4,3]:
117.546 um

Result units:
Volume

d(0.1): 19.014 um **d(0.5):** 74.091 um **d(0.9):** 233.731 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.03
2.000	1.03
3.900	

Size (μm)	Volume In %
3.900	2.28
7.800	4.51
15.600	10.66
31.000	4.63
37.000	5.48
44.000	6.91
53.000	

Size (μm)	Volume In %
53.000	7.22
63.000	7.20
74.000	7.93
88.000	7.85
105.000	7.13
125.000	6.24
149.000	

Size (μm)	Volume In %
149.000	5.03
177.000	3.92
210.000	3.00
250.000	2.27
300.000	1.41
350.000	1.26
420.000	

Size (μm)	Volume In %
420.000	0.95
500.000	0.75
590.000	0.71
710.000	0.53
840.000	0.43
1000.000	0.65
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
340_360c

SOP Name:
Marine Sediment

Measured:
Thursday, 7 June 2007 6:53:01 p.m.

Sample Source & type:
15

Measured by:
gmdr1

Analysed:
Thursday, 7 June 2007 6:53:03 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
14.86 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.245 %

Result Emulation:
Off

Concentration:
0.0757 %Vol

Span :
2.551

Uniformity:
0.895

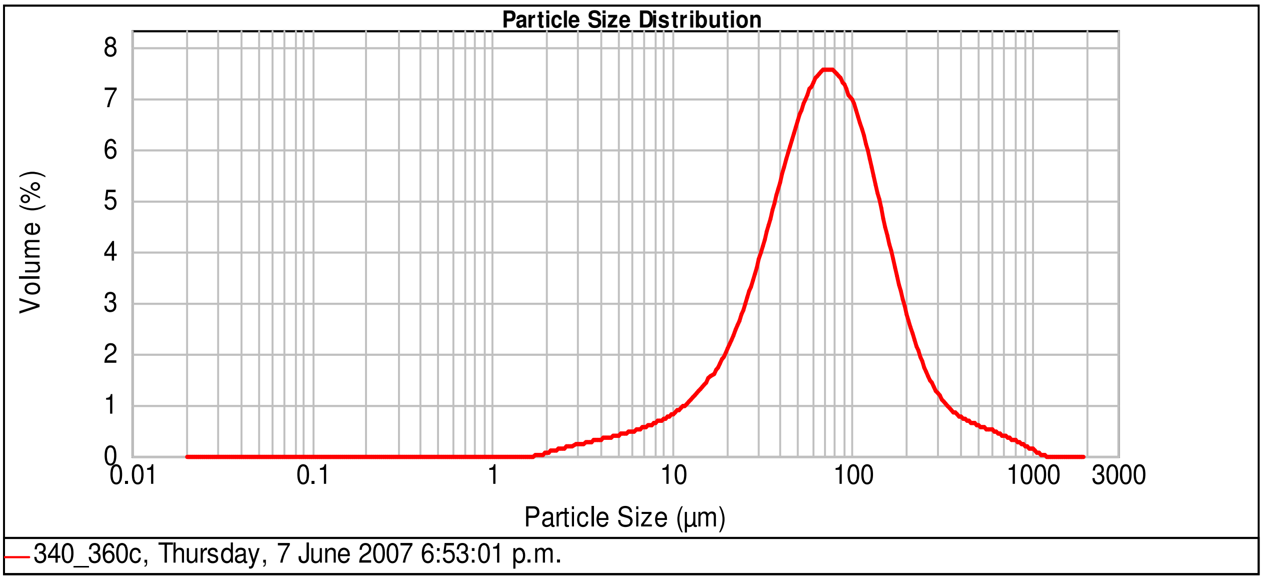
Result units:
Volume

Specific Surface Area:
0.157 m²/g

Surface Weighted Mean D[3,2]:
38.255 um

Vol. Weighted Mean D[4,3]:
99.905 um

d(0.1): 20.043 um **d(0.5): 69.241 um** **d(0.9): 196.647 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.01
2.000	0.84
3.900	

Size (µm)	Volume In %
3.900	2.05
7.800	4.27
15.600	11.16
31.000	5.12
37.000	6.13
44.000	7.75
53.000	

Size (µm)	Volume In %
53.000	8.05
63.000	7.91
74.000	8.52
88.000	8.20
105.000	7.18
125.000	6.01
149.000	

Size (µm)	Volume In %
149.000	4.60
177.000	3.38
210.000	2.44
250.000	1.77
300.000	1.08
350.000	0.99
420.000	

Size (µm)	Volume In %
420.000	0.76
500.000	0.60
590.000	0.54
710.000	0.36
840.000	0.22
1000.000	0.07
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

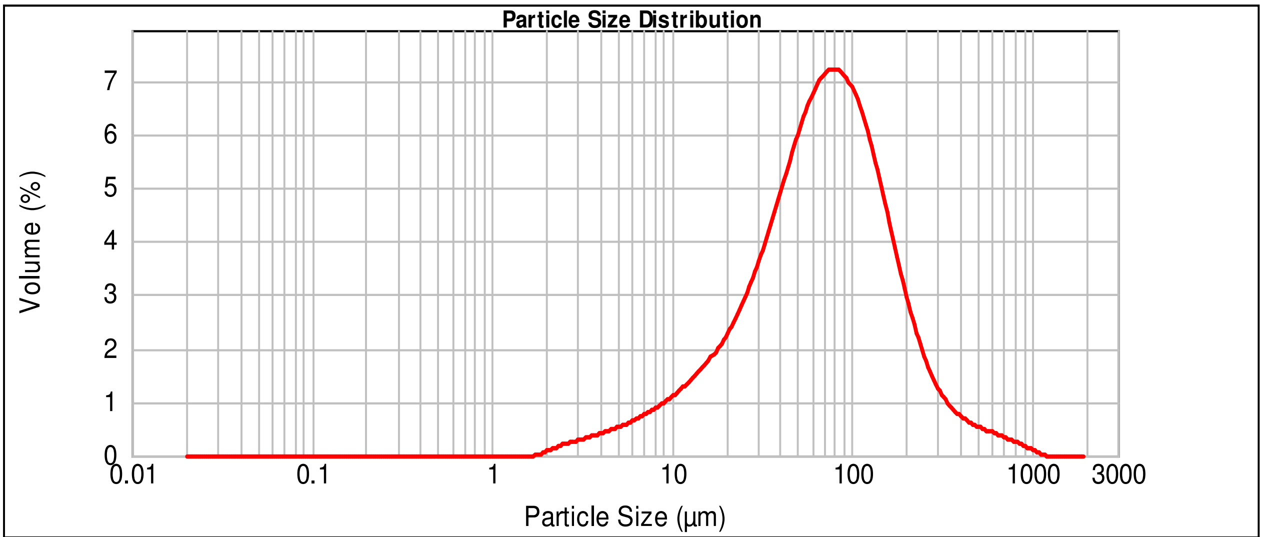
Result Analysis Report

Sample Name: 320_340c	**SOP Name:** Marine Sediment	**Measured:** Sunday, 10 June 2007 12:02:25 p.m.
Sample Source & type: 9	**Measured by:** gmdr1	**Analysed:** Sunday, 10 June 2007 12:02:26 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 12.00 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.307 %	**Result Emulation:** Off

Concentration: 0.0537 %Vol	**Span :** 2.614	**Uniformity:** 0.902	**Result units:** Volume
Specific Surface Area: 0.174 m²/g	**Surface Weighted Mean D[3,2]:** 34.500 um	**Vol. Weighted Mean D[4,3]:** 98.304 um	

d(0.1): 16.469 um **d(0.5): 69.179 um** **d(0.9): 197.301 um**



320_340c, Sunday, 10 June 2007 12:02:25 p.m.

Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.03
2.000	1.08
3.900	

Size (μm)	Volume In %
3.900	2.71
7.800	5.56
15.600	11.55
31.000	4.75
37.000	5.59
44.000	7.06
53.000	

Size (μm)	Volume In %
53.000	7.41
63.000	7.41
74.000	8.17
88.000	8.05
105.000	7.22
125.000	6.18
149.000	

Size (μm)	Volume In %
149.000	4.82
177.000	3.59
210.000	2.61
250.000	1.86
300.000	1.10
350.000	0.96
420.000	

Size (μm)	Volume In %
420.000	0.71
500.000	0.54
590.000	0.47
710.000	0.31
840.000	0.20
1000.000	0.06
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
300_320c

SOP Name:
Marine Sediment

Measured:
Sunday, 10 June 2007 11:09:41 a.m.

Sample Source & type:
20

Measured by:
gmdr1

Analysed:
Sunday, 10 June 2007 11:09:42 a.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
12.10 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.228 %

Result Emulation:
Off

Concentration:
0.0605 %Vol

Span :
3.201

Uniformity:
0.962

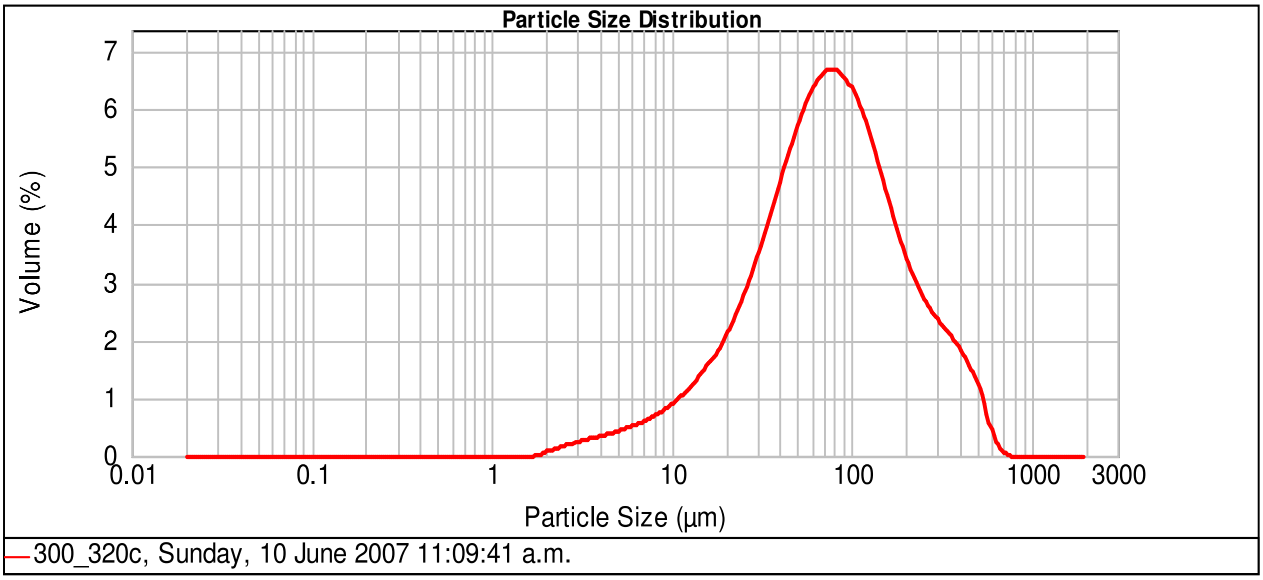
Result units:
Volume

Specific Surface Area:
0.156 m²/g

Surface Weighted Mean D[3,2]:
38.342 um

Vol. Weighted Mean D[4,3]:
111.114 um

d(0.1): 18.963 um **d(0.5): 74.958 um** **d(0.9): 258.892 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.02
2.000	0.91
3.900	

Size (μm)	Volume In %
3.900	2.19
7.800	4.67
15.600	10.93
31.000	4.62
37.000	5.41
44.000	6.75
53.000	

Size (μm)	Volume In %
53.000	7.00
63.000	6.93
74.000	7.57
88.000	7.45
105.000	6.73
125.000	5.92
149.000	

Size (μm)	Volume In %
149.000	4.88
177.000	4.00
210.000	3.40
250.000	3.03
300.000	2.25
350.000	2.32
420.000	

Size (μm)	Volume In %
420.000	1.74
500.000	1.06
590.000	0.22
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
280_300c

SOP Name:
Marine Sediment

Measured:
Thursday, 7 June 2007 7:18:45 p.m.

Sample Source & type:
48

Measured by:
gmdr1

Analysed:
Thursday, 7 June 2007 7:18:46 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
11.03 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.228 %

Result Emulation:
Off

Concentration:
0.0480 %Vol

Span :
2.732

Uniformity:
0.897

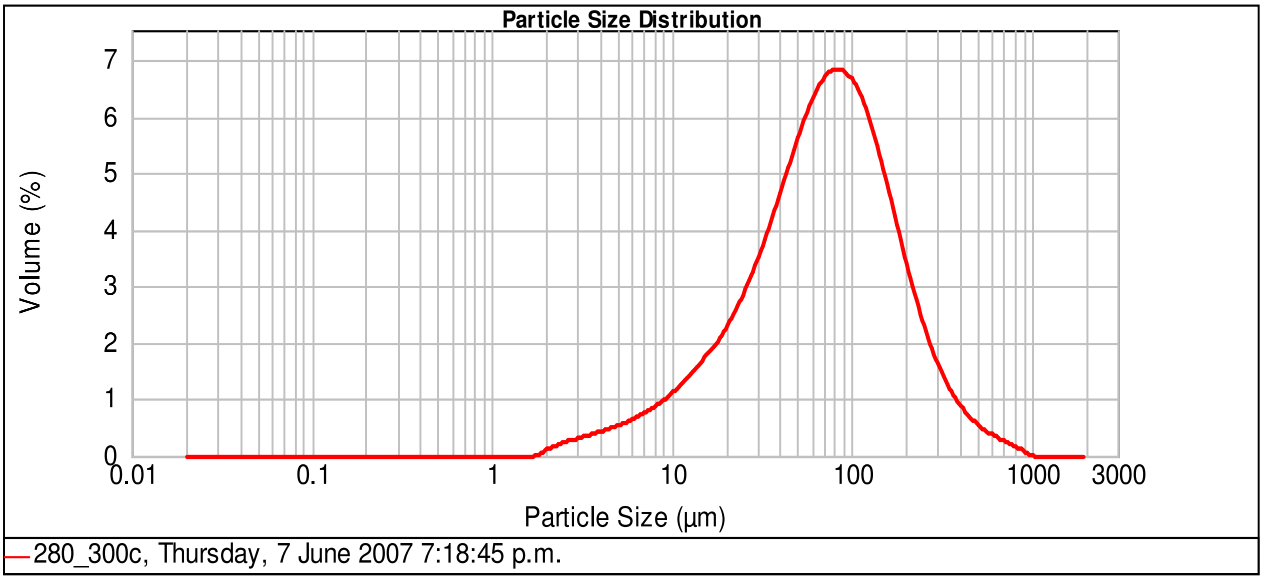
Result units:
Volume

Specific Surface Area:
0.176 m²/g

Surface Weighted Mean D[3,2]:
34.033 um

Vol. Weighted Mean D[4,3]:
99.974 um

d(0.1): 16.064 um **d(0.5): 71.239 um** **d(0.9): 210.659 um**



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.03
2.000	
	1.21
3.900	

Size (µm)	Volume In %
3.900	
	2.75
7.800	
	5.66
15.600	
	11.57
31.000	
	4.58
37.000	
	5.31
44.000	
	6.64
53.000	

Size (µm)	Volume In %
53.000	
	6.95
63.000	
	6.97
74.000	
	7.75
88.000	
	7.77
105.000	
	7.15
125.000	
	6.34
149.000	

Size (µm)	Volume In %
149.000	
	5.17
177.000	
	4.07
210.000	
	3.13
250.000	
	2.35
300.000	
	1.42
350.000	
	1.19
420.000	

Size (µm)	Volume In %
420.000	
	0.79
500.000	
	0.52
590.000	
	0.38
710.000	
	0.20
840.000	
	0.08
1000.000	
	0.00
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

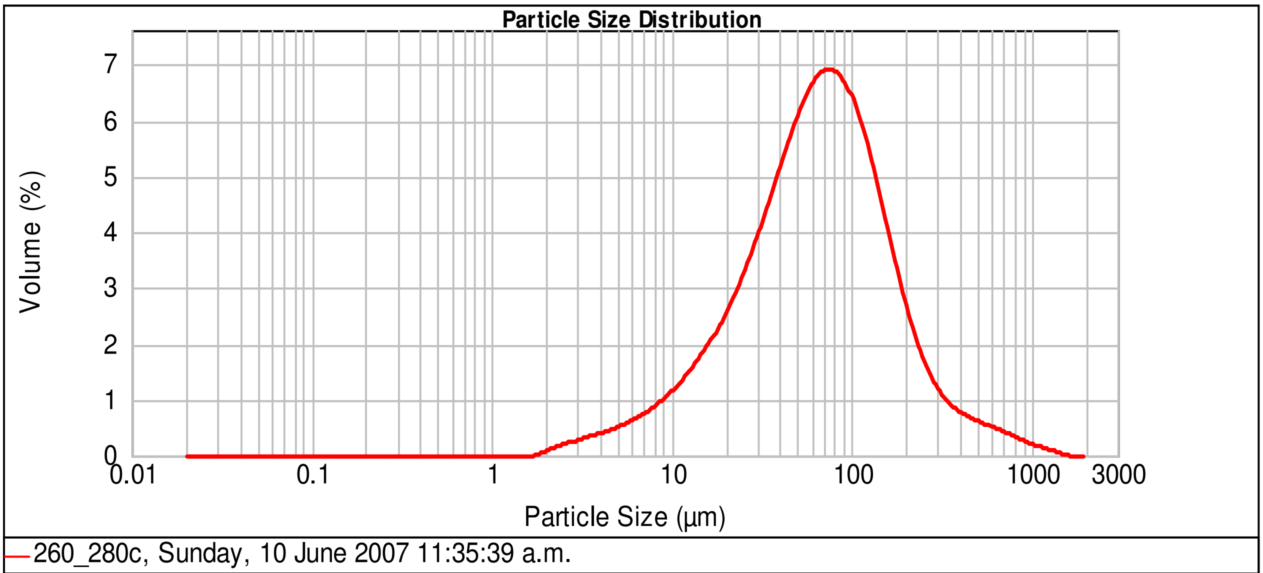
Result Analysis Report

Sample Name: 260_280c	**SOP Name:** Marine Sediment	**Measured:** Sunday, 10 June 2007 11:35:39 a.m.
Sample Source & type: 46	**Measured by:** gmdr1	**Analysed:** Sunday, 10 June 2007 11:35:40 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 14.68 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.331 %	**Result Emulation:** Off

Concentration: 0.0649 %Vol	**Span :** 2.804	**Uniformity:** 1.02	**Result units:** Volume
Specific Surface Area: 0.179 m²/g	**Surface Weighted Mean D[3,2]:** 33.549 um	**Vol. Weighted Mean D[4,3]:** 100.261 um	

d(0.1): 15.940 um **d(0.5): 65.286 um** **d(0.9): 199.003 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.03
2.000	1.06
3.900	

Size (μm)	Volume In %
3.900	2.66
7.800	5.98
15.600	13.03
31.000	5.16
37.000	5.90
44.000	7.22
53.000	

Size (μm)	Volume In %
53.000	7.38
63.000	7.22
74.000	7.80
88.000	7.56
105.000	6.68
125.000	5.64
149.000	

Size (μm)	Volume In %
149.000	4.36
177.000	3.23
210.000	2.36
250.000	1.72
300.000	1.06
350.000	0.98
420.000	

Size (μm)	Volume In %
420.000	0.77
500.000	0.62
590.000	0.57
710.000	0.40
840.000	0.29
1000.000	0.31
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

MALVERN INSTRUMENTS

Result Analysis Report

Sample Name:
240_260c

Sample Source & type:
50

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Sunday, 10 June 2007 11:21:25 a.m.

Analysed:
Sunday, 10 June 2007 11:21:26 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.296 %

Sensitivity:
Enhanced

Obscuration:
17.11 %

Result Emulation:
Off

Concentration:
0.0741 %Vol

Specific Surface Area:
0.183 m²/g

Span :
2.679

Surface Weighted Mean D[3,2]:
32.731 um

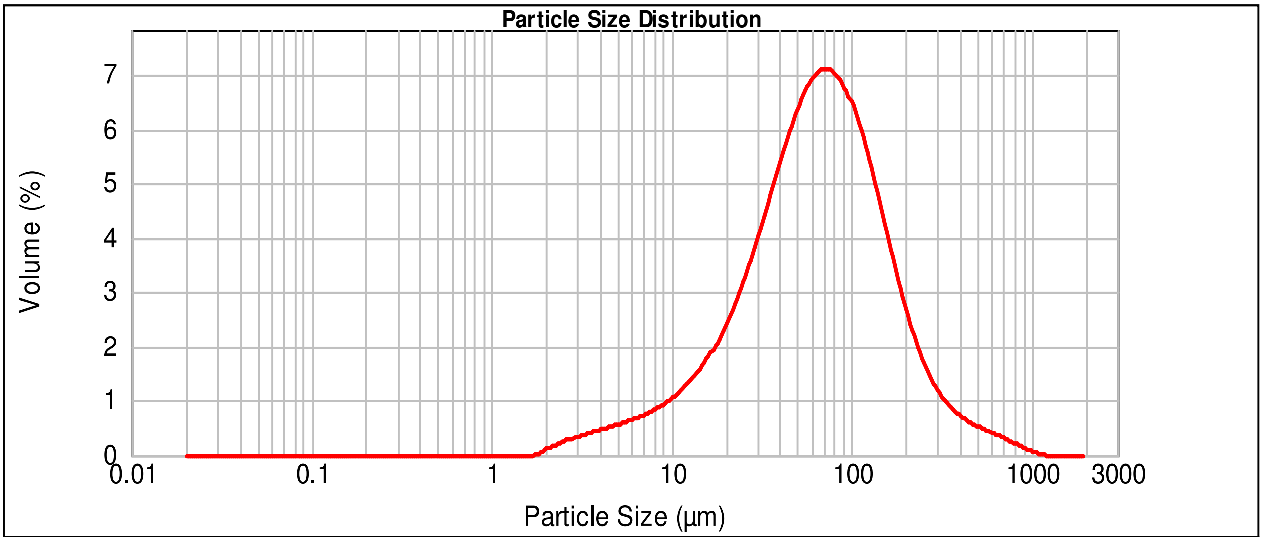
Uniformity:
0.92

Vol. Weighted Mean D[4,3]:
93.464 um

Result units:
Volume

d(0.1): 16.220 um **d(0.5):** 64.720 um **d(0.9):** 189.597 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	1.30
3.900	

Size (µm)	Volume In %
3.900	2.81
7.800	5.40
15.600	12.55
31.000	5.29
37.000	6.14
44.000	7.55
53.000	

Size (µm)	Volume In %
53.000	7.69
63.000	7.46
74.000	7.98
88.000	7.66
105.000	6.71
125.000	5.65
149.000	

Size (µm)	Volume In %
149.000	4.36
177.000	3.23
210.000	2.37
250.000	1.72
300.000	1.05
350.000	0.94
420.000	

Size (µm)	Volume In %
420.000	0.70
500.000	0.53
590.000	0.44
710.000	0.27
840.000	0.14
1000.000	0.03
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
220_240c

Sample Source & type:
13

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 2:37:47 p.m.

Analysed:
Thursday, 7 June 2007 2:37:48 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.344 %

Sensitivity:
Enhanced

Obscuration:
14.70 %

Result Emulation:
Off

Concentration:
0.0648 %Vol

Specific Surface Area:
0.179 m²/g

Span :
2.669

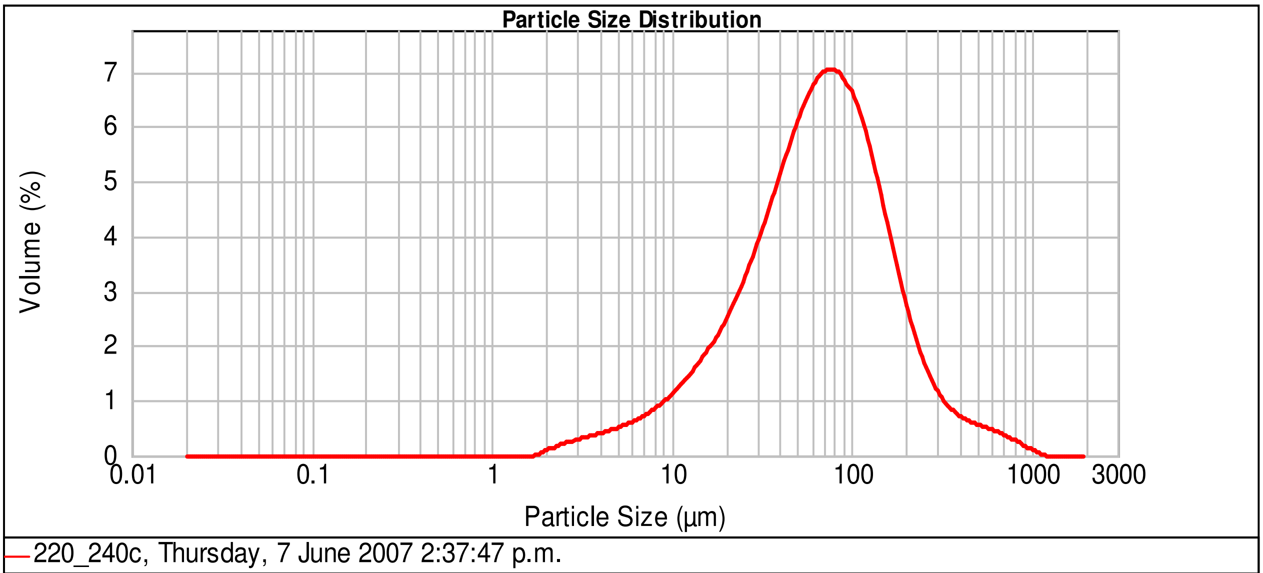
Surface Weighted Mean D[3,2]:
33.582 um

Uniformity:
0.933

Vol. Weighted Mean D[4,3]:
95.893 um

Result units:
Volume

d(0.1): 16.147 um **d(0.5): 66.006 um** **d(0.9): 192.308 um**



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	2.62	53.000	7.43	149.000	4.52	420.000	0.71	2000.000	0.00
0.120	0.00	7.800	5.79	63.000	7.32	177.000	3.33	500.000	0.57	4000.000	
0.241	0.00	15.600	12.74	74.000	7.96	210.000	2.39	590.000	0.51		
0.490	0.00	31.000	5.09	88.000	7.77	250.000	1.70	710.000	0.33		
0.980	0.03	37.000	5.86	105.000	6.90	300.000	1.02	840.000	0.20		
2.000	1.12	44.000	7.22	125.000	5.86	350.000	0.92	1000.000	0.06		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
200_220

Sample Source & type:
1

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 5:11:09 p.m.

Analysed:
Thursday, 7 June 2007 5:11:11 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.269 %

Sensitivity:
Enhanced

Obscuration:
10.77 %

Result Emulation:
Off

Concentration:
0.0417 %Vol

Specific Surface Area:
0.2 m²/g

Span :
2.421

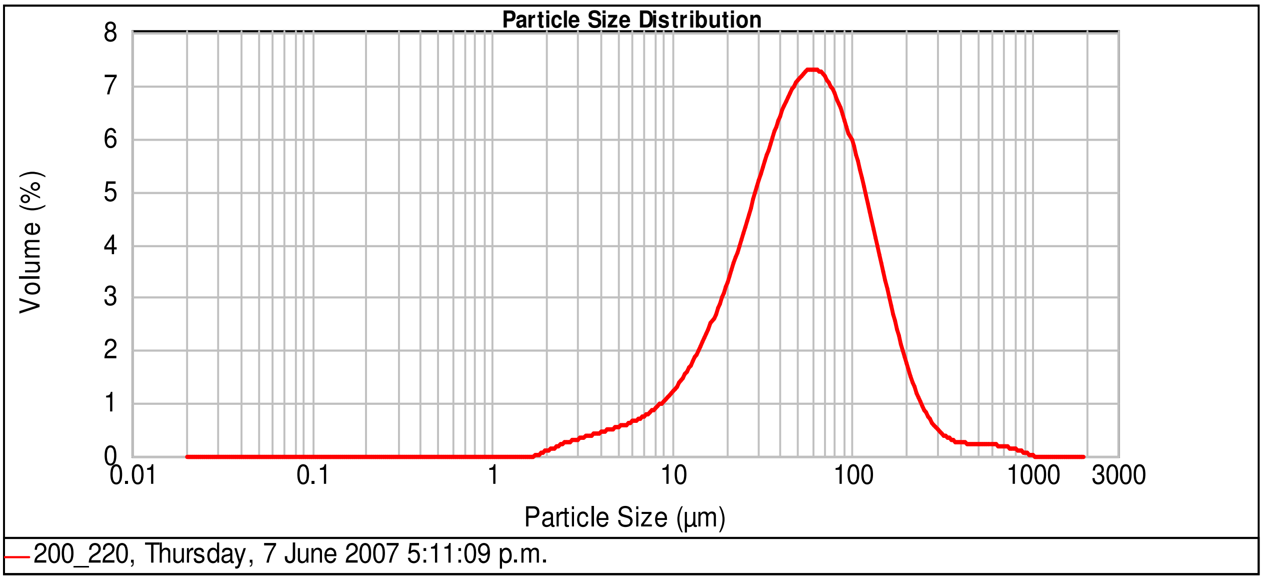
Surface Weighted Mean D[3,2]:
30.041 um

Uniformity:
0.833

Vol. Weighted Mean D[4,3]:
73.423 um

Result units:
Volume

d(0.1): 15.065 um **d(0.5): 53.542 um** **d(0.9): 144.709 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.03
2.000	1.21
3.900	

Size (µm)	Volume In %
3.900	2.77
7.800	6.50
15.600	16.60
31.000	6.60
37.000	7.30
44.000	8.52
53.000	

Size (µm)	Volume In %
53.000	8.23
63.000	7.61
74.000	7.76
88.000	7.07
105.000	5.87
125.000	4.62
149.000	

Size (µm)	Volume In %
149.000	3.28
177.000	2.18
210.000	1.36
250.000	0.81
300.000	0.40
350.000	0.33
420.000	

Size (µm)	Volume In %
420.000	0.27
500.000	0.24
590.000	0.24
710.000	0.15
840.000	0.07
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
190_200c

Sample Source & type:
8

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 6:40:50 p.m.

Analysed:
Thursday, 7 June 2007 6:40:51 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.294 %

Sensitivity:
Enhanced

Obscuration:
11.36 %

Result Emulation:
Off

Concentration:
0.0346 %Vol

Specific Surface Area:
0.248 m²/g

Span :
3.240

Surface Weighted Mean D[3,2]:
24.210 um

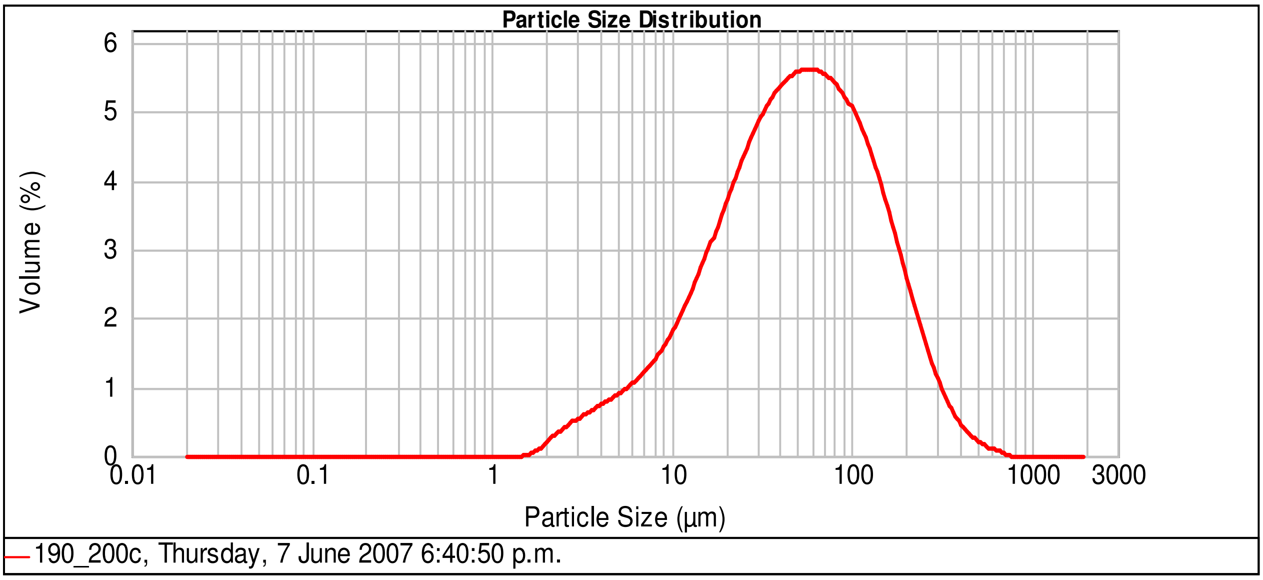
Uniformity:
1.03

Vol. Weighted Mean D[4,3]:
75.199 um

Result units:
Volume

d(0.1): 10.703 um **d(0.5):** 49.693 um **d(0.9):** 171.684 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.12
2.000	2.07
3.900	

Size (μm)	Volume In %
3.900	4.49
7.800	9.20
15.600	17.76
31.000	5.88
37.000	6.08
44.000	6.75
53.000	

Size (μm)	Volume In %
53.000	6.34
63.000	5.86
74.000	6.13
88.000	5.92
105.000	5.36
125.000	4.76
149.000	

Size (μm)	Volume In %
149.000	3.91
177.000	3.09
210.000	2.36
250.000	1.69
300.000	0.93
350.000	0.67
420.000	

Size (μm)	Volume In %
420.000	0.35
500.000	0.18
590.000	0.09
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
180_190c

Sample Source & type:
58

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 4:58:55 p.m.

Analysed:
Thursday, 7 June 2007 4:58:56 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.289 %

Sensitivity:
Enhanced

Obscuration:
12.74 %

Result Emulation:
Off

Concentration:
0.0615 %Vol

Specific Surface Area:
0.164 m²/g

Span :
2.232

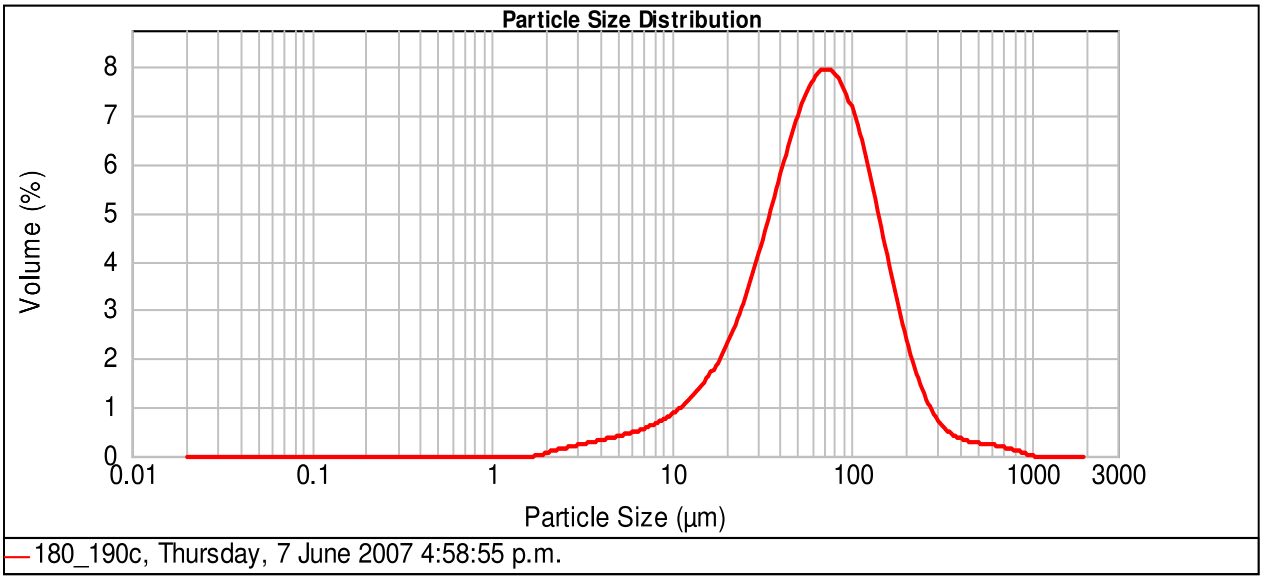
Surface Weighted Mean D[3,2]:
36.644 um

Uniformity:
0.755

Vol. Weighted Mean D[4,3]:
84.796 um

Result units:
Volume

d(0.1): 19.260 um **d(0.5): 64.721 um** **d(0.9): 163.696 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.01
2.000	0.85
3.900	

Size (μm)	Volume In %
3.900	2.05
7.800	4.56
15.600	12.23
31.000	5.54
37.000	6.59
44.000	8.27
53.000	

Size (μm)	Volume In %
53.000	8.53
63.000	8.33
74.000	8.90
88.000	8.46
105.000	7.26
125.000	5.90
149.000	

Size (μm)	Volume In %
149.000	4.32
177.000	2.96
210.000	1.93
250.000	1.19
300.000	0.60
350.000	0.47
420.000	

Size (μm)	Volume In %
420.000	0.34
500.000	0.27
590.000	0.25
710.000	0.15
840.000	0.06
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
170_180c

Sample Source & type:
36

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 6:01:51 p.m.

Analysed:
Thursday, 7 June 2007 6:01:52 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.286 %

Sensitivity:
Enhanced

Obscuration:
18.09 %

Result Emulation:
Off

Concentration:
0.0791 %Vol

Specific Surface Area:
0.185 m²/g

Span :
2.750

Surface Weighted Mean D[3,2]:
32.469 um

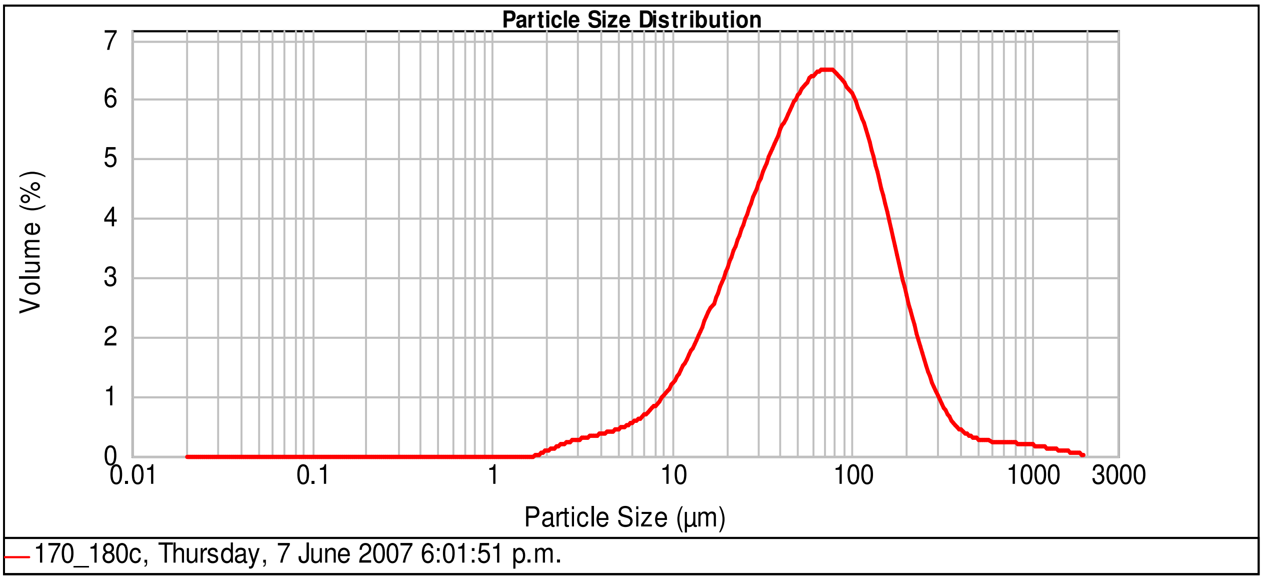
Uniformity:
1.02

Vol. Weighted Mean D[4,3]:
92.261 um

Result units:
Volume

d(0.1): 15.631 um **d(0.5):** 60.213 um **d(0.9):** 181.201 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.03
2.000	1.04
3.900	

Size (μm)	Volume In %
3.900	2.39
7.800	6.52
15.600	15.57
31.000	5.73
37.000	6.22
44.000	7.26
53.000	

Size (μm)	Volume In %
53.000	7.14
63.000	6.83
74.000	7.32
88.000	7.13
105.000	6.40
125.000	5.54
149.000	

Size (μm)	Volume In %
149.000	4.37
177.000	3.27
210.000	2.34
250.000	1.57
300.000	0.83
350.000	0.61
420.000	

Size (μm)	Volume In %
420.000	0.38
500.000	0.29
590.000	0.29
710.000	0.24
840.000	0.23
1000.000	0.46
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
160_170c

Sample Source & type:
57

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 3:39:53 p.m.

Analysed:
Thursday, 7 June 2007 3:39:54 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.301 %

Sensitivity:
Enhanced

Obscuration:
15.29 %

Result Emulation:
Off

Concentration:
0.0462 %Vol

Specific Surface Area:
0.253 m²/g

Span :
3.260

Surface Weighted Mean D[3,2]:
23.732 um

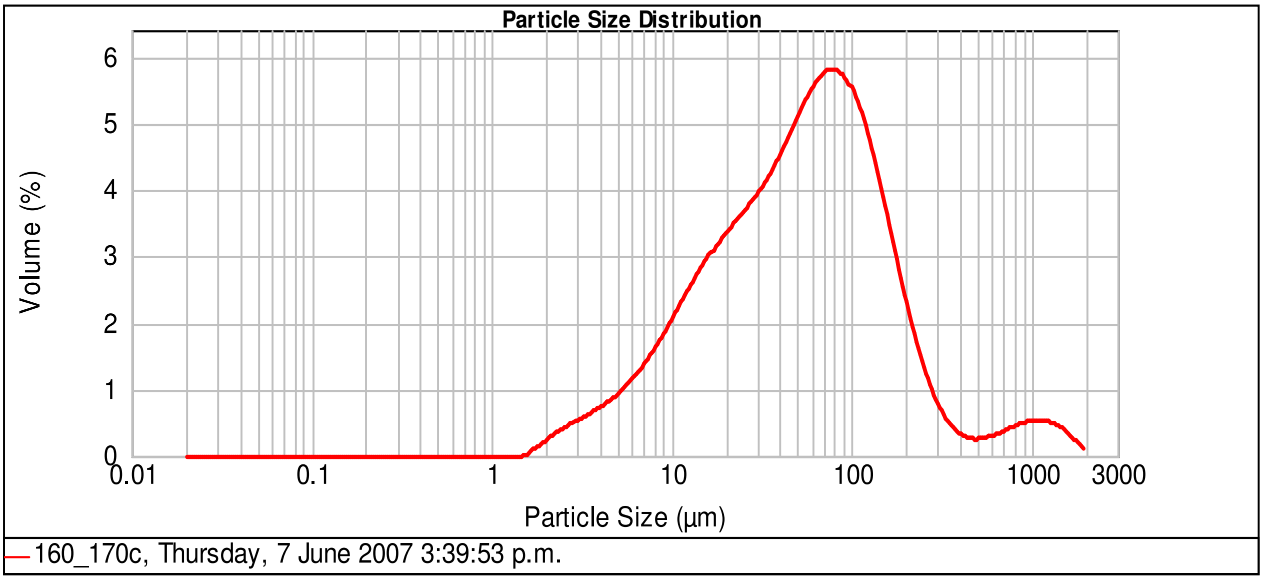
Uniformity:
1.52

Vol. Weighted Mean D[4,3]:
107.251 um

Result units:
Volume

d(0.1): 9.929 um **d(0.5):** 54.366 um **d(0.9):** 187.146 um

---



Size (µm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.19
3.900	2.13

Size (µm)	Volume In %
3.900	
7.800	4.86
15.600	10.19
31.000	15.68
37.000	4.83
44.000	5.16
53.000	6.08

Size (µm)	Volume In %
53.000	
63.000	6.14
74.000	6.03
88.000	6.59
105.000	6.48
125.000	5.80
149.000	4.96

Size (µm)	Volume In %
149.000	
177.000	3.85
210.000	2.82
250.000	1.96
300.000	1.27
350.000	0.64
420.000	0.45

Size (µm)	Volume In %
420.000	
500.000	0.30
590.000	0.29
710.000	0.41
840.000	0.48
1000.000	0.58
2000.000	1.83

Size (µm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
150_160c

Sample Source & type:
49

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 4:16:55 p.m.

Analysed:
Thursday, 7 June 2007 4:16:56 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.377 %

Sensitivity:
Enhanced

Obscuration:
13.20 %

Result Emulation:
Off

Concentration:
0.0491 %Vol

Specific Surface Area:
0.208 m²/g

Span :
2.767

Surface Weighted Mean D[3,2]:
28.777 um

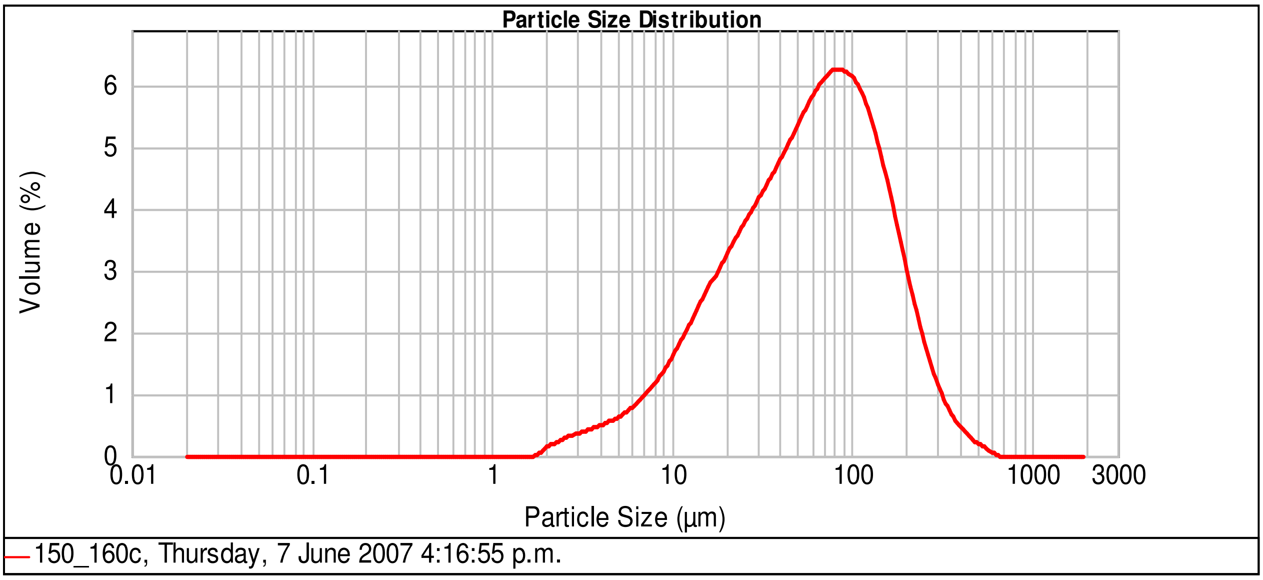
Uniformity:
0.889

Vol. Weighted Mean D[4,3]:
81.959 um

Result units:
Volume

d(0.1): 12.870 um **d(0.5):** 59.935 um **d(0.9):** 178.730 um

---



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.04
2.000	
	1.40
3.900	

Size (μm)	Volume In %
3.900	
	3.32
7.800	
	8.26
15.600	
	15.52
31.000	
	5.09
37.000	
	5.44
44.000	
	6.39
53.000	

Size (μm)	Volume In %
53.000	
	6.44
63.000	
	6.36
74.000	
	7.07
88.000	
	7.14
105.000	
	6.62
125.000	
	5.89
149.000	

Size (μm)	Volume In %
149.000	
	4.77
177.000	
	3.65
210.000	
	2.66
250.000	
	1.80
300.000	
	0.94
350.000	
	0.66
420.000	

Size (μm)	Volume In %
420.000	
	0.35
500.000	
	0.17
590.000	
	0.01
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
140

Sample Source & type:
28

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 3:04:08 p.m.

Analysed:
Thursday, 7 June 2007 3:04:09 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.333 %

Sensitivity:
Enhanced

Obscuration:
12.68 %

Result Emulation:
Off

Concentration:
0.0507 %Vol

Specific Surface Area:
0.193 m²/g

Span :
3.173

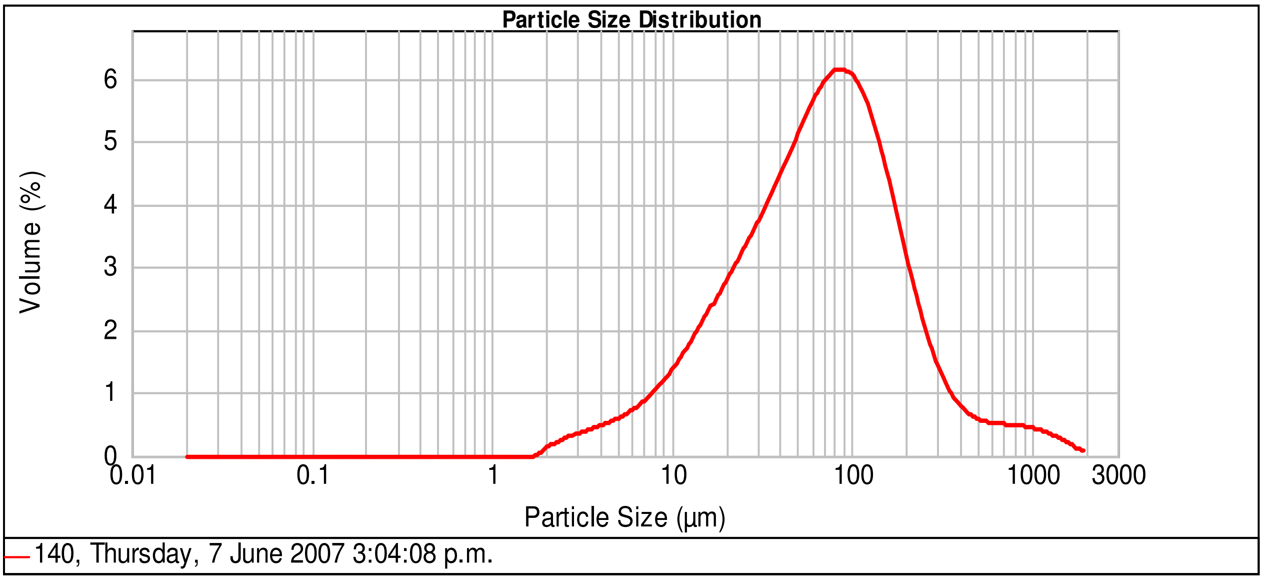
Surface Weighted Mean D[3,2]:
31.143 um

Uniformity:
1.27

Vol. Weighted Mean D[4,3]:
118.532 um

Result units:
Volume

d(0.1): 13.910 um **d(0.5): 67.940 um** **d(0.9): 229.508 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	1.39
3.900	

Size (µm)	Volume In %
3.900	3.11
7.800	7.05
15.600	13.52
31.000	4.66
37.000	5.08
44.000	6.08
53.000	

Size (µm)	Volume In %
53.000	6.21
63.000	6.20
74.000	6.93
88.000	7.04
105.000	6.57
125.000	5.90
149.000	

Size (µm)	Volume In %
149.000	4.84
177.000	3.79
210.000	2.88
250.000	2.11
300.000	1.24
350.000	1.04
420.000	

Size (µm)	Volume In %
420.000	0.75
500.000	0.60
590.000	0.63
710.000	0.55
840.000	0.53
1000.000	1.25
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
130_140c

Sample Source & type:
17

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 2:50:36 p.m.

Analysed:
Thursday, 7 June 2007 2:50:37 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.310 %

Sensitivity:
Enhanced

Obscuration:
12.14 %

Result Emulation:
Off

Concentration:
0.0457 %Vol

Specific Surface Area:
0.205 m²/g

Span :
3.239

Surface Weighted Mean D[3,2]:
29.254 um

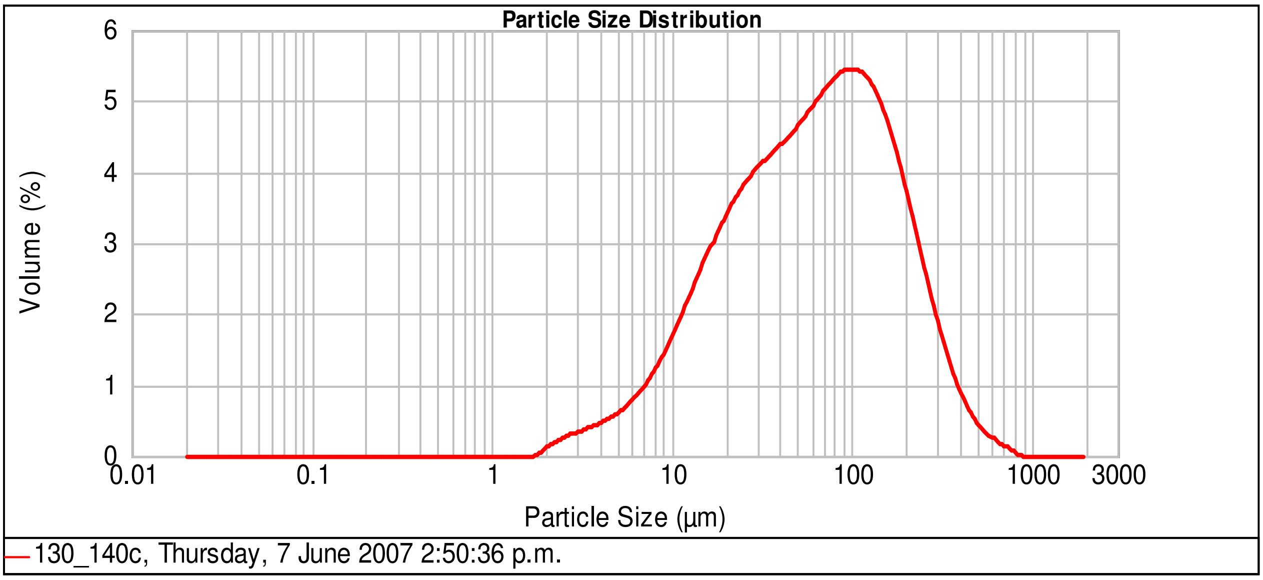
Uniformity:
1.05

Vol. Weighted Mean D[4,3]:
94.063 um

Result units:
Volume

d(0.1): 12.751 um **d(0.5):** 62.616 um **d(0.9):** 215.551 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	1.30
3.900	

Size (μm)	Volume In %
3.900	3.28
7.800	8.73
15.600	15.95
31.000	4.86
37.000	4.97
44.000	5.59
53.000	

Size (μm)	Volume In %
53.000	5.48
63.000	5.36
74.000	6.02
88.000	6.28
105.000	6.14
125.000	5.86
149.000	

Size (μm)	Volume In %
149.000	5.17
177.000	4.37
210.000	3.56
250.000	2.74
300.000	1.62
350.000	1.25
420.000	

Size (μm)	Volume In %
420.000	0.71
500.000	0.39
590.000	0.24
710.000	0.09
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
120_130c

Sample Source & type:
41

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 5:48:26 p.m.

Analysed:
Thursday, 7 June 2007 5:48:27 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.320 %

Sensitivity:
Enhanced

Obscuration:
11.81 %

Result Emulation:
Off

Concentration:
0.0429 %Vol

Specific Surface Area:
0.212 m²/g

Span :
2.981

Surface Weighted Mean D[3,2]:
28.248 um

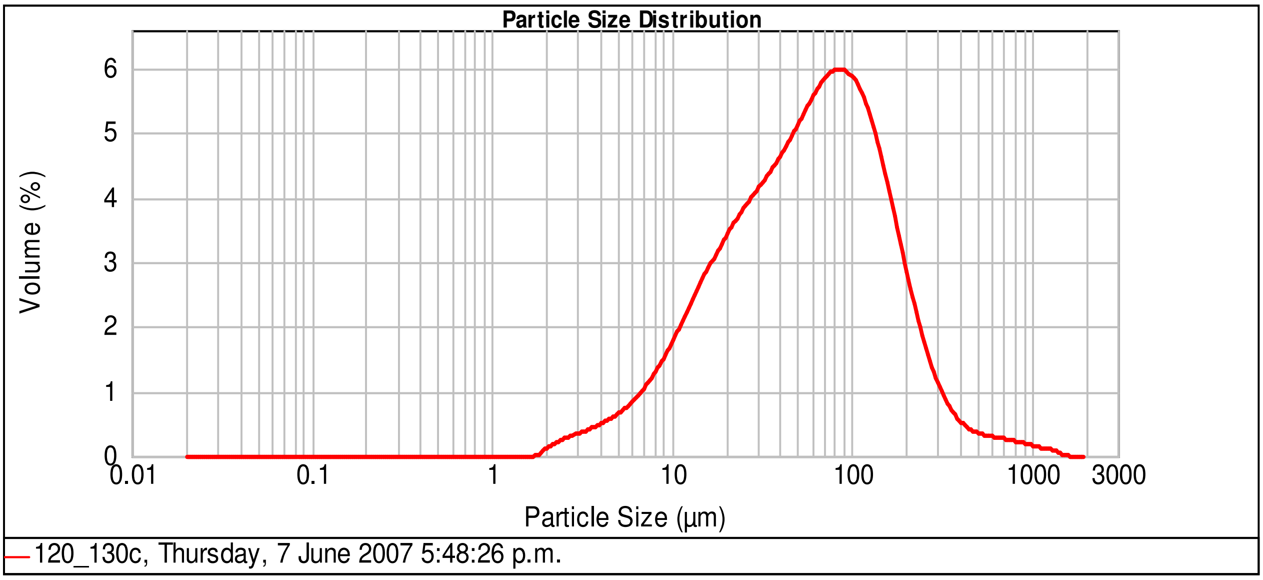
Uniformity:
1.07

Vol. Weighted Mean D[4,3]:
90.413 um

Result units:
Volume

d(0.1): 12.337 um **d(0.5):** 58.805 um **d(0.9):** 187.631 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	1.34
3.900	

Size (µm)	Volume In %
3.900	3.52
7.800	9.01
15.600	16.04
31.000	5.02
37.000	5.27
44.000	6.12
53.000	

Size (µm)	Volume In %
53.000	6.14
63.000	6.07
74.000	6.76
88.000	6.84
105.000	6.35
125.000	5.64
149.000	

Size (µm)	Volume In %
149.000	4.54
177.000	3.46
210.000	2.51
250.000	1.73
300.000	0.94
350.000	0.73
420.000	

Size (µm)	Volume In %
420.000	0.47
500.000	0.35
590.000	0.34
710.000	0.26
840.000	0.22
1000.000	0.28
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

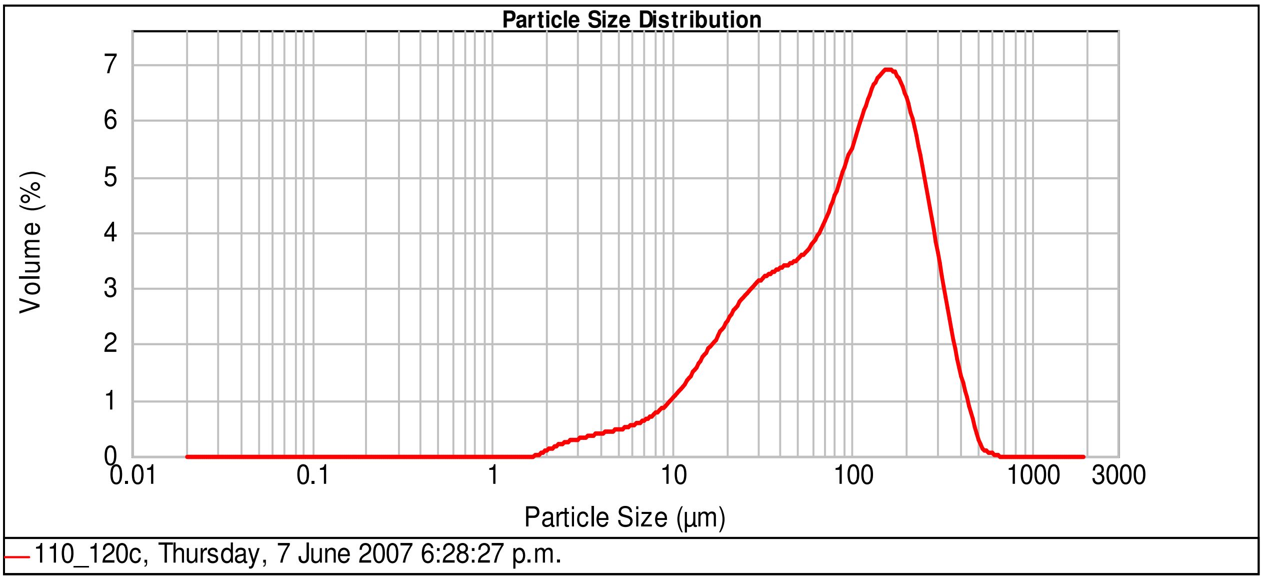
Result Analysis Report

Sample Name: 110_120c	**SOP Name:** Marine Sediment	**Measured:** Thursday, 7 June 2007 6:28:27 p.m.
Sample Source & type: 19	**Measured by:** gmdr1	**Analysed:** Thursday, 7 June 2007 6:28:28 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 11.01 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.569 %	**Result Emulation:** Off

Concentration: 0.0530 %Vol	**Span :** 2.481	**Uniformity:** 0.791	**Result units:** Volume
Specific Surface Area: 0.159 m²/g	**Surface Weighted Mean D[3,2]:** 37.731 um	**Vol. Weighted Mean D[4,3]:** 121.725 um	

d(0.1): 16.936 um **d(0.5):** 99.074 um **d(0.9):** 262.692 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.03
2.000	1.15
3.900	

Size (μm)	Volume In %
3.900	2.37
7.800	5.42
15.600	11.52
31.000	3.74
37.000	3.80
44.000	4.24
53.000	

Size (μm)	Volume In %
53.000	4.18
63.000	4.28
74.000	5.23
88.000	6.19
105.000	6.99
125.000	7.71
149.000	

Size (μm)	Volume In %
149.000	7.77
177.000	7.33
210.000	6.48
250.000	5.24
300.000	3.08
350.000	2.17
420.000	

Size (μm)	Volume In %
420.000	0.95
500.000	0.15
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
100_110c

Sample Source & type:
11

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 4:47:03 p.m.

Analysed:
Thursday, 7 June 2007 4:47:04 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.459 %

Sensitivity:
Enhanced

Obscuration:
10.92 %

Result Emulation:
Off

Concentration:
0.0361 %Vol

Specific Surface Area:
0.229 m²/g

Span :
3.017

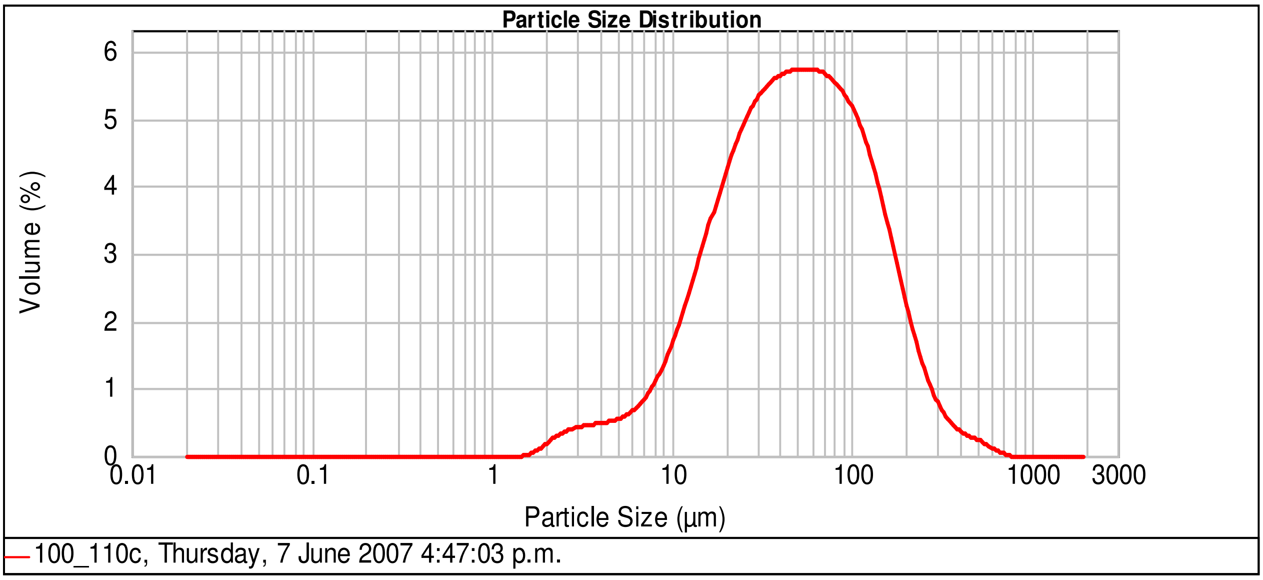
Surface Weighted Mean D[3,2]:
26.165 um

Uniformity:
0.983

Vol. Weighted Mean D[4,3]:
71.702 um

Result units:
Volume

d(0.1): 12.732 um **d(0.5):** 48.087 um **d(0.9):** 157.828 um



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060		3.900		53.000		149.000		420.000		2000.000	
0.120	0.00	7.800	2.93	63.000	6.48	177.000	3.70	500.000	0.33	4000.000	0.00
0.241	0.00	15.600	9.12	74.000	5.99	210.000	2.72	590.000	0.22		
0.490	0.00	31.000	20.12	88.000	6.30	250.000	1.90	710.000	0.08		
0.980	0.00	37.000	6.36	105.000	6.08	300.000	1.24	840.000	0.00		
2.000	0.12	44.000	6.40	125.000	5.45	350.000	0.65	1000.000	0.00		
3.900	1.63	53.000	6.96	149.000	4.71	420.000	0.50	2000.000	0.00		

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
90_100c

Sample Source & type:
18

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 5:22:40 p.m.

Analysed:
Thursday, 7 June 2007 5:22:41 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.297 %

Sensitivity:
Enhanced

Obscuration:
12.09 %

Result Emulation:
Off

Concentration:
0.0333 %Vol

Specific Surface Area:
0.272 m²/g

Span :
3.128

Surface Weighted Mean D[3,2]:
22.051 um

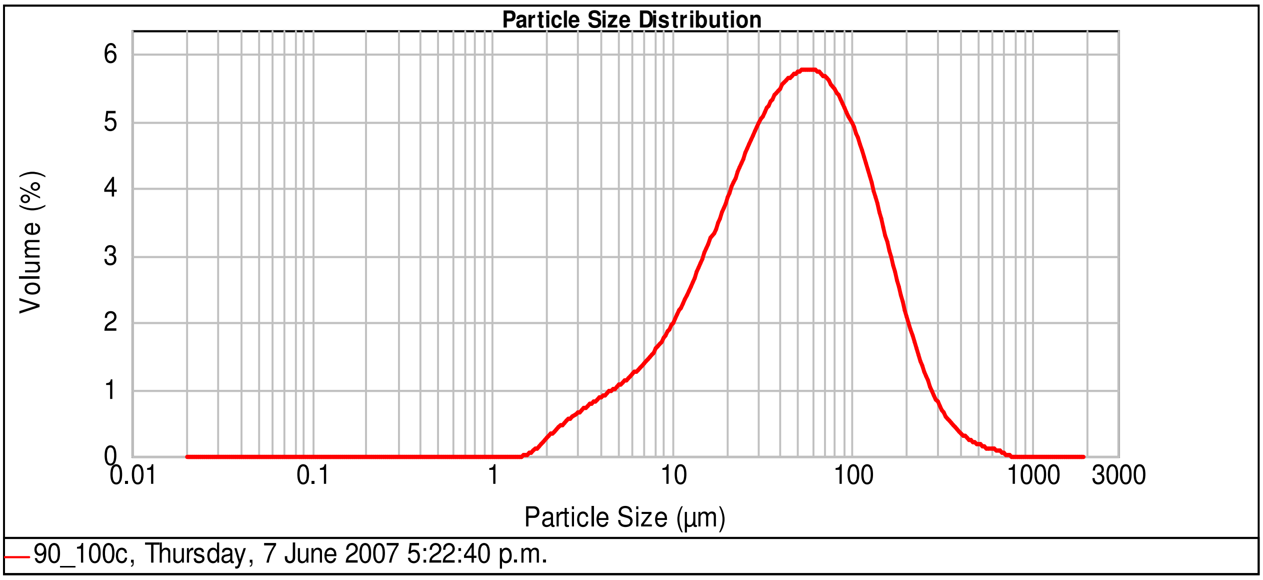
Uniformity:
1.01

Vol. Weighted Mean D[4,3]:
68.501 um

Result units:
Volume

d(0.1): 9.488 um **d(0.5):** 45.988 um **d(0.9):** 153.335 um

---



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.17
2.000	
	2.49
3.900	

Size (μm)	Volume In %
3.900	
	5.20
7.800	
	9.97
15.600	
	18.30
31.000	
	6.01
37.000	
	6.23
44.000	
	6.94
53.000	

Size (μm)	Volume In %
53.000	
	6.52
63.000	
	6.00
74.000	
	6.21
88.000	
	5.86
105.000	
	5.13
125.000	
	4.35
149.000	

Size (μm)	Volume In %
149.000	
	3.40
177.000	
	2.53
210.000	
	1.81
250.000	
	1.23
300.000	
	0.66
350.000	
	0.48
420.000	

Size (μm)	Volume In %
420.000	
	0.27
500.000	
	0.16
590.000	
	0.09
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
80_90c

Sample Source & type:
8

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 3:55:53 p.m.

Analysed:
Thursday, 7 June 2007 3:55:54 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.324 %

Sensitivity:
Enhanced

Obscuration:
12.13 %

Result Emulation:
Off

Concentration:
0.0526 %Vol

Specific Surface Area:
0.179 m²/g

Span :
2.421

Surface Weighted Mean D[3,2]:
33.457 um

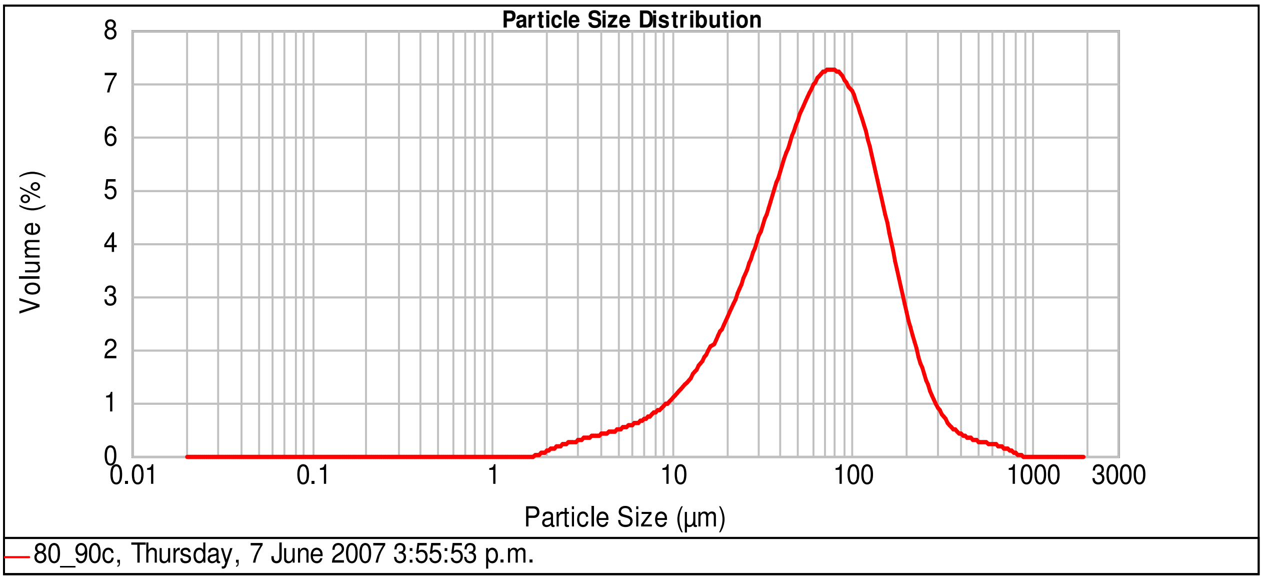
Uniformity:
0.801

Vol. Weighted Mean D[4,3]:
85.194 um

Result units:
Volume

d(0.1): 16.465 um　　**d(0.5):** 64.261 um　　**d(0.9):** 172.047 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.03
2.000	1.11
3.900	

Size (µm)	Volume In %
3.900	2.51
7.800	5.66
15.600	13.22
31.000	5.32
37.000	6.09
44.000	7.48
53.000	

Size (µm)	Volume In %
53.000	7.67
63.000	7.55
74.000	8.22
88.000	8.03
105.000	7.14
125.000	6.04
149.000	

Size (µm)	Volume In %
149.000	4.62
177.000	3.32
210.000	2.27
250.000	1.46
300.000	0.75
350.000	0.56
420.000	

Size (µm)	Volume In %
420.000	0.38
500.000	0.28
590.000	0.23
710.000	0.09
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

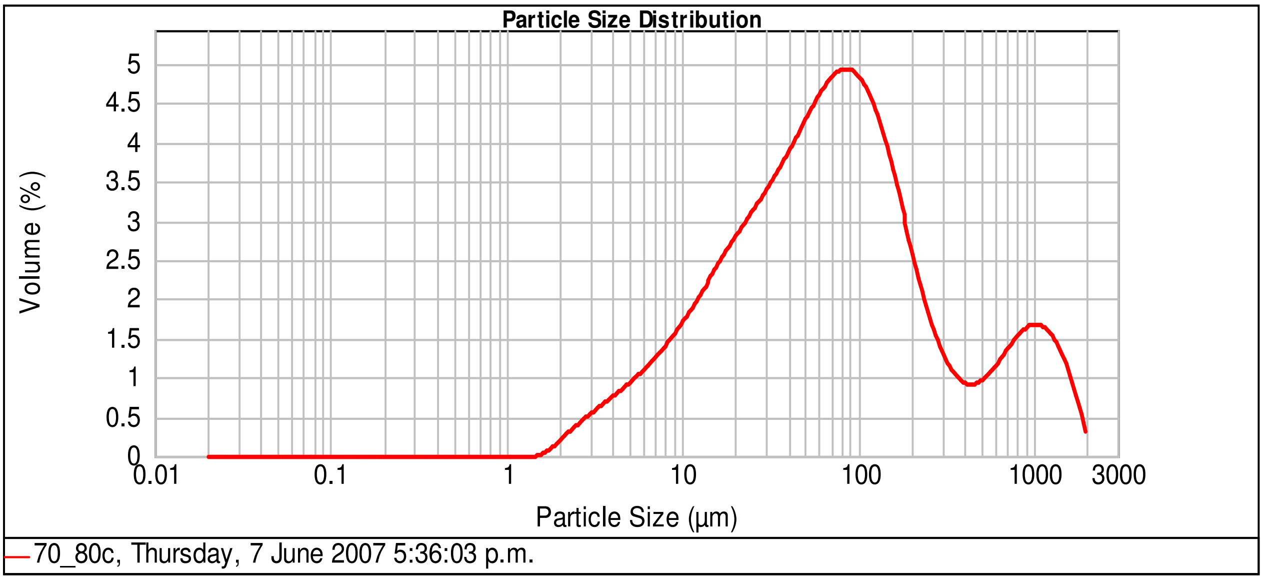
Result Analysis Report

Sample Name: 70_80c	**SOP Name:** Marine Sediment	**Measured:** Thursday, 7 June 2007 5:36:03 p.m.
Sample Source & type: 37	**Measured by:** gmdr1	**Analysed:** Thursday, 7 June 2007 5:36:04 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 10.71 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.362 %	**Result Emulation:** Off

Concentration: 0.0354 %Vol	**Span :** 8.976	**Uniformity:** 2.4	**Result units:** Volume
Specific Surface Area: 0.225 m²/g	**Surface Weighted Mean D[3,2]:** 26.609 um	**Vol. Weighted Mean D[4,3]:** 194.739 um	

d(0.1): 10.560 um **d(0.5): 68.928 um** **d(0.9): 629.253 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.14
2.000	2.06
3.900	

Size (µm)	Volume In %
3.900	4.67
7.800	8.46
15.600	13.09
31.000	4.13
37.000	4.39
44.000	5.13
53.000	

Size (µm)	Volume In %
53.000	5.13
63.000	5.04
74.000	5.58
88.000	5.64
105.000	5.26
125.000	4.76
149.000	

Size (µm)	Volume In %
149.000	3.96
177.000	3.17
210.000	2.48
250.000	1.90
300.000	1.20
350.000	1.16
420.000	

Size (µm)	Volume In %
420.000	1.05
500.000	1.11
590.000	1.50
710.000	1.62
840.000	1.87
1000.000	5.50
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
60_70c

Sample Source & type:
69

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 1:12:01 p.m.

Analysed:
Thursday, 7 June 2007 1:12:02 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.948 %

Sensitivity:
Enhanced

Obscuration:
11.56 %

Result Emulation:
Off

Concentration:
0.0317 %Vol

Specific Surface Area:
0.264 m²/g

Span :
2.657

Surface Weighted Mean D[3,2]:
22.732 um

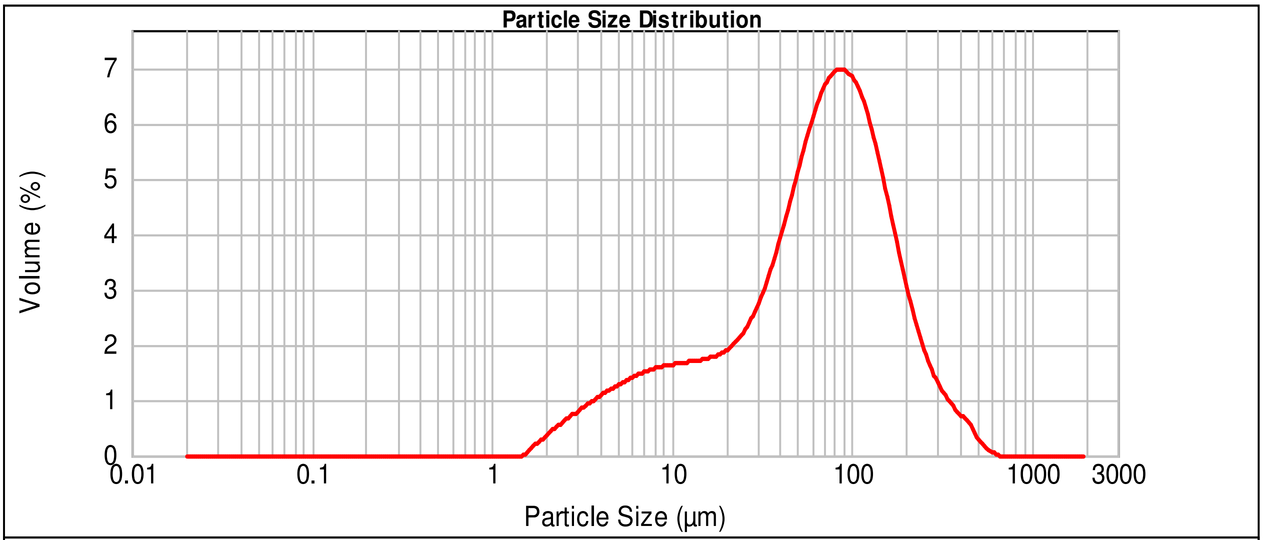
Uniformity:
0.849

Vol. Weighted Mean D[4,3]:
87.232 um

Result units:
Volume

d(0.1): 8.177 um **d(0.5):** 67.229 um **d(0.9):** 186.773 um

---



Size (μm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.31
3.900	3.14

Size (μm)	Volume In %
3.900	
7.800	6.07
15.600	7.54
31.000	9.46
37.000	3.67
44.000	4.50
53.000	5.98

Size (μm)	Volume In %
53.000	
63.000	6.61
74.000	6.90
88.000	7.87
105.000	7.99
125.000	7.32
149.000	6.36

Size (μm)	Volume In %
149.000	
177.000	4.99
210.000	3.71
250.000	2.69
300.000	1.92
350.000	1.15
420.000	0.98

Size (μm)	Volume In %
420.000	
500.000	0.63
590.000	0.20
710.000	0.01
840.000	0.00
1000.000	0.00
2000.000	0.00

Size (μm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
50_60c

Sample Source & type:
4

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 2:24:45 p.m.

Analysed:
Thursday, 7 June 2007 2:24:46 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
1.073 %

Sensitivity:
Enhanced

Obscuration:
13.20 %

Result Emulation:
Off

Concentration:
0.0354 %Vol

Specific Surface Area:
0.281 m²/g

Span :
3.690

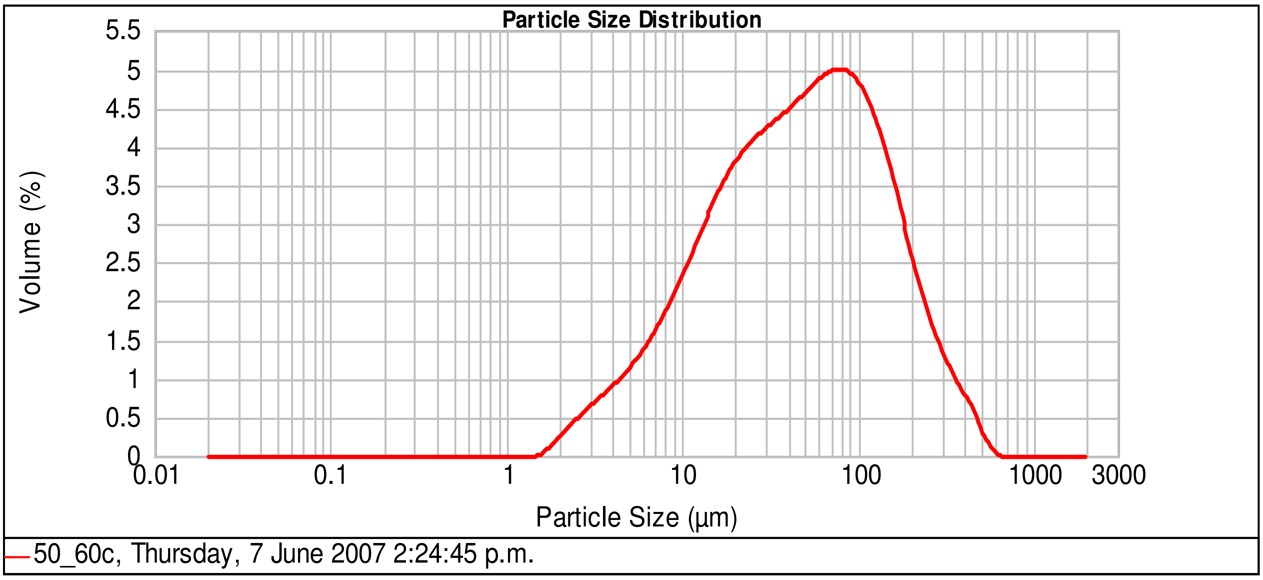
Surface Weighted Mean D[3,2]:
21.349 um

Uniformity:
1.18

Vol. Weighted Mean D[4,3]:
76.937 um

Result units:
Volume

d(0.1): 8.739 um **d(0.5): 47.329 um** **d(0.9): 183.403 um**



Size (µm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.18
3.900	2.51

Size (µm)	Volume In %
3.900	
7.800	5.87
15.600	11.70
31.000	17.44
37.000	5.02
44.000	5.09
53.000	5.67

Size (µm)	Volume In %
53.000	
63.000	5.47
74.000	5.23
88.000	5.67
105.000	5.64
125.000	5.22
149.000	4.69

Size (µm)	Volume In %
149.000	
177.000	3.90
210.000	3.13
250.000	2.47
300.000	1.93
350.000	1.23
420.000	1.06

Size (µm)	Volume In %
420.000	
500.000	0.67
590.000	0.21
710.000	0.01
840.000	0.00
1000.000	0.00
2000.000	0.00

Size (µm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
40_50c

Sample Source & type:
42

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 1:42:23 p.m.

Analysed:
Thursday, 7 June 2007 1:42:24 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.299 %

Sensitivity:
Enhanced

Obscuration:
11.01 %

Result Emulation:
Off

Concentration:
0.0241 %Vol

Specific Surface Area:
0.325 m²/g

Span :
4.055

Surface Weighted Mean D[3,2]:
18.438 um

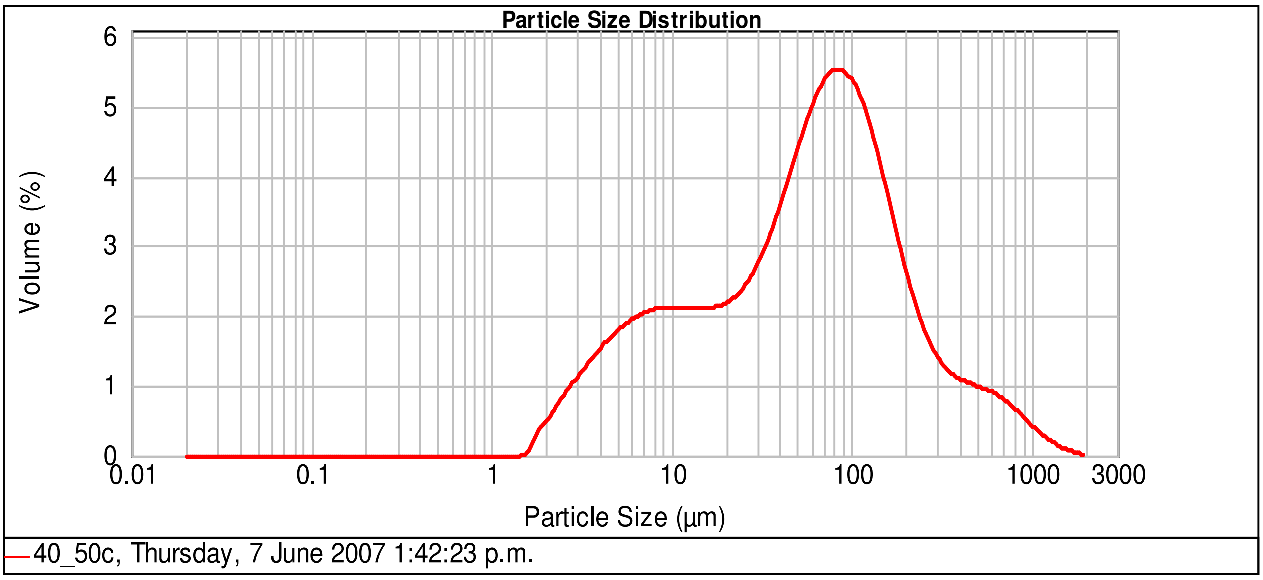
Uniformity:
1.49

Vol. Weighted Mean D[4,3]:
113.018 um

Result units:
Volume

d(0.1): 6.123 um **d(0.5):** 60.229 um **d(0.9):** 250.374 um

---



Size (µm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.42
3.900	4.40

Size (µm)	Volume In %
3.900	
7.800	8.40
15.600	9.59
31.000	10.43
37.000	3.53
44.000	4.08
53.000	5.16

Size (µm)	Volume In %
53.000	
63.000	5.48
74.000	5.57
88.000	6.24
105.000	6.28
125.000	5.75
149.000	5.04

Size (µm)	Volume In %
149.000	
177.000	4.05
210.000	3.14
250.000	2.43
300.000	1.92
350.000	1.31
420.000	1.35

Size (µm)	Volume In %
420.000	
500.000	1.18
590.000	1.04
710.000	1.04
840.000	0.78
1000.000	0.60
2000.000	0.79

Size (µm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
30_40c

Sample Source & type:
7

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 1:26:01 p.m.

Analysed:
Thursday, 7 June 2007 1:26:02 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.307 %

Sensitivity:
Enhanced

Obscuration:
10.39 %

Result Emulation:
Off

Concentration:
0.0289 %Vol

Specific Surface Area:
0.258 m²/g

Span :
3.034

Surface Weighted Mean D[3,2]:
23.249 um

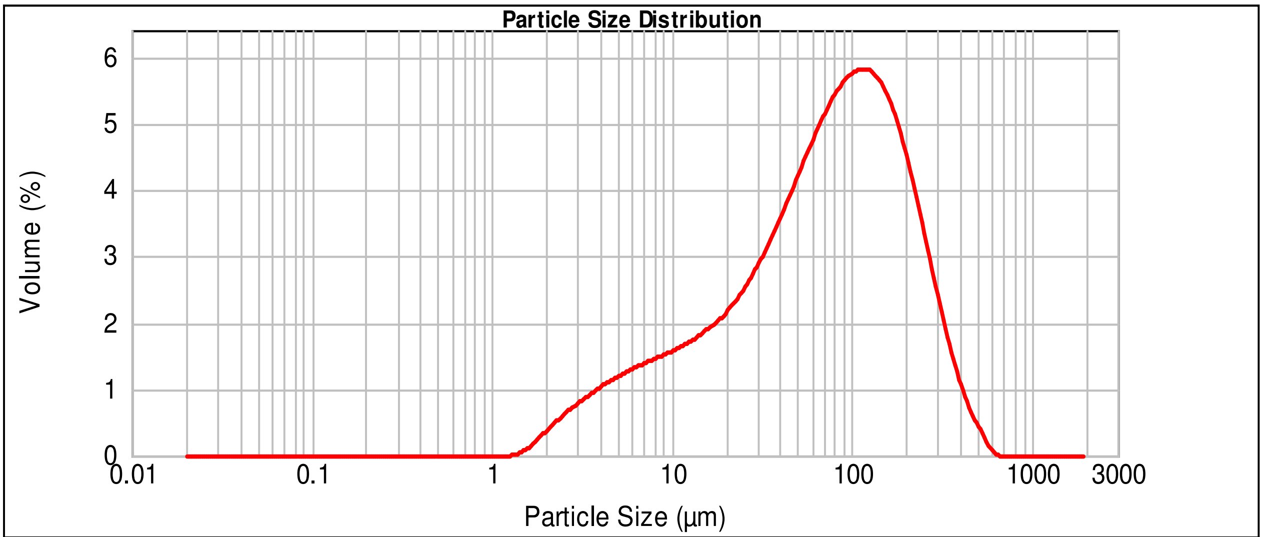
Uniformity:
0.952

Vol. Weighted Mean D[4,3]:
100.993 um

Result units:
Volume

d(0.1): 8.563 um **d(0.5):** 73.592 um **d(0.9):** 231.876 um

---



30_40c, Thursday, 7 June 2007 1:26:01 p.m.

Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.40
2.000	3.07
3.900	

Size (µm)	Volume In %
3.900	5.63
7.800	7.41
15.600	10.48
31.000	3.64
37.000	4.08
44.000	4.98
53.000	

Size (µm)	Volume In %
53.000	5.20
63.000	5.30
74.000	6.14
88.000	6.59
105.000	6.63
125.000	6.55
149.000	

Size (µm)	Volume In %
149.000	6.00
177.000	5.26
210.000	4.42
250.000	3.48
300.000	2.06
350.000	1.55
420.000	

Size (µm)	Volume In %
420.000	0.78
500.000	0.34
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
20_30

SOP Name:
Marine Sediment

Measured:
Thursday, 7 June 2007 3:19:01 p.m.

Sample Source & type:
d2

Measured by:
gmdr1

Analysed:
Thursday, 7 June 2007 3:19:02 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
13.77 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.561 %

Result Emulation:
Off

Concentration:
0.0516 %Vol

Span :
2.622

Uniformity:
0.851

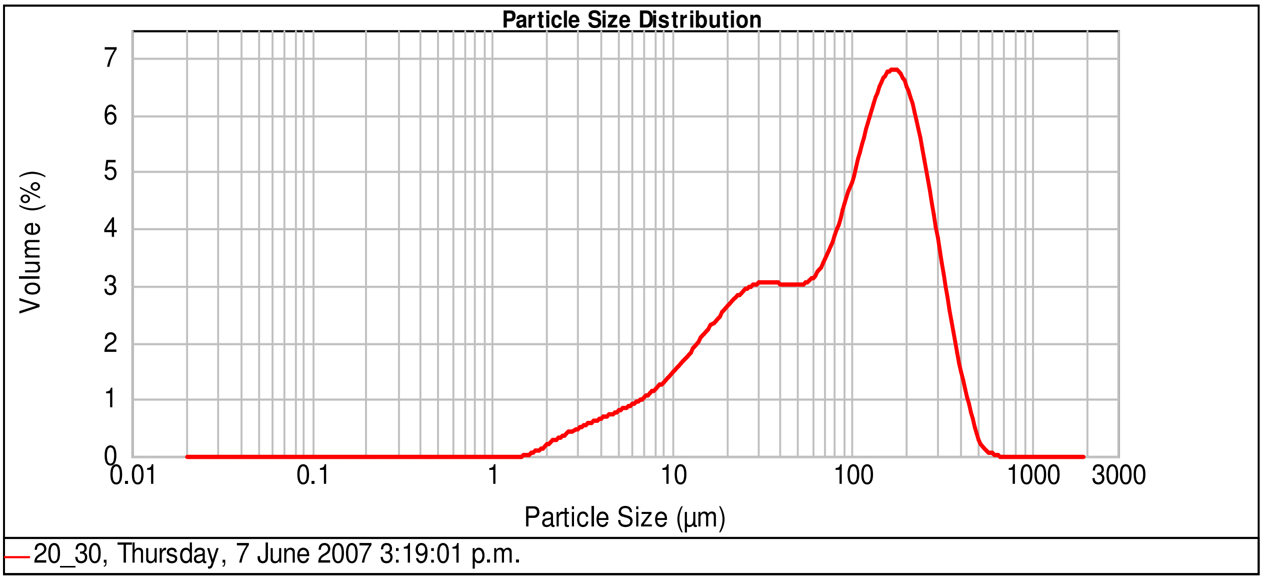
Result units:
Volume

Specific Surface Area:
0.202 m²/g

Surface Weighted Mean D[3,2]:
29.748 um

Vol. Weighted Mean D[4,3]:
119.856 um

d(0.1): 12.182 um **d(0.5): 96.899 um** **d(0.9): 266.295 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.13
2.000	1.88
3.900	

Size (µm)	Volume In %
3.900	3.89
7.800	7.26
15.600	12.14
31.000	3.53
37.000	3.42
44.000	3.64
53.000	

Size (µm)	Volume In %
53.000	3.46
63.000	3.50
74.000	4.36
88.000	5.35
105.000	6.32
125.000	7.29
149.000	

Size (µm)	Volume In %
149.000	7.62
177.000	7.40
210.000	6.70
250.000	5.50
300.000	3.24
350.000	2.26
420.000	

Size (µm)	Volume In %
420.000	0.94
500.000	0.16
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
10_20c

Sample Source & type:
c3

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 11:50:52 a.m.

Analysed:
Thursday, 7 June 2007 11:50:53 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
1.214 %

Sensitivity:
Enhanced

Obscuration:
10.86 %

Result Emulation:
Off

Concentration:
0.0711 %Vol

Specific Surface Area:
0.111 m²/g

Span :
1.635

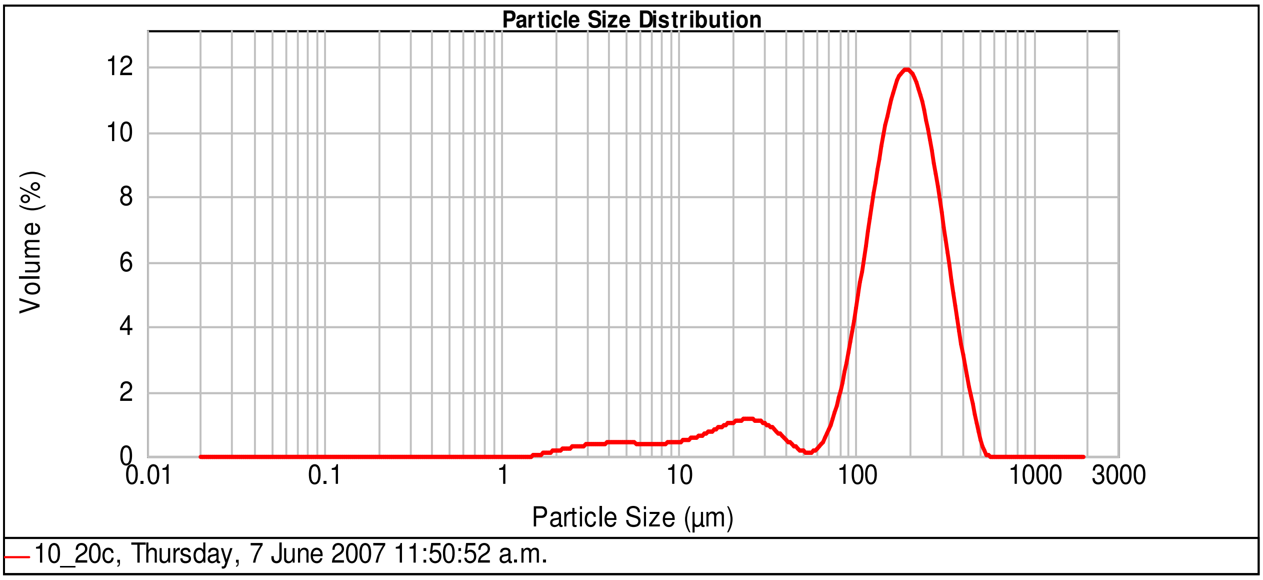
Surface Weighted Mean D[3,2]:
54.220 um

Uniformity:
0.452

Vol. Weighted Mean D[4,3]:
181.869 um

Result units:
Volume

d(0.1): 29.947 um **d(0.5):** 174.651 um **d(0.9):** 315.494 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.14
2.000	1.31
3.900	

Size (μm)	Volume In %
3.900	1.78
7.800	2.38
15.600	4.63
31.000	0.97
37.000	0.56
44.000	0.22
53.000	

Size (μm)	Volume In %
53.000	0.19
63.000	0.74
74.000	2.24
88.000	4.73
105.000	7.69
125.000	10.77
149.000	

Size (μm)	Volume In %
149.000	12.70
177.000	13.31
210.000	12.63
250.000	10.67
300.000	6.36
350.000	4.34
420.000	

Size (μm)	Volume In %
420.000	1.61
500.000	0.04
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
0_10c

Sample Source & type:
44

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Thursday, 7 June 2007 12:03:11 p.m.

Analysed:
Thursday, 7 June 2007 12:03:12 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.981 %

Sensitivity:
Enhanced

Obscuration:
11.36 %

Result Emulation:
Off

Concentration:
0.0572 %Vol

Specific Surface Area:
0.143 m²/g

Span :
1.743

Surface Weighted Mean D[3,2]:
42.068 um

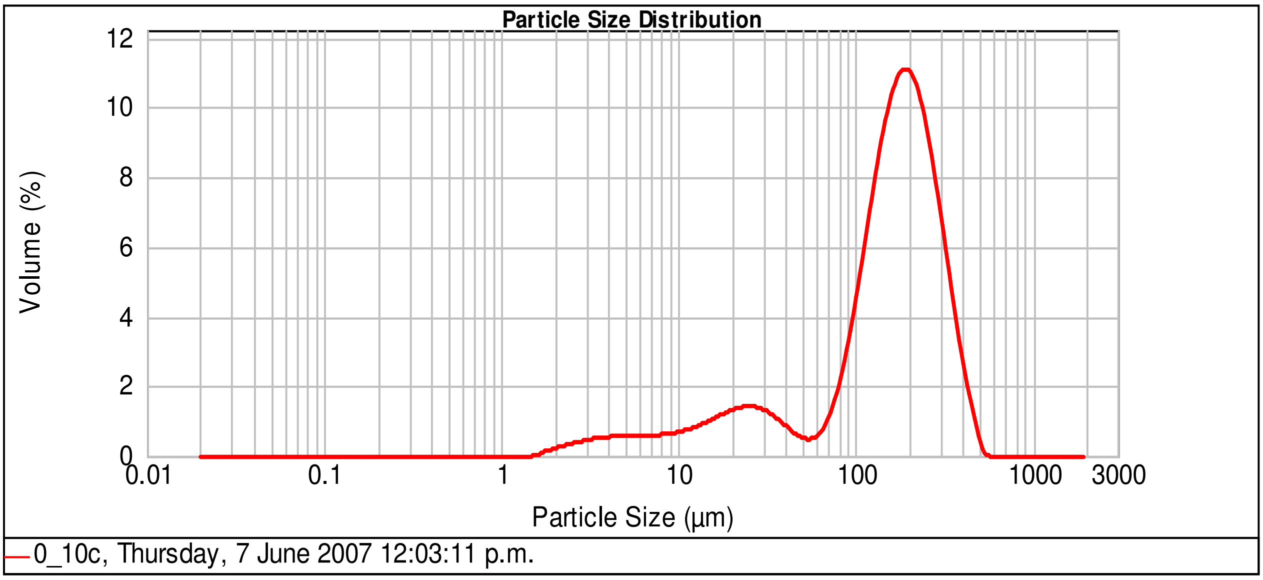
Uniformity:
0.497

Vol. Weighted Mean D[4,3]:
168.646 um

Result units:
Volume

d(0.1): 19.824 um **d(0.5):** 163.850 um **d(0.9):** 305.478 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.21
2.000	1.77
3.900	

Size (µm)	Volume In %
3.900	2.61
7.800	3.53
15.600	5.93
31.000	1.35
37.000	0.95
44.000	0.67
53.000	

Size (µm)	Volume In %
53.000	0.60
63.000	1.07
74.000	2.47
88.000	4.75
105.000	7.45
125.000	10.22
149.000	

Size (µm)	Volume In %
149.000	11.91
177.000	12.37
210.000	11.63
250.000	9.71
300.000	5.69
350.000	3.77
420.000	

Size (µm)	Volume In %
420.000	1.30
500.000	0.03
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
980_1000d

Sample Source & type:
B2

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 6 July 2007 11:19:23 a.m.

Analysed:
Friday, 6 July 2007 11:19:24 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.826 %

Sensitivity:
Enhanced

Obscuration:
16.50 %

Result Emulation:
Off

Concentration:
0.1211 %Vol

Specific Surface Area:
0.104 m²/g

Span :
2.639

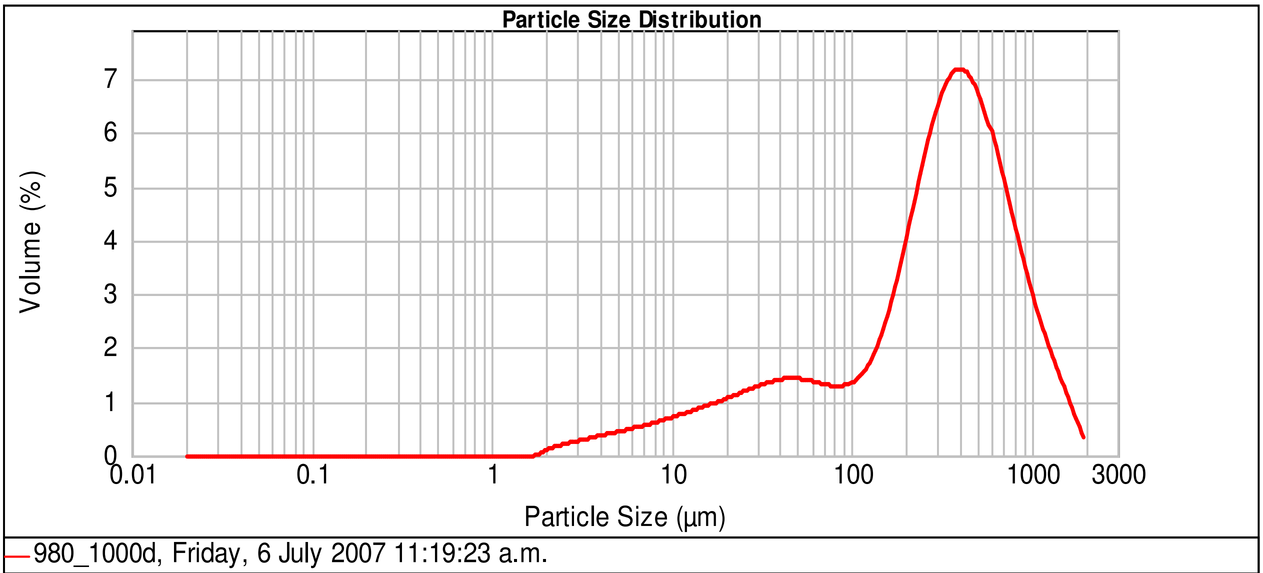
Surface Weighted Mean D[3,2]:
57.466 um

Uniformity:
0.811

Vol. Weighted Mean D[4,3]:
399.514 um

Result units:
Volume

d(0.1): 25.179 um **d(0.5):** 322.400 um **d(0.9):** 876.016 um



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.03
2.000	
	1.06
3.900	

Size (µm)	Volume In %
3.900	
	2.17
7.800	
	3.42
15.600	
	5.02
31.000	
	1.57
37.000	
	1.60
44.000	
	1.74
53.000	

Size (µm)	Volume In %
53.000	
	1.58
63.000	
	1.41
74.000	
	1.47
88.000	
	1.54
105.000	
	1.76
125.000	
	2.32
149.000	

Size (µm)	Volume In %
149.000	
	3.13
177.000	
	4.24
210.000	
	5.61
250.000	
	7.18
300.000	
	6.86
350.000	
	8.54
420.000	

Size (µm)	Volume In %
420.000	
	8.03
500.000	
	7.00
590.000	
	6.72
710.000	
	4.93
840.000	
	3.98
1000.000	
	7.08
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

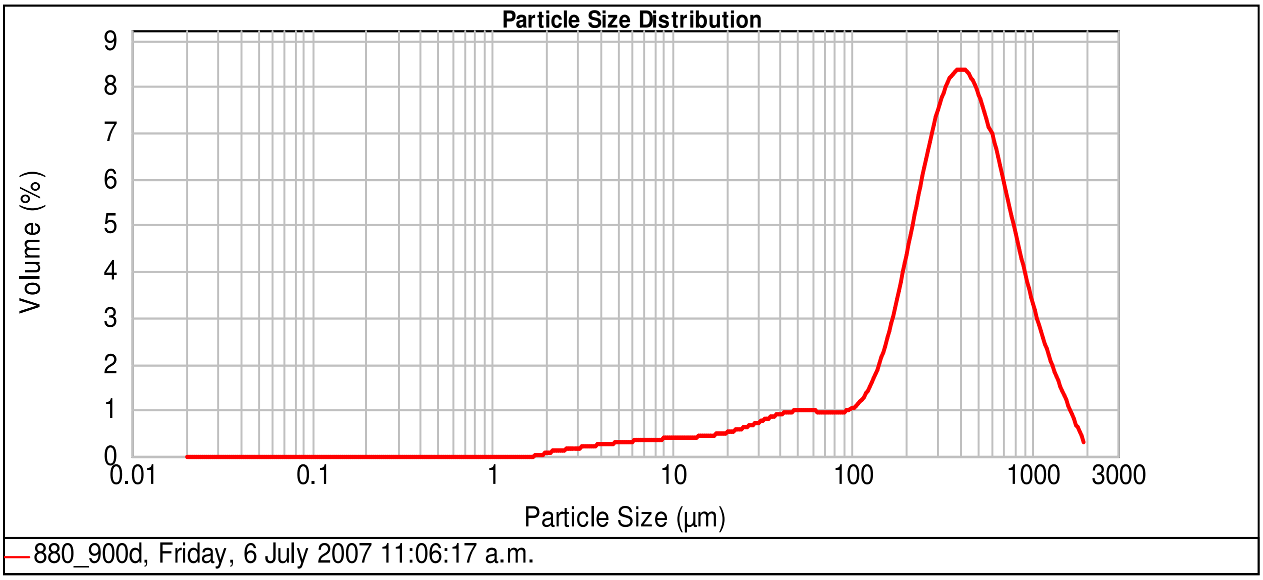
Result Analysis Report

Sample Name: 880_900d	**SOP Name:** Marine Sediment	**Measured:** Friday, 6 July 2007 11:06:17 a.m.
Sample Source & type: A45	**Measured by:** gmdr1	**Analysed:** Friday, 6 July 2007 11:06:18 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 13.44 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.996 %	**Result Emulation:** Off

Concentration: 0.1484 %Vol	**Span :** 2.291	**Uniformity:** 0.682	**Result units:** Volume
Specific Surface Area: 0.0687 m²/g	**Surface Weighted Mean D[3,2]:** 87.293 um	**Vol. Weighted Mean D[4,3]:** 443.091 um	

d(0.1): 57.196 um **d(0.5):** 368.511 um **d(0.9):** 901.451 um



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.02
2.000	0.68
3.900	

Size (µm)	Volume In %
3.900	1.37
7.800	1.76
15.600	2.53
31.000	0.93
37.000	1.03
44.000	1.18
53.000	

Size (µm)	Volume In %
53.000	1.11
63.000	1.00
74.000	1.04
88.000	1.14
105.000	1.43
125.000	2.11
149.000	

Size (µm)	Volume In %
149.000	3.13
177.000	4.50
210.000	6.20
250.000	8.15
300.000	7.91
350.000	9.93
420.000	

Size (µm)	Volume In %
420.000	9.35
500.000	8.13
590.000	7.76
710.000	5.63
840.000	4.46
1000.000	7.50
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name: 780_800d	**SOP Name:** Marine Sediment	**Measured:** Friday, 6 July 2007 10:52:53 a.m.
Sample Source & type: A44	**Measured by:** gmdr1	**Analysed:** Friday, 6 July 2007 10:52:55 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 16.38 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 1.014 %	**Result Emulation:** Off

---

Concentration: 0.2763 %Vol	**Span :** 2.034	**Uniformity:** 0.606	**Result units:** Volume
Specific Surface Area: 0.0471 m²/g	**Surface Weighted Mean D[3,2]:** 127.414 um	**Vol. Weighted Mean D[4,3]:** 520.686 um	

d(0.1): 104.816 um **d(0.5):** 447.540 um **d(0.9):** 1015.245 um

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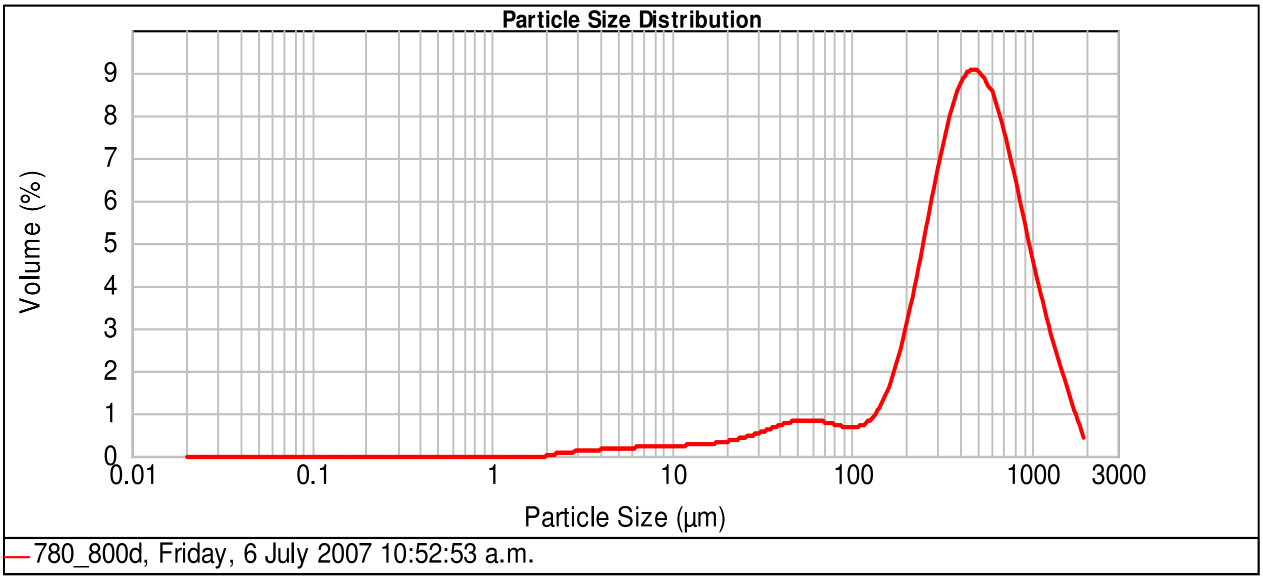


Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	0.84	53.000	0.96	149.000	1.92	420.000	10.29	2000.000	0.00
0.120	0.00	7.800	1.11	63.000	0.86	177.000	3.10	500.000	9.61	4000.000	
0.241	0.00	15.600	1.73	74.000	0.84	210.000	4.78	590.000	9.77		
0.490	0.00	31.000	0.71	88.000	0.78	250.000	6.97	710.000	7.47		
0.980	0.00	37.000	0.82	105.000	0.83	300.000	7.39	840.000	6.13		
2.000	0.38	44.000	0.99	125.000	1.19	350.000	10.08	1000.000	10.46		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
640_660d

Sample Source & type:
A43

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 6 July 2007 10:37:21 a.m.

Analysed:
Friday, 6 July 2007 10:37:22 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.822 %

Sensitivity:
Enhanced

Obscuration:
16.49 %

Result Emulation:
Off

Concentration:
0.1195 %Vol

Specific Surface Area:
0.103 m²/g

Span :
2.502

Surface Weighted Mean D[3,2]:
58.093 um

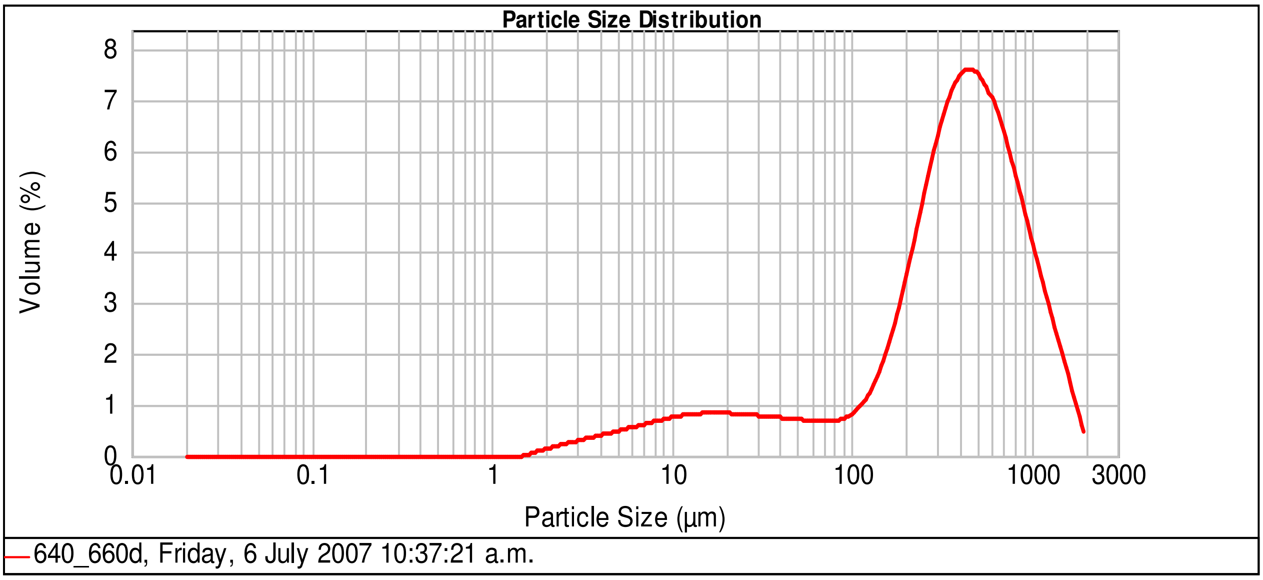
Uniformity:
0.735

Vol. Weighted Mean D[4,3]:
473.719 um

Result units:
Volume

d(0.1): 26.050 um **d(0.5):** 392.830 um **d(0.9):** 1009.086 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.12
2.000	1.18
3.900	

Size (μm)	Volume In %
3.900	2.40
7.800	3.50
15.600	3.71
31.000	0.90
37.000	0.85
44.000	0.88
53.000	

Size (μm)	Volume In %
53.000	0.79
63.000	0.71
74.000	0.78
88.000	0.91
105.000	1.19
125.000	1.75
149.000	

Size (μm)	Volume In %
149.000	2.57
177.000	3.67
210.000	5.08
250.000	6.78
300.000	6.74
350.000	8.77
420.000	

Size (μm)	Volume In %
420.000	8.66
500.000	7.96
590.000	8.11
710.000	6.34
840.000	5.41
1000.000	10.25
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
620_640d

Sample Source & type:
A42

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 6 July 2007 10:23:01 a.m.

Analysed:
Friday, 6 July 2007 10:23:02 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.820 %

Sensitivity:
Enhanced

Obscuration:
14.31 %

Result Emulation:
Off

Concentration:
0.0703 %Vol

Specific Surface Area:
0.151 m²/g

Span :
2.925

Surface Weighted Mean D[3,2]:
39.794 um

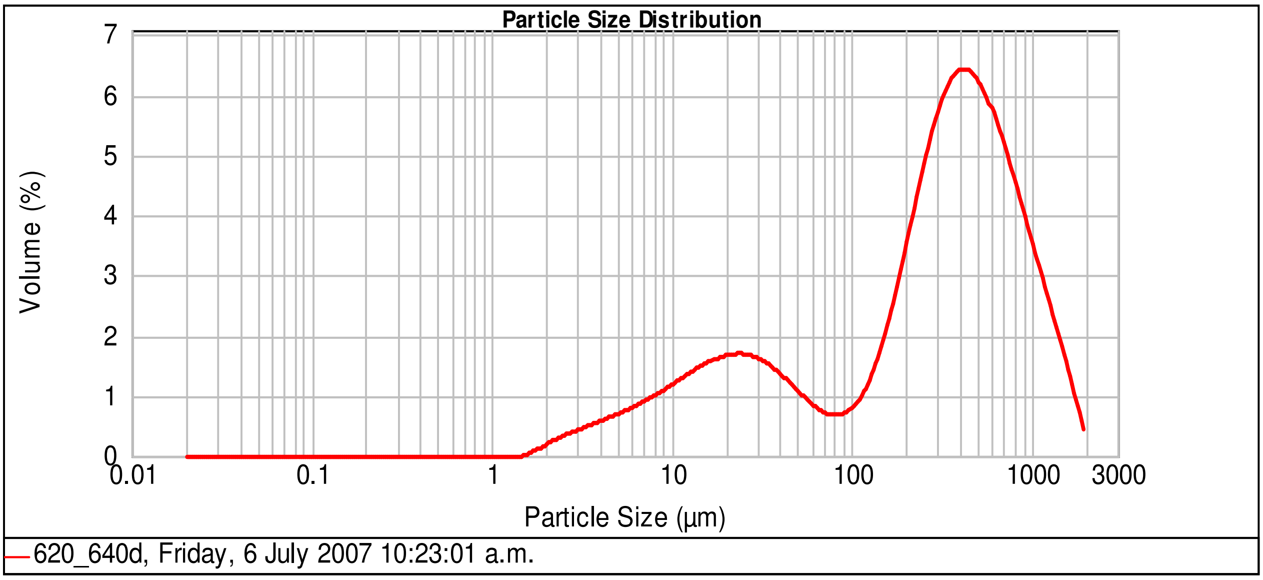
Uniformity:
0.904

Vol. Weighted Mean D[4,3]:
411.615 um

Result units:
Volume

d(0.1): 14.086 um **d(0.5):** 323.207 um **d(0.9):** 959.355 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.15
2.000	1.69
3.900	

Size (μm)	Volume In %
3.900	3.44
7.800	5.71
15.600	7.44
31.000	1.78
37.000	1.54
44.000	1.39
53.000	

Size (μm)	Volume In %
53.000	1.04
63.000	0.79
74.000	0.77
88.000	0.87
105.000	1.19
125.000	1.81
149.000	

Size (μm)	Volume In %
149.000	2.64
177.000	3.68
210.000	4.91
250.000	6.29
300.000	6.03
350.000	7.59
420.000	

Size (μm)	Volume In %
420.000	7.29
500.000	6.57
590.000	6.64
710.000	5.21
840.000	4.52
1000.000	9.01
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
600_620d

SOP Name:
Marine Sediment

Measured:
Friday, 6 July 2007 10:11:02 a.m.

Sample Source & type:
A41

Measured by:
gmdr1

Analysed:
Friday, 6 July 2007 10:11:03 a.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
16.70 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.006 %

Result Emulation:
Off

Concentration:
0.1540 %Vol

Span :
2.358

Uniformity:
0.675

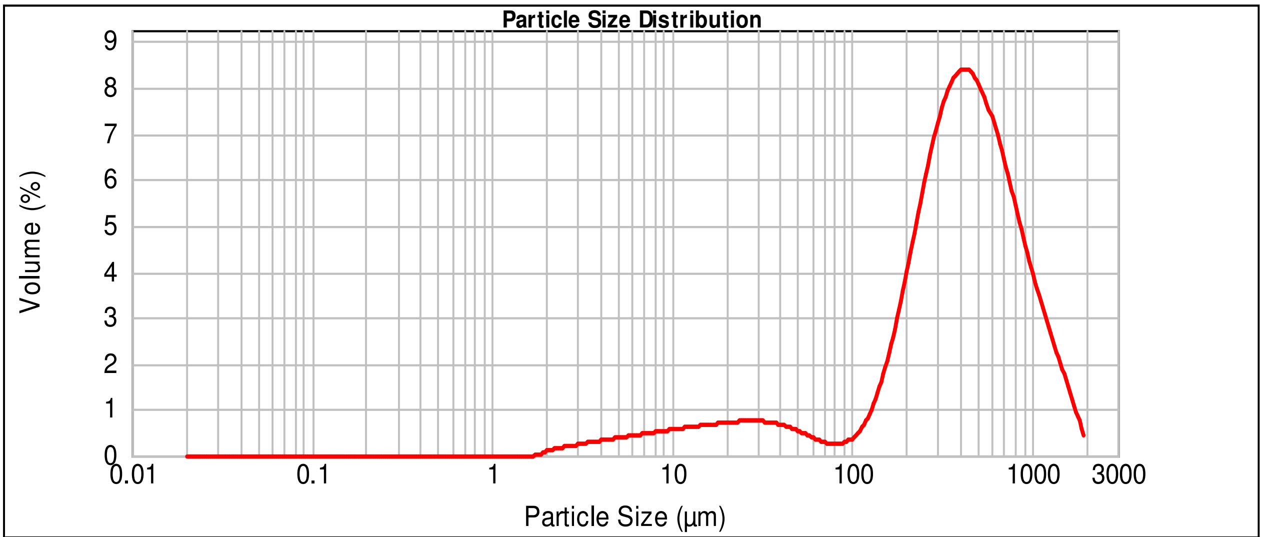
Result units:
Volume

Specific Surface Area:
0.0823 m²/g

Surface Weighted Mean D[3,2]:
72.880 um

Vol. Weighted Mean D[4,3]:
481.373 um

d(0.1): 40.692 um **d(0.5): 400.728 um** **d(0.9): 985.756 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.03
2.000	0.94
3.900	

Size (μm)	Volume In %
3.900	1.86
7.800	2.65
15.600	3.25
31.000	0.84
37.000	0.76
44.000	0.69
53.000	

Size (μm)	Volume In %
53.000	0.49
63.000	0.33
74.000	0.28
88.000	0.38
105.000	0.74
125.000	1.50
149.000	

Size (μm)	Volume In %
149.000	2.61
177.000	4.05
210.000	5.80
250.000	7.81
300.000	7.71
350.000	9.87
420.000	

Size (μm)	Volume In %
420.000	9.51
500.000	8.48
590.000	8.34
710.000	6.28
840.000	5.19
1000.000	9.62
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
580_600d

SOP Name:
Marine Sediment

Measured:
Friday, 6 July 2007 9:54:57 a.m.

Sample Source & type:
A40

Measured by:
gmdr1

Analysed:
Friday, 6 July 2007 9:54:58 a.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
14.53 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.677 %

Result Emulation:
Off

Concentration:
0.0678 %Vol

Span :
2.639

Uniformity:
0.81

Result units:
Volume

Specific Surface Area:
0.154 m²/g

Surface Weighted Mean D[3,2]:
38.945 um

Vol. Weighted Mean D[4,3]:
374.921 um

d(0.1): 14.973 um **d(0.5):** 304.756 um **d(0.9):** 819.116 um

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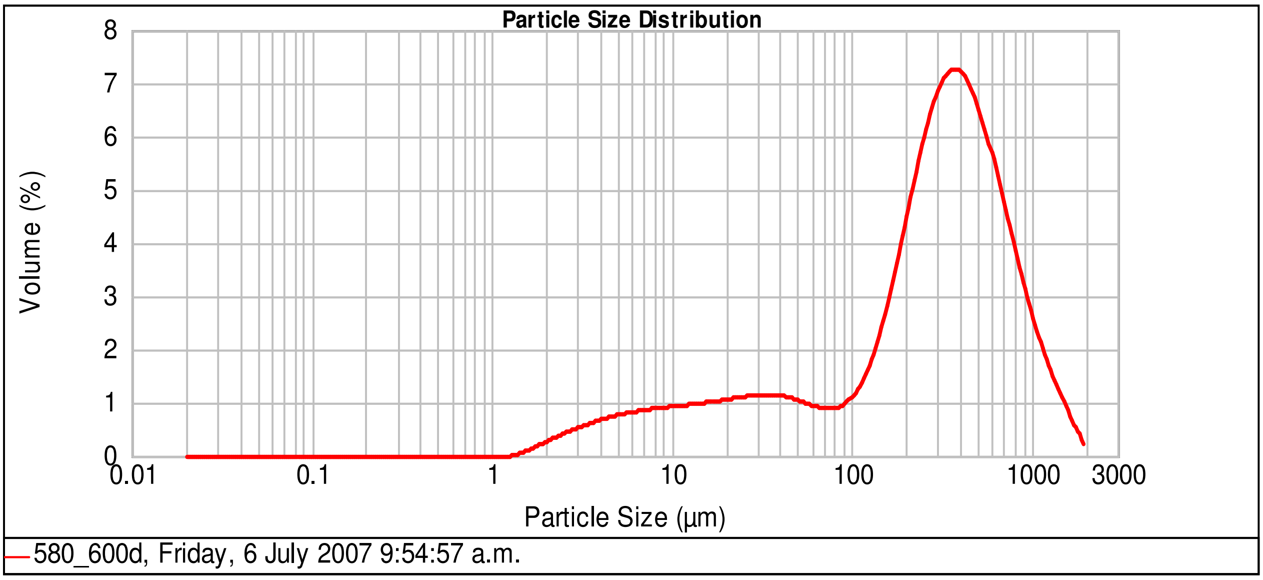


Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.060	0.00	3.900	3.59	53.000	1.11	149.000	3.44	420.000	7.92	2000.000	0.00
0.120	0.00	7.800	4.27	63.000	0.95	177.000	4.69	500.000	6.74	4000.000	
0.241	0.00	15.600	4.86	74.000	1.01	210.000	6.13	590.000	6.32		
0.490	0.00	31.000	1.34	88.000	1.20	250.000	7.66	710.000	4.53		
0.980	0.33	37.000	1.29	105.000	1.63	300.000	7.14	840.000	3.56		
2.000	2.08	44.000	1.30	125.000	2.41	350.000	8.66	1000.000	5.84		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
560_580d

Sample Source & type:
A39

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Friday, 6 July 2007 9:39:56 a.m.

Analysed:
Friday, 6 July 2007 9:39:57 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
5.991 %

Sensitivity:
Enhanced

Obscuration:
11.55 %

Result Emulation:
Off

Concentration:
0.0115 %Vol

Specific Surface Area:
0.691 m²/g

Span :
2.964

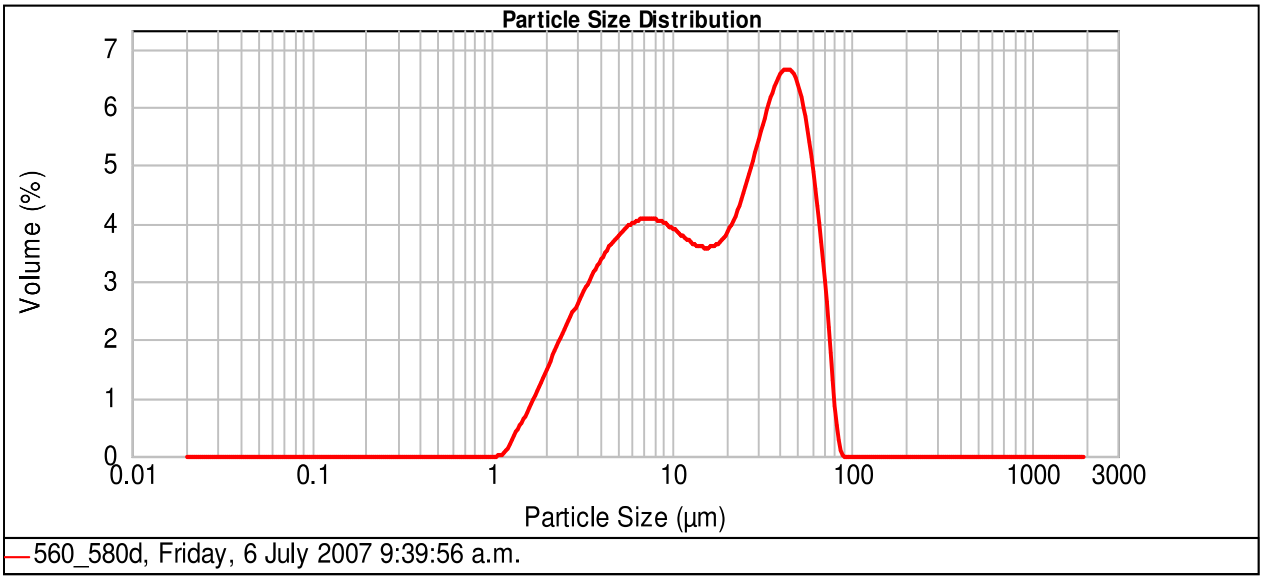
Surface Weighted Mean D[3,2]:
8.689 um

Uniformity:
0.958

Vol. Weighted Mean D[4,3]:
23.873 um

Result units:
Volume

d(0.1): 3.380 um **d(0.5):** 17.264 um **d(0.9):** 54.558 um



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	2.40
2.000	10.53
3.900	

Size (µm)	Volume In %
3.900	17.38
7.800	17.31
15.600	19.00
31.000	6.89
37.000	7.42
44.000	7.91
53.000	

Size (µm)	Volume In %
53.000	6.19
63.000	3.82
74.000	1.14
88.000	0.00
105.000	0.00
125.000	0.00
149.000	

Size (µm)	Volume In %
149.000	0.00
177.000	0.00
210.000	0.00
250.000	0.00
300.000	0.00
350.000	0.00
420.000	

Size (µm)	Volume In %
420.000	0.00
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

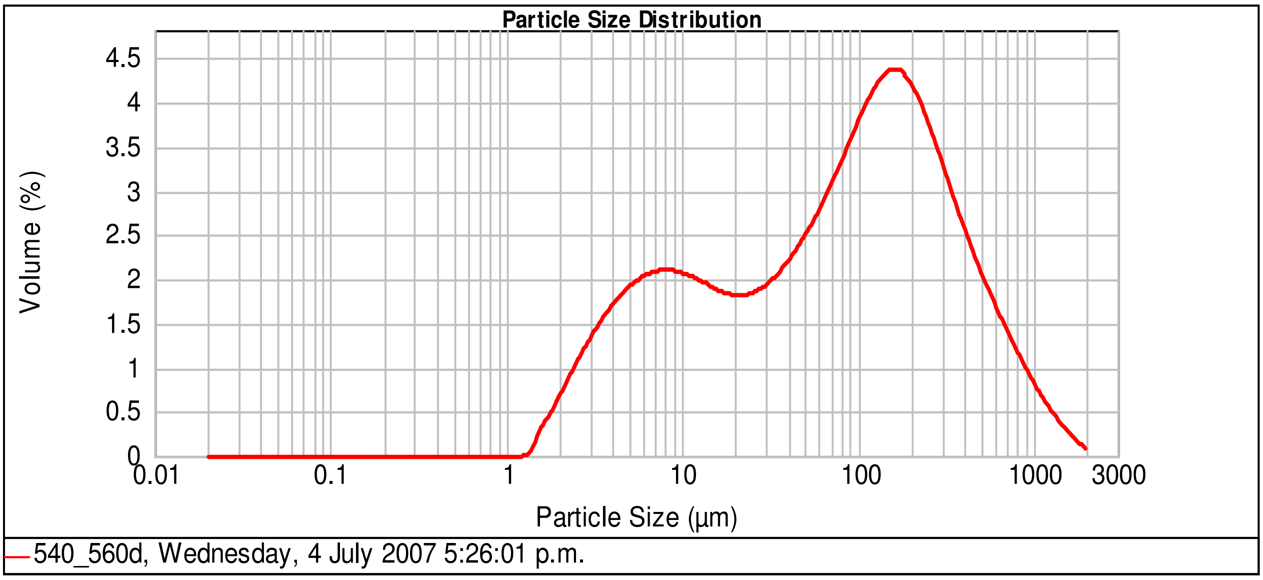
Result Analysis Report

Sample Name: 540_560d	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 4 July 2007 5:26:01 p.m.
Sample Source & type: A38	**Measured by:** gmdr1	**Analysed:** Wednesday, 4 July 2007 5:26:02 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 11.12 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.368 %	**Result Emulation:** Off

Concentration: 0.0221 %Vol	**Span :** 5.064	**Uniformity:** 1.67	**Result units:** Volume
Specific Surface Area: 0.348 m²/g	**Surface Weighted Mean D[3,2]:** 17.250 um	**Vol. Weighted Mean D[4,3]:** 171.284 um	

d(0.1): 5.363 um **d(0.5): 86.455 um** **d(0.9): 443.190 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.90
2.000	5.27
3.900	

Size (µm)	Volume In %
3.900	8.87
7.800	9.17
15.600	8.32
31.000	2.35
37.000	2.51
44.000	2.98
53.000	

Size (µm)	Volume In %
53.000	3.08
63.000	3.18
74.000	3.80
88.000	4.29
105.000	4.62
125.000	4.93
149.000	

Size (µm)	Volume In %
149.000	4.93
177.000	4.77
210.000	4.55
250.000	4.27
300.000	3.17
350.000	3.23
420.000	

Size (µm)	Volume In %
420.000	2.60
500.000	2.07
590.000	1.91
710.000	1.38
840.000	1.10
1000.000	1.79
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
520_540d

SOP Name:
Marine Sediment

Measured:
Wednesday, 4 July 2007 5:14:01 p.m.

Sample Source & type:
A37

Measured by:
gmdr1

Analysed:
Wednesday, 4 July 2007 5:14:02 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
10.51 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.300 %

Result Emulation:
Off

Concentration:
0.0220 %Vol

Span :
4.774

Uniformity:
1.59

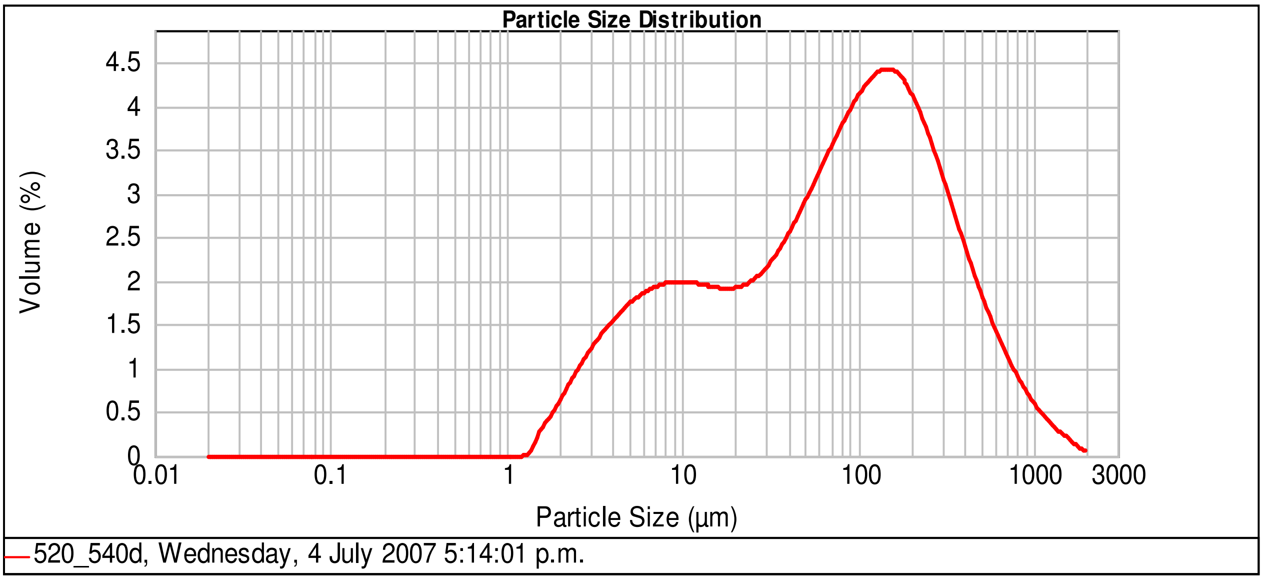
Result units:
Volume

Specific Surface Area:
0.331 m²/g

Surface Weighted Mean D[3,2]:
18.142 um

Vol. Weighted Mean D[4,3]:
156.063 um

d(0.1): 5.779 um **d(0.5): 81.115 um** **d(0.9): 392.997 um**



Size (µm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.84
3.900	4.79

Size (µm)	Volume In %
3.900	
7.800	8.11
15.600	8.92
31.000	8.88
37.000	2.64
44.000	2.88
53.000	3.46

Size (µm)	Volume In %
53.000	
63.000	3.59
74.000	3.66
88.000	4.28
105.000	4.69
125.000	4.88
149.000	5.06

Size (µm)	Volume In %
149.000	
177.000	4.94
210.000	4.71
250.000	4.45
300.000	4.15
350.000	3.05
420.000	3.05

Size (µm)	Volume In %
420.000	
500.000	2.38
590.000	1.81
710.000	1.58
840.000	1.08
1000.000	0.82
2000.000	1.29

Size (µm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

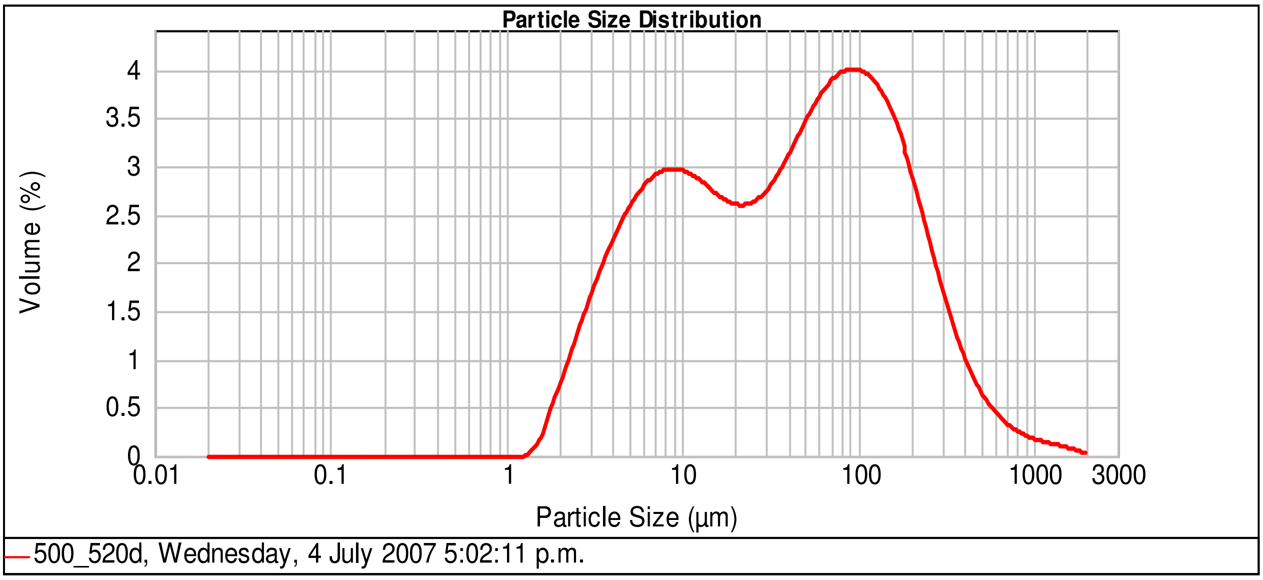
Result Analysis Report

Sample Name: 500_520d	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 4 July 2007 5:02:11 p.m.
Sample Source & type: A36	**Measured by:** gmdr1	**Analysed:** Wednesday, 4 July 2007 5:02:12 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 12.09 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.317 %	**Result Emulation:** Off

Concentration: 0.0195 %Vol	**Span :** 5.301	**Uniformity:** 1.85	**Result units:** Volume
Specific Surface Area: 0.437 m²/g	**Surface Weighted Mean D[3,2]:** 13.740 um	**Vol. Weighted Mean D[4,3]:** 91.619 um	

d(0.1): 4.679 um **d(0.5): 41.717 um** **d(0.9): 225.816 um**



Size (μm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.79
3.900	6.43

Size (μm)	Volume In %
3.900	
7.800	12.06
15.600	13.11
31.000	11.88
37.000	3.32
44.000	3.53
53.000	4.14

Size (μm)	Volume In %
53.000	
63.000	4.14
74.000	4.06
88.000	4.50
105.000	4.62
125.000	4.48
149.000	4.31

Size (μm)	Volume In %
149.000	
177.000	3.90
210.000	3.43
250.000	2.94
300.000	2.43
350.000	1.57
420.000	1.36

Size (μm)	Volume In %
420.000	
500.000	0.91
590.000	0.61
710.000	0.48
840.000	0.30
1000.000	0.23
2000.000	0.46

Size (μm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
480_500d

Sample Source & type:
A35

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 4:49:11 p.m.

Analysed:
Wednesday, 4 July 2007 4:49:12 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.314 %

Sensitivity:
Enhanced

Obscuration:
17.66 %

Result Emulation:
Off

Concentration:
0.0341 %Vol

Specific Surface Area:
0.373 m²/g

Span :
4.550

Surface Weighted Mean D[3,2]:
16.087 um

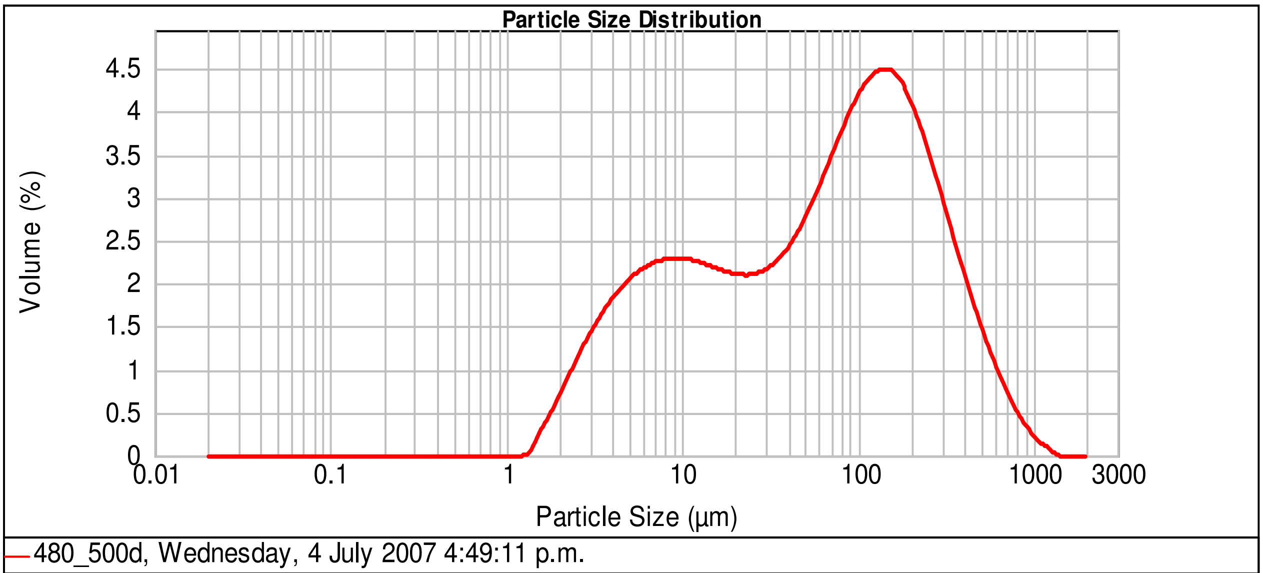
Uniformity:
1.49

Vol. Weighted Mean D[4,3]:
124.835 um

Result units:
Volume

d(0.1): 5.134 um **d(0.5):** 69.247 um **d(0.9):** 320.243 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.88
2.000	5.61
3.900	

Size (μm)	Volume In %
3.900	9.52
7.800	10.25
15.600	9.56
31.000	2.60
37.000	2.76
44.000	3.29
53.000	

Size (μm)	Volume In %
53.000	3.45
63.000	3.60
74.000	4.29
88.000	4.77
105.000	5.00
125.000	5.16
149.000	

Size (μm)	Volume In %
149.000	4.99
177.000	4.70
210.000	4.35
250.000	3.95
300.000	2.82
350.000	2.71
420.000	

Size (μm)	Volume In %
420.000	2.00
500.000	1.42
590.000	1.10
710.000	0.63
840.000	0.37
1000.000	0.20
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
460_480d

Sample Source & type:
A34

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 4:35:14 p.m.

Analysed:
Wednesday, 4 July 2007 4:35:15 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.404 %

Sensitivity:
Enhanced

Obscuration:
14.70 %

Result Emulation:
Off

Concentration:
0.0397 %Vol

Specific Surface Area:
0.264 m²/g

Span :
3.509

Surface Weighted Mean D[3,2]:
22.704 um

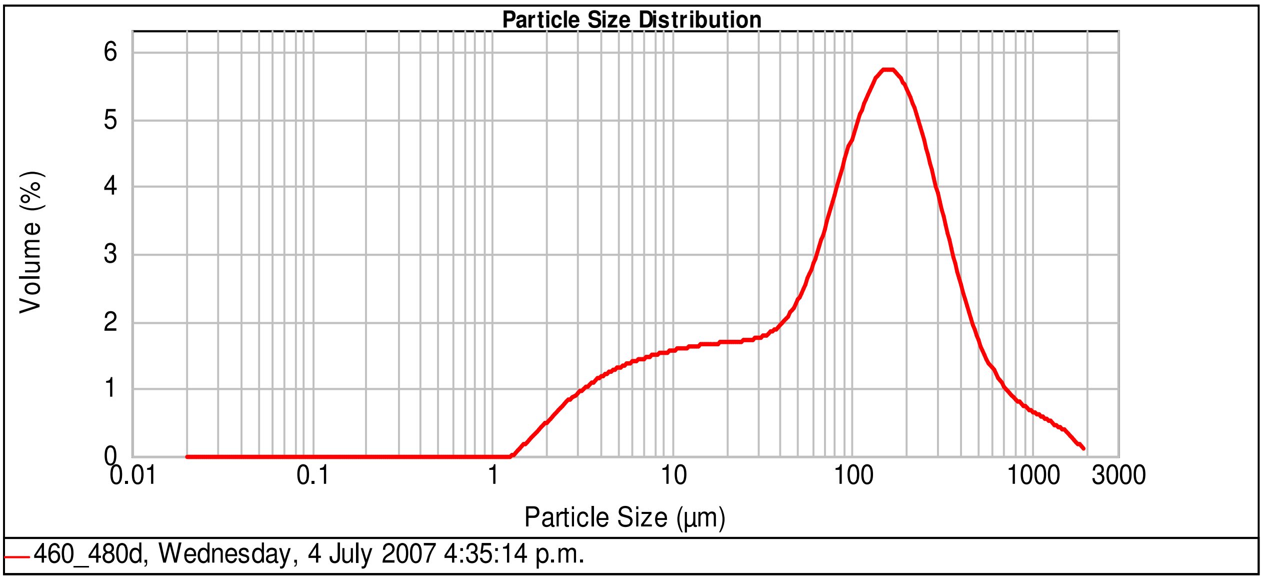
Uniformity:
1.22

Vol. Weighted Mean D[4,3]:
176.810 um

Result units:
Volume

d(0.1): 7.484 um **d(0.5):** 111.145 um **d(0.9):** 397.482 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.65
2.000	3.68
3.900	

Size (µm)	Volume In %
3.900	6.07
7.800	7.15
15.600	7.60
31.000	2.08
37.000	2.21
44.000	2.71
53.000	

Size (µm)	Volume In %
53.000	3.00
63.000	3.37
74.000	4.36
88.000	5.26
105.000	5.91
125.000	6.43
149.000	

Size (µm)	Volume In %
149.000	6.45
177.000	6.18
210.000	5.74
250.000	5.15
300.000	3.58
350.000	3.32
420.000	

Size (µm)	Volume In %
420.000	2.37
500.000	1.67
590.000	1.39
710.000	0.98
840.000	0.83
1000.000	1.86
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
440_460d

Sample Source & type:
A33

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 4:23:11 p.m.

Analysed:
Wednesday, 4 July 2007 4:23:12 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.489 %

Sensitivity:
Enhanced

Obscuration:
12.98 %

Result Emulation:
Off

Concentration:
0.0609 %Vol

Specific Surface Area:
0.152 m²/g

Span :
2.469

Surface Weighted Mean D[3,2]:
39.588 um

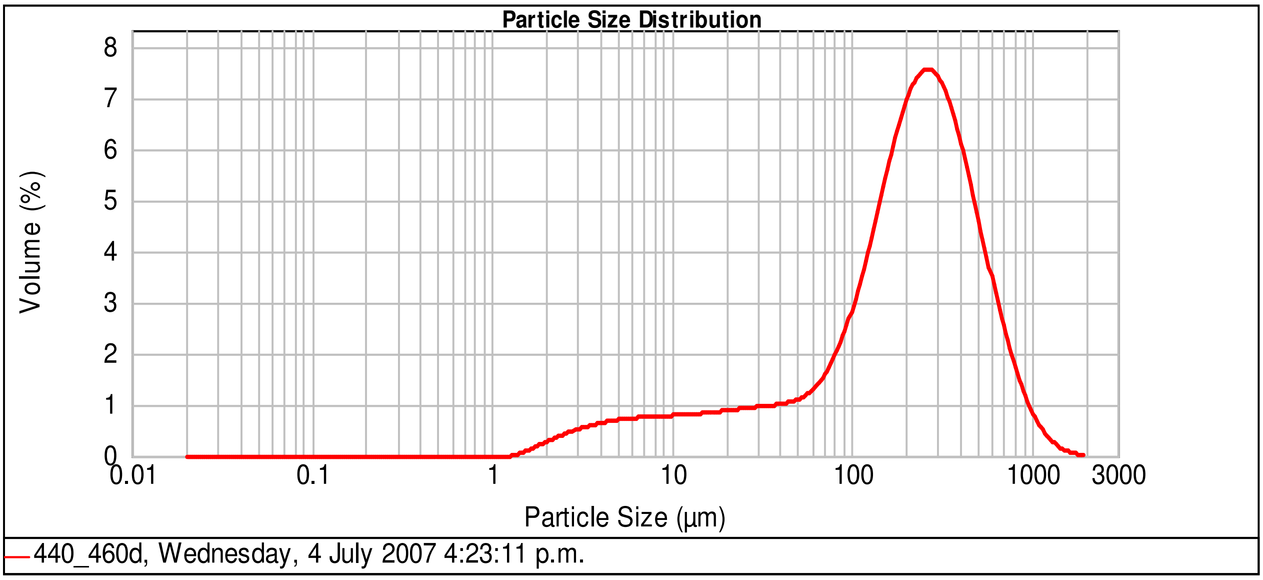
Uniformity:
0.758

Vol. Weighted Mean D[4,3]:
262.925 um

Result units:
Volume

d(0.1): 17.761 um **d(0.5):** 215.739 um **d(0.9):** 550.432 um

---



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.35
2.000	
	2.05
3.900	

Size (μm)	Volume In %
3.900	
	3.25
7.800	
	3.63
15.600	
	4.06
31.000	
	1.13
37.000	
	1.15
44.000	
	1.31
53.000	

Size (μm)	Volume In %
53.000	
	1.38
63.000	
	1.57
74.000	
	2.20
88.000	
	3.06
105.000	
	4.10
125.000	
	5.39
149.000	

Size (μm)	Volume In %
149.000	
	6.55
177.000	
	7.56
210.000	
	8.42
250.000	
	8.99
300.000	
	7.27
350.000	
	7.70
420.000	

Size (μm)	Volume In %
420.000	
	6.11
500.000	
	4.51
590.000	
	3.60
710.000	
	2.13
840.000	
	1.33
1000.000	
	1.21
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
420_440d

Sample Source & type:
A32

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 4:10:42 p.m.

Analysed:
Wednesday, 4 July 2007 4:10:43 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
1.940 %

Sensitivity:
Enhanced

Obscuration:
12.07 %

Result Emulation:
Off

Concentration:
0.0764 %Vol

Specific Surface Area:
0.104 m²/g

Span :
1.786

Surface Weighted Mean D[3,2]:
57.674 um

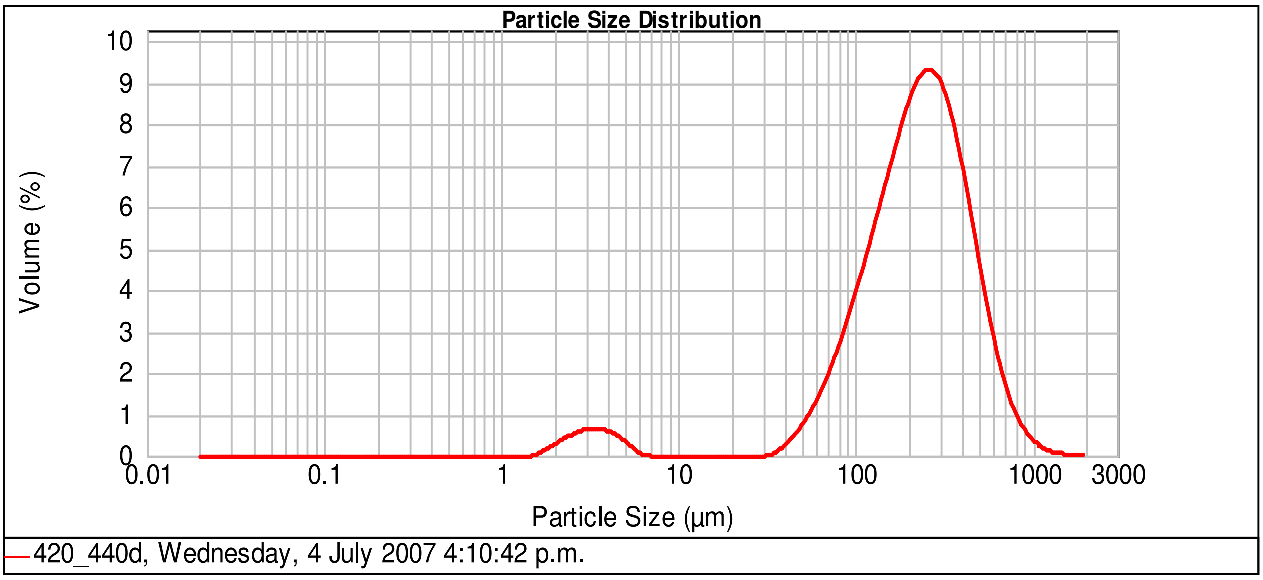
Uniformity:
0.572

Vol. Weighted Mean D[4,3]:
260.674 um

Result units:
Volume

d(0.1): 81.844 um **d(0.5):** 224.845 um **d(0.9):** 483.384 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.23
2.000	2.41
3.900	

Size (μm)	Volume In %
3.900	1.08
7.800	0.00
15.600	0.00
31.000	0.06
37.000	0.33
44.000	0.83
53.000	

Size (μm)	Volume In %
53.000	1.39
63.000	2.00
74.000	3.09
88.000	4.33
105.000	5.58
125.000	7.01
149.000	

Size (μm)	Volume In %
149.000	8.24
177.000	9.40
210.000	10.44
250.000	11.04
300.000	8.67
350.000	8.68
420.000	

Size (μm)	Volume In %
420.000	6.23
500.000	3.99
590.000	2.63
710.000	1.24
840.000	0.63
1000.000	0.47
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
400_420d

SOP Name:
Marine Sediment

Measured:
Wednesday, 4 July 2007 3:57:12 p.m.

Sample Source & type:
A31

Measured by:
gmdr1

Analysed:
Wednesday, 4 July 2007 3:57:13 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
18.66 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.260 %

Result Emulation:
Off

Concentration:
0.0629 %Vol

Span :
2.220

Uniformity:
0.659

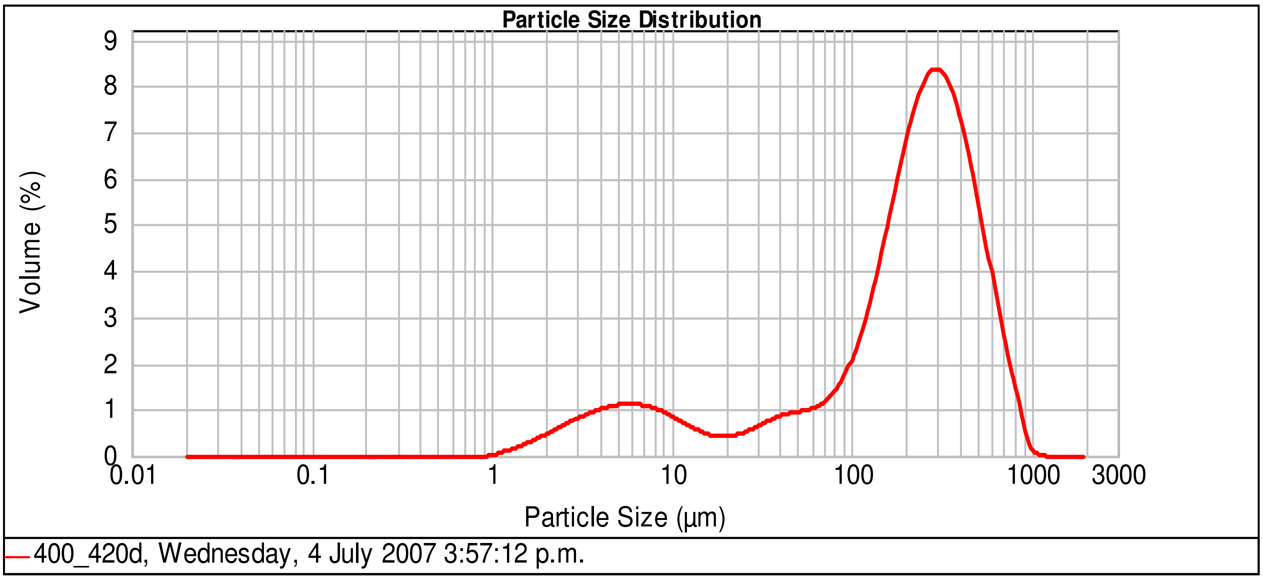
Result units:
Volume

Specific Surface Area:
0.213 m²/g

Surface Weighted Mean D[3,2]:
28.149 um

Vol. Weighted Mean D[4,3]:
258.095 um

d(0.1): 8.855 um **d(0.5): 232.948 um** **d(0.9): 525.937 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.97
2.000	3.26
3.900	

Size (µm)	Volume In %
3.900	4.94
7.800	3.51
15.600	2.20
31.000	0.86
37.000	0.98
44.000	1.15
53.000	

Size (µm)	Volume In %
53.000	1.14
63.000	1.18
74.000	1.58
88.000	2.23
105.000	3.17
125.000	4.50
149.000	

Size (µm)	Volume In %
149.000	5.91
177.000	7.34
210.000	8.73
250.000	9.88
300.000	8.34
350.000	9.08
420.000	

Size (µm)	Volume In %
420.000	7.26
500.000	5.26
590.000	3.91
710.000	1.94
840.000	0.63
1000.000	0.05
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
380_400d

Sample Source & type:
A30

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 3:42:28 p.m.

Analysed:
Wednesday, 4 July 2007 3:42:29 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
1.927 %

Sensitivity:
Enhanced

Obscuration:
19.59 %

Result Emulation:
Off

Concentration:
0.0696 %Vol

Specific Surface Area:
0.239 m²/g

Span :
23.315

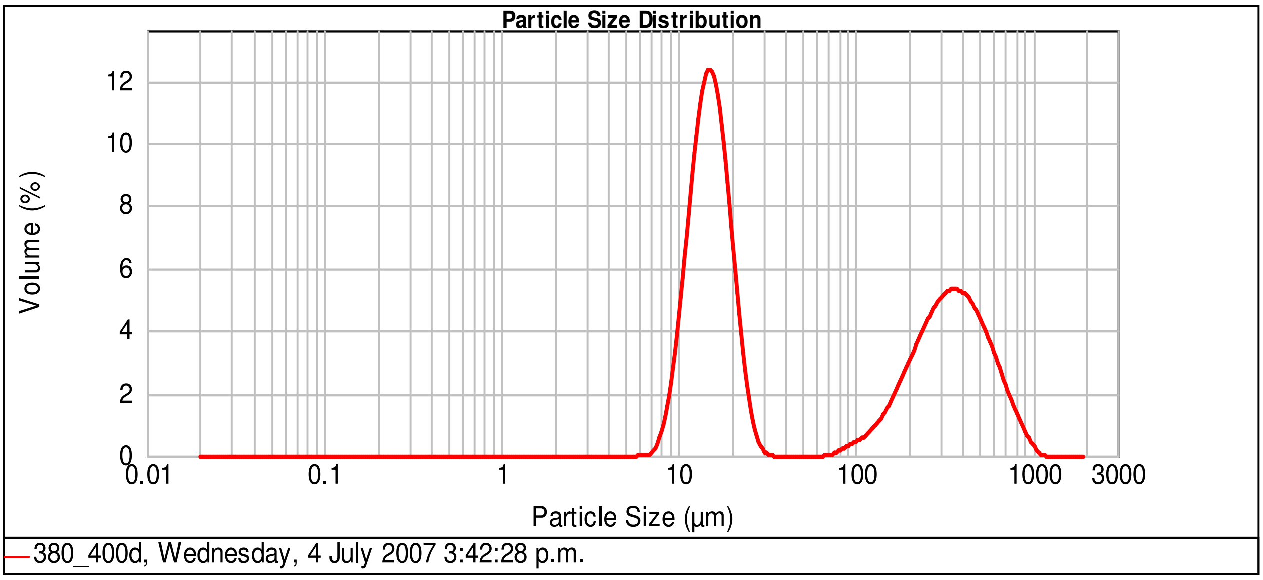
Surface Weighted Mean D[3,2]:
25.157 um

Uniformity:
7.81

Vol. Weighted Mean D[4,3]:
178.731 um

Result units:
Volume

d(0.1): 11.660 um **d(0.5):** 21.036 um **d(0.9):** 502.113 um



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.00
3.900	

Size (µm)	Volume In %
3.900	0.18
7.800	31.29
15.600	23.19
31.000	0.00
37.000	0.00
44.000	0.00
53.000	

Size (µm)	Volume In %
53.000	0.00
63.000	0.01
74.000	0.20
88.000	0.47
105.000	0.79
125.000	1.35
149.000	

Size (µm)	Volume In %
149.000	2.17
177.000	3.19
210.000	4.37
250.000	5.62
300.000	5.28
350.000	6.29
420.000	

Size (µm)	Volume In %
420.000	5.46
500.000	4.22
590.000	3.32
710.000	1.73
840.000	0.76
1000.000	0.10
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
360_380d

Sample Source & type:
A29

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 3:19:01 p.m.

Analysed:
Wednesday, 4 July 2007 3:19:02 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.914 %

Sensitivity:
Enhanced

Obscuration:
12.02 %

Result Emulation:
Off

Concentration:
0.0580 %Vol

Specific Surface Area:
0.148 m²/g

Span :
2.029

Surface Weighted Mean D[3,2]:
40.522 um

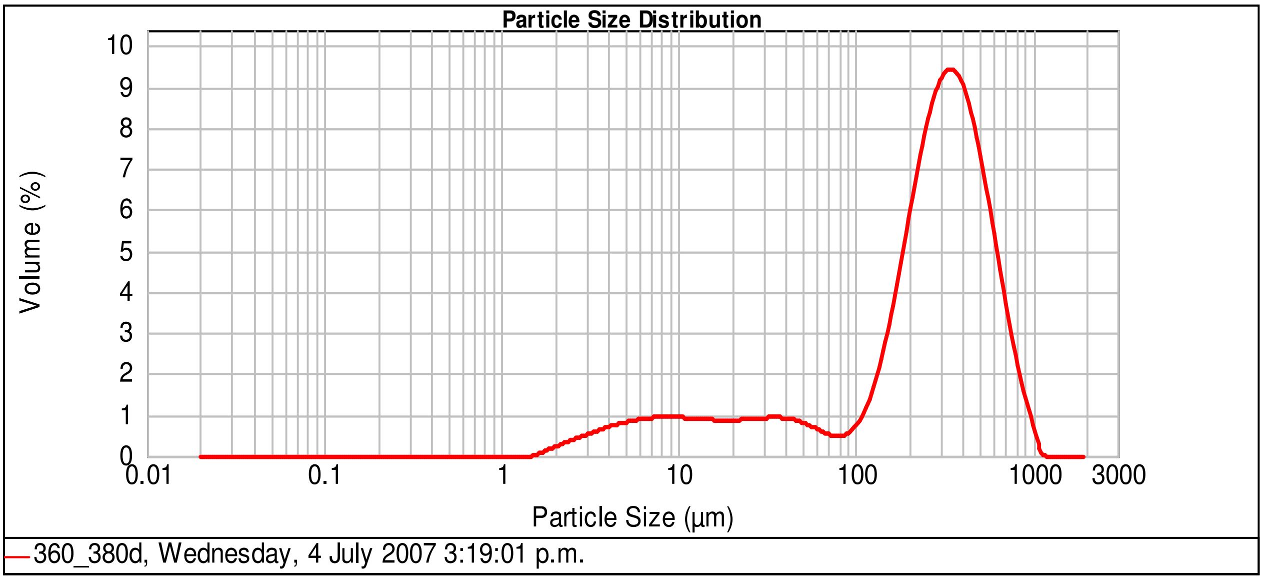
Uniformity:
0.595

Vol. Weighted Mean D[4,3]:
302.333 um

Result units:
Volume

d(0.1): 14.882 um **d(0.5):** 283.122 um **d(0.9):** 589.380 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.20
2.000	2.03
3.900	

Size (μm)	Volume In %
3.900	3.85
7.800	4.19
15.600	4.00
31.000	1.08
37.000	1.04
44.000	1.01
53.000	

Size (μm)	Volume In %
53.000	0.78
63.000	0.57
74.000	0.56
88.000	0.78
105.000	1.41
125.000	2.63
149.000	

Size (μm)	Volume In %
149.000	4.27
177.000	6.23
210.000	8.37
250.000	10.44
300.000	9.48
350.000	10.94
420.000	

Size (μm)	Volume In %
420.000	9.21
500.000	6.95
590.000	5.43
710.000	2.89
840.000	1.42
1000.000	0.23
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
340_360d

SOP Name:
Marine Sediment

Measured:
Wednesday, 4 July 2007 3:06:41 p.m.

Sample Source & type:
A28

Measured by:
gmdr1

Analysed:
Wednesday, 4 July 2007 3:06:43 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
15.76 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.786 %

Result Emulation:
Off

Concentration:
0.0660 %Vol

Span :
2.218

Uniformity:
0.698

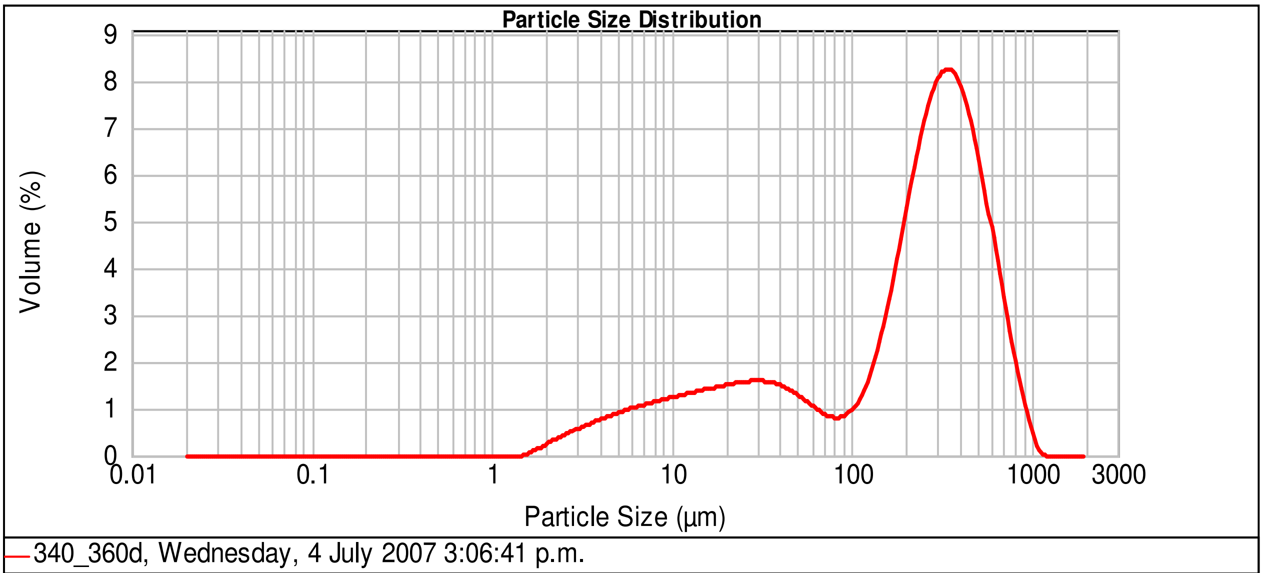
Result units:
Volume

Specific Surface Area:
0.176 m²/g

Surface Weighted Mean D[3,2]:
34.032 um

Vol. Weighted Mean D[4,3]:
271.979 um

d(0.1): 11.688 um **d(0.5): 252.380 um** **d(0.9): 571.539 um**



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	4.35	53.000	1.27	149.000	3.87	420.000	8.22	2000.000	0.00
0.120	0.00	7.800	5.79	63.000	0.97	177.000	5.49	500.000	6.27	4000.000	
0.241	0.00	15.600	6.88	74.000	0.93	210.000	7.30	590.000	4.94		
0.490	0.00	31.000	1.83	88.000	1.06	250.000	9.09	710.000	2.62		
0.980	0.20	37.000	1.70	105.000	1.54	300.000	8.29	840.000	1.21		
2.000	2.23	44.000	1.63	125.000	2.53	350.000	9.65	1000.000	0.16		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
320_340d

Sample Source & type:
A27

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 2:55:10 p.m.

Analysed:
Wednesday, 4 July 2007 2:55:11 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.866 %

Sensitivity:
Enhanced

Obscuration:
11.64 %

Result Emulation:
Off

Concentration:
0.0448 %Vol

Specific Surface Area:
0.185 m²/g

Span :
2.141

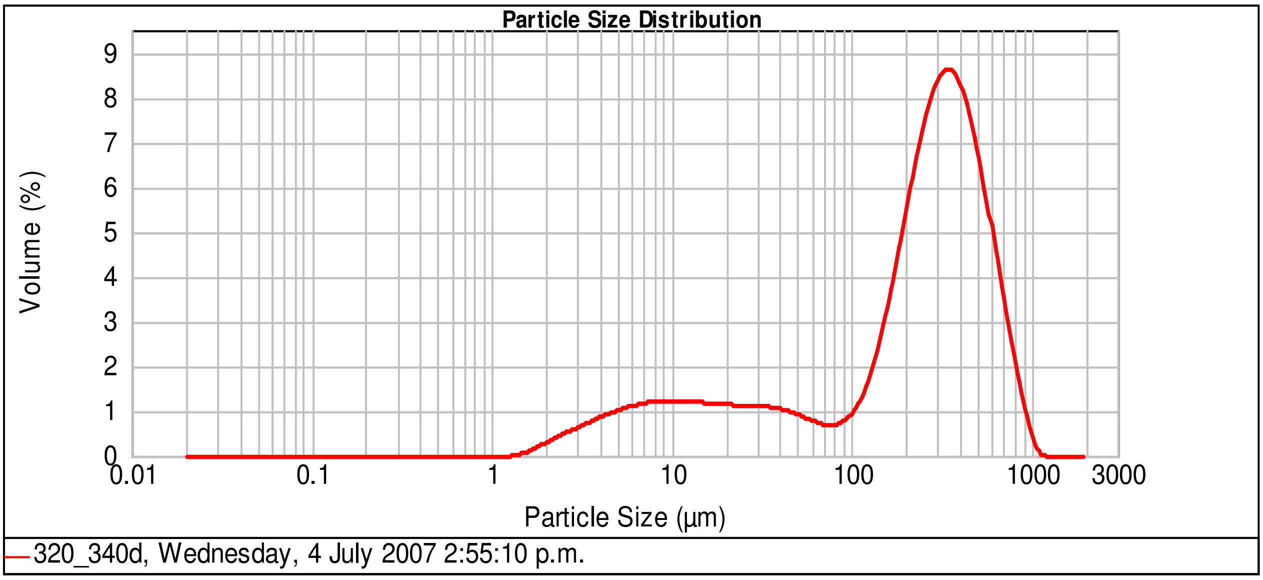
Surface Weighted Mean D[3,2]:
32.494 um

Uniformity:
0.655

Vol. Weighted Mean D[4,3]:
282.084 um

Result units:
Volume

d(0.1): 10.435 um **d(0.5):** 264.410 um **d(0.9):** 576.583 um



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.34
2.000	
	2.51
3.900	

Size (μm)	Volume In %
3.900	
	4.81
7.800	
	5.53
15.600	
	5.14
31.000	
	1.28
37.000	
	1.19
44.000	
	1.17
53.000	

Size (μm)	Volume In %
53.000	
	0.94
63.000	
	0.76
74.000	
	0.79
88.000	
	1.02
105.000	
	1.59
125.000	
	2.66
149.000	

Size (μm)	Volume In %
149.000	
	4.08
177.000	
	5.77
210.000	
	7.64
250.000	
	9.51
300.000	
	8.68
350.000	
	10.14
420.000	

Size (μm)	Volume In %
420.000	
	8.66
500.000	
	6.61
590.000	
	5.18
710.000	
	2.71
840.000	
	1.17
1000.000	
	0.13
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
300_320d

Sample Source & type:
A26

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 2:41:49 p.m.

Analysed:
Wednesday, 4 July 2007 2:41:50 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
1.092 %

Sensitivity:
Enhanced

Obscuration:
12.47 %

Result Emulation:
Off

Concentration:
0.0881 %Vol

Specific Surface Area:
0.102 m²/g

Span :
1.817

Surface Weighted Mean D[3,2]:
58.653 um

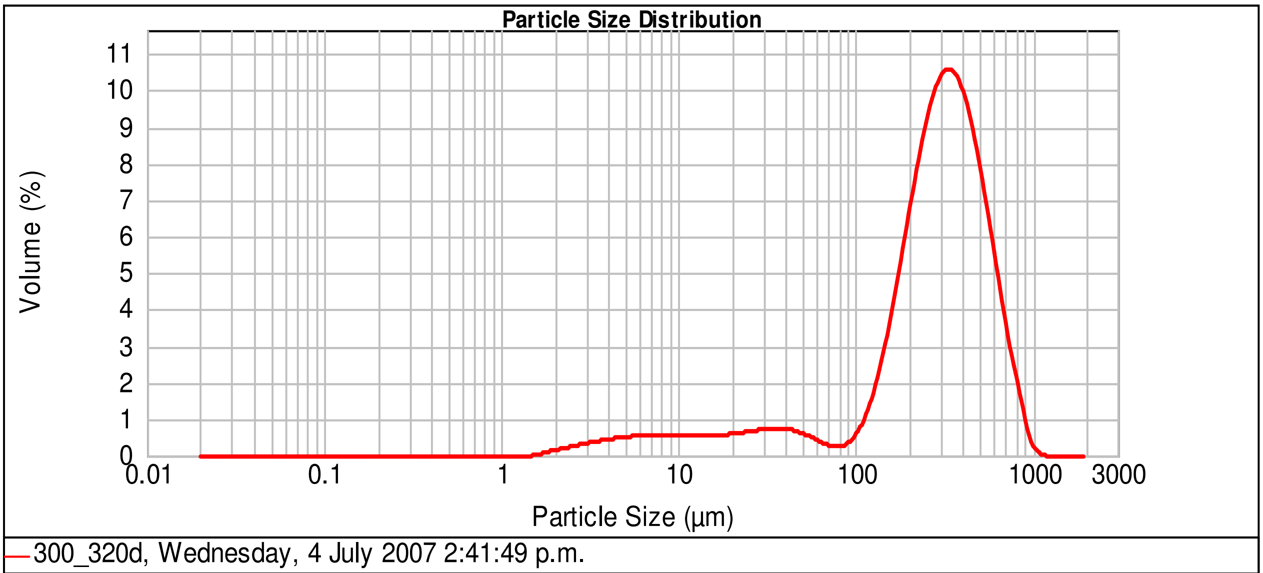
Uniformity:
0.507

Vol. Weighted Mean D[4,3]:
315.407 um

Result units:
Volume

d(0.1): 36.890 um **d(0.5):** 296.066 um **d(0.9):** 574.812 um

---



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.14
2.000	
	1.32
3.900	

Size (μm)	Volume In %
3.900	
	2.36
7.800	
	2.52
15.600	
	2.82
31.000	
	0.86
37.000	
	0.83
44.000	
	0.77
53.000	

Size (μm)	Volume In %
53.000	
	0.52
63.000	
	0.32
74.000	
	0.29
88.000	
	0.57
105.000	
	1.37
125.000	
	2.85
149.000	

Size (μm)	Volume In %
149.000	
	4.82
177.000	
	7.12
210.000	
	9.57
250.000	
	11.86
300.000	
	10.66
350.000	
	12.13
420.000	

Size (μm)	Volume In %
420.000	
	9.99
500.000	
	7.32
590.000	
	5.43
710.000	
	2.64
840.000	
	0.85
1000.000	
	0.07
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
280_300d

Sample Source & type:
A25

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 2:28:51 p.m.

Analysed:
Wednesday, 4 July 2007 2:28:53 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
1.156 %

Sensitivity:
Enhanced

Obscuration:
12.87 %

Result Emulation:
Off

Concentration:
0.1177 %Vol

Specific Surface Area:
0.0818 m²/g

Span :
1.737

Surface Weighted Mean D[3,2]:
73.380 um

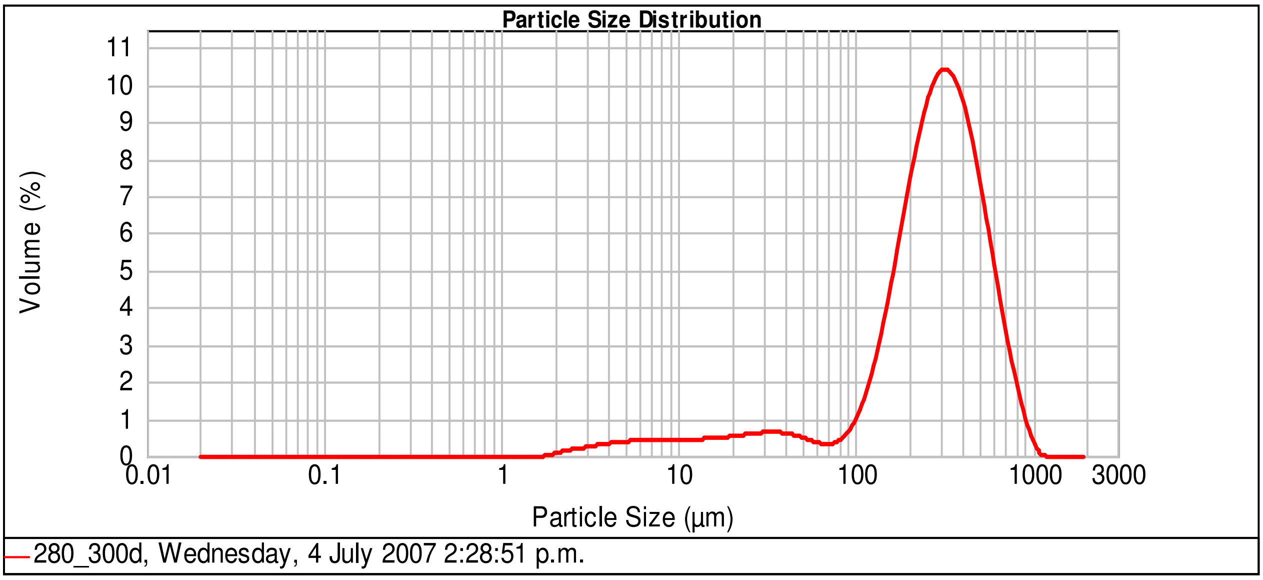
Uniformity:
0.51

Vol. Weighted Mean D[4,3]:
311.561 um

Result units:
Volume

d(0.1): 68.642 um **d(0.5):** 286.695 um **d(0.9):** 566.589 um

---



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.03
2.000	
	0.93
3.900	

Size (µm)	Volume In %
3.900	
	1.83
7.800	
	2.05
15.600	
	2.49
31.000	
	0.74
37.000	
	0.69
44.000	
	0.62
53.000	

Size (µm)	Volume In %
53.000	
	0.44
63.000	
	0.34
74.000	
	0.49
88.000	
	1.01
105.000	
	2.04
125.000	
	3.70
149.000	

Size (µm)	Volume In %
149.000	
	5.70
177.000	
	7.88
210.000	
	10.08
250.000	
	12.01
300.000	
	10.49
350.000	
	11.66
420.000	

Size (µm)	Volume In %
420.000	
	9.42
500.000	
	6.81
590.000	
	5.03
710.000	
	2.46
840.000	
	0.97
1000.000	
	0.09
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
260_280d

Sample Source & type:
A24

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 2:09:37 p.m.

Analysed:
Wednesday, 4 July 2007 2:09:38 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
1.021 %

Sensitivity:
Enhanced

Obscuration:
16.96 %

Result Emulation:
Off

Concentration:
0.1198 %Vol

Specific Surface Area:
0.106 m²/g

Span :
1.871

Surface Weighted Mean D[3,2]:
56.643 um

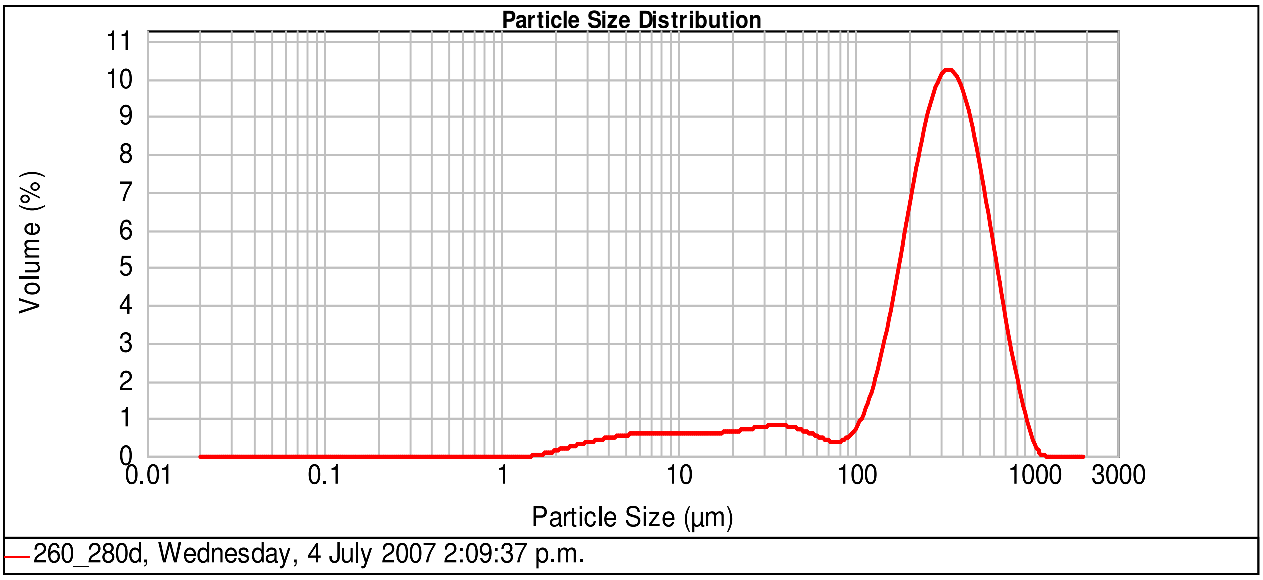
Uniformity:
0.529

Vol. Weighted Mean D[4,3]:
312.393 um

Result units:
Volume

d(0.1): 32.254 um **d(0.5):** 292.079 um **d(0.9):** 578.729 um

---



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.11
2.000	
	1.33
3.900	

Size (μm)	Volume In %
3.900	
	2.54
7.800	
	2.76
15.600	
	3.05
31.000	
	0.93
37.000	
	0.90
44.000	
	0.86
53.000	

Size (μm)	Volume In %
53.000	
	0.62
63.000	
	0.44
74.000	
	0.44
88.000	
	0.74
105.000	
	1.52
125.000	
	2.94
149.000	

Size (μm)	Volume In %
149.000	
	4.81
177.000	
	6.98
210.000	
	9.30
250.000	
	11.48
300.000	
	10.30
350.000	
	11.75
420.000	

Size (μm)	Volume In %
420.000	
	9.73
500.000	
	7.19
590.000	
	5.42
710.000	
	2.70
840.000	
	1.07
1000.000	
	0.09
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
240_260d

Sample Source & type:
A23

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 1:57:01 p.m.

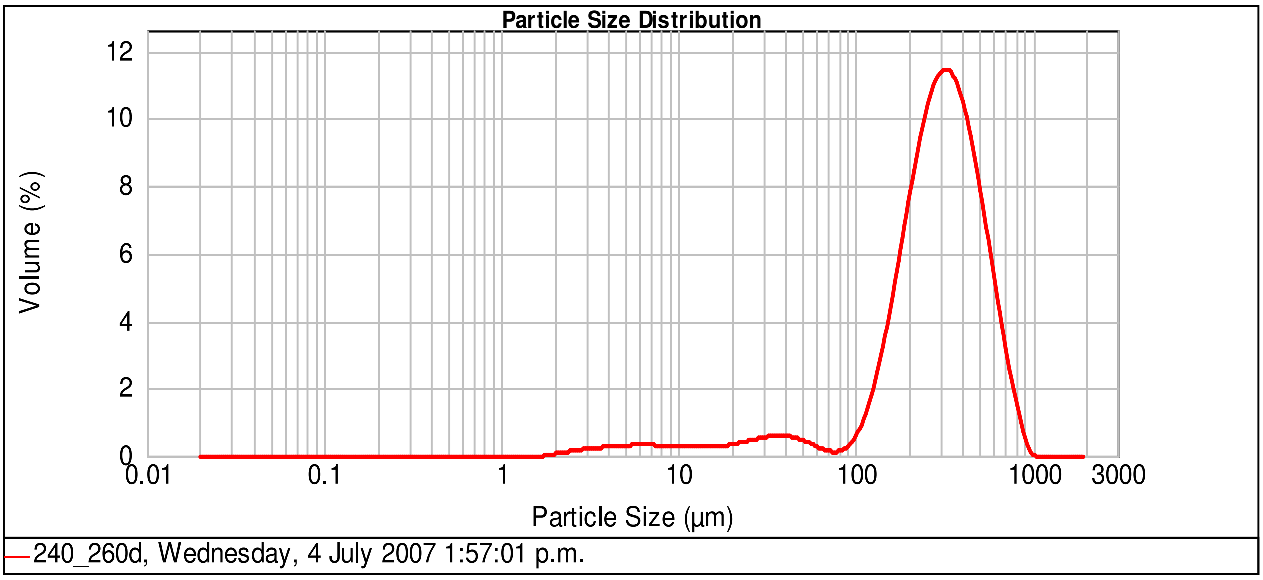
Analysed:
Wednesday, 4 July 2007 1:57:02 p.m.

Particle Name:	**Accessory Name:**	**Analysis model:**	**Sensitivity:**
Marine Sediment	None	General purpose	Enhanced
Particle RI:	**Absorption:**	**Size range:**	**Obscuration:**
1.500	0	0.020 to 2000.000 um	12.81 %
Dispersant Name:	**Dispersant RI:**	**Weighted Residual:**	**Result Emulation:**
Water	1.330	1.308 %	Off

Concentration:	**Span :**	**Uniformity:**	**Result units:**
0.1444 %Vol	1.438	0.451	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.0665 m²/g	90.186 um	318.577 um	

d(0.1): 125.894 um **d(0.5):** 297.251 um **d(0.9):** 553.345 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.02
2.000	0.76
3.900	

Size (µm)	Volume In %
3.900	1.39
7.800	1.25
15.600	1.77
31.000	0.68
37.000	0.67
44.000	0.60
53.000	

Size (µm)	Volume In %
53.000	0.35
63.000	0.16
74.000	0.16
88.000	0.55
105.000	1.54
125.000	3.30
149.000	

Size (µm)	Volume In %
149.000	5.56
177.000	8.11
210.000	10.74
250.000	13.08
300.000	11.53
350.000	12.82
420.000	

Size (µm)	Volume In %
420.000	10.24
500.000	7.21
590.000	5.02
710.000	2.10
840.000	0.40
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
220_240d

Sample Source & type:
A22

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 1:28:33 p.m.

Analysed:
Wednesday, 4 July 2007 1:28:34 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.617 %

Sensitivity:
Enhanced

Obscuration:
14.46 %

Result Emulation:
Off

Concentration:
0.0609 %Vol

Specific Surface Area:
0.174 m²/g

Span :
2.203

Surface Weighted Mean D[3,2]:
34.404 um

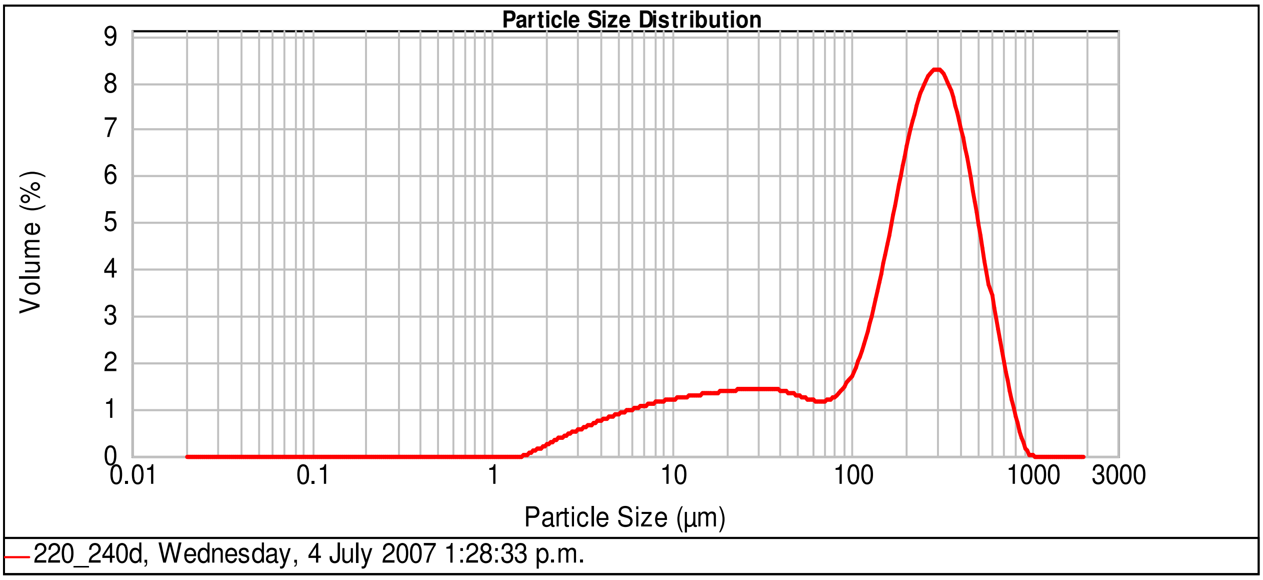
Uniformity:
0.686

Vol. Weighted Mean D[4,3]:
235.936 um

Result units:
Volume

d(0.1): 11.970 um **d(0.5):** 217.536 um **d(0.9):** 491.181 um

---



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.060	0.00	3.900	4.28	53.000	1.38	149.000	5.44	420.000	6.86	2000.000	0.00
0.120	0.00	7.800	5.60	63.000	1.23	177.000	7.00	500.000	4.71	4000.000	
0.241	0.00	15.600	6.29	74.000	1.43	210.000	8.53	590.000	3.19		
0.490	0.00	31.000	1.67	88.000	1.87	250.000	9.77	710.000	1.27		
0.980	0.19	37.000	1.59	105.000	2.67	300.000	8.24	840.000	0.21		
2.000	2.17	44.000	1.61	125.000	3.95	350.000	8.85	1000.000	0.00		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
200_220d

Sample Source & type:
A21

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 1:15:51 p.m.

Analysed:
Wednesday, 4 July 2007 1:15:52 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.872 %

Sensitivity:
Enhanced

Obscuration:
16.21 %

Result Emulation:
Off

Concentration:
0.1132 %Vol

Specific Surface Area:
0.107 m²/g

Span :
1.975

Surface Weighted Mean D[3,2]:
56.059 um

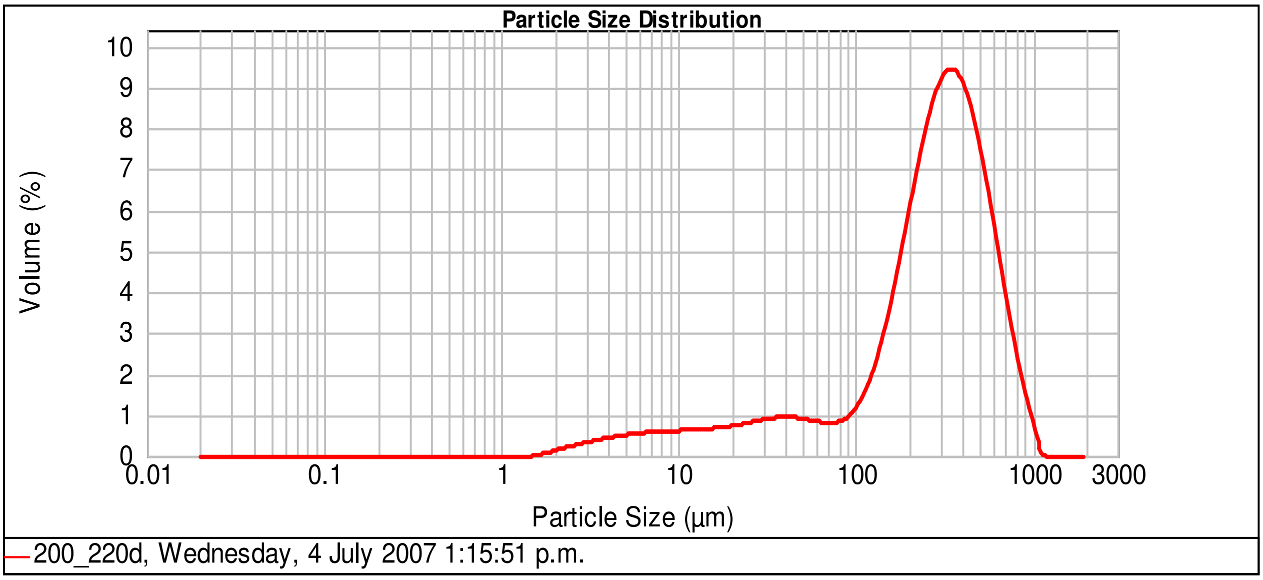
Uniformity:
0.576

Vol. Weighted Mean D[4,3]:
311.883 um

Result units:
Volume

d(0.1): 30.134 um **d(0.5):** 287.862 um **d(0.9):** 598.524 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.11
2.000	1.29
3.900	

Size (μm)	Volume In %
3.900	2.42
7.800	2.87
15.600	3.48
31.000	1.07
37.000	1.07
44.000	1.12
53.000	

Size (μm)	Volume In %
53.000	0.97
63.000	0.85
74.000	0.96
88.000	1.27
105.000	1.93
125.000	3.11
149.000	

Size (μm)	Volume In %
149.000	4.63
177.000	6.44
210.000	8.45
250.000	10.43
300.000	9.47
350.000	11.00
420.000	

Size (μm)	Volume In %
420.000	9.36
500.000	7.16
590.000	5.68
710.000	3.07
840.000	1.54
1000.000	0.25
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
190_200d

Sample Source & type:
A20

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 12:59:30 p.m.

Analysed:
Wednesday, 4 July 2007 12:59:31 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.748 %

Sensitivity:
Enhanced

Obscuration:
12.91 %

Result Emulation:
Off

Concentration:
0.0477 %Vol

Specific Surface Area:
0.193 m²/g

Span :
2.301

Surface Weighted Mean D[3,2]:
31.110 um

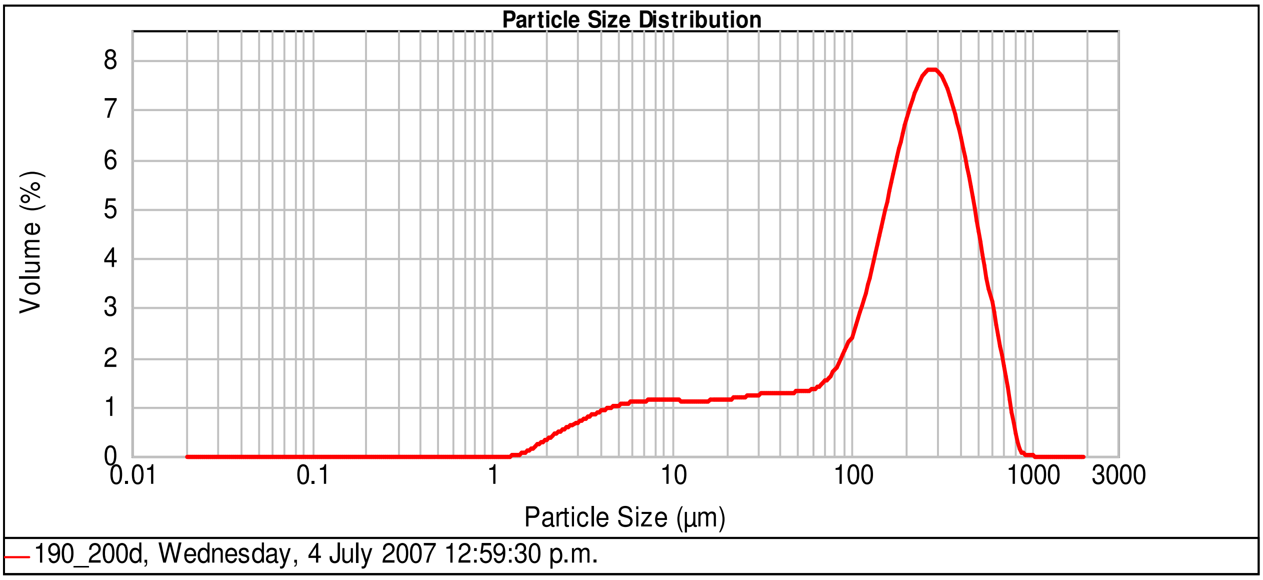
Uniformity:
0.709

Vol. Weighted Mean D[4,3]:
223.693 um

Result units:
Volume

d(0.1): 10.536 um **d(0.5):** 200.874 um **d(0.9):** 472.697 um

---



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.36
2.000	
	2.71
3.900	

Size (µm)	Volume In %
3.900	
	4.71
7.800	
	5.07
15.600	
	5.26
31.000	
	1.46
37.000	
	1.45
44.000	
	1.57
53.000	

Size (µm)	Volume In %
53.000	
	1.50
63.000	
	1.52
74.000	
	1.96
88.000	
	2.63
105.000	
	3.54
125.000	
	4.82
149.000	

Size (µm)	Volume In %
149.000	
	6.10
177.000	
	7.33
210.000	
	8.46
250.000	
	9.30
300.000	
	7.66
350.000	
	8.12
420.000	

Size (µm)	Volume In %
420.000	
	6.29
500.000	
	4.32
590.000	
	2.89
710.000	
	0.90
840.000	
	0.04
1000.000	
	0.00
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
180_190d

SOP Name:
Marine Sediment

Measured:
Wednesday, 4 July 2007 12:10:17 p.m.

Sample Source & type:
A19

Measured by:
gmdr1

Analysed:
Wednesday, 4 July 2007 12:10:18 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
12.95 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.643 %

Result Emulation:
Off

Concentration:
0.0588 %Vol

Span :
2.218

Uniformity:
0.667

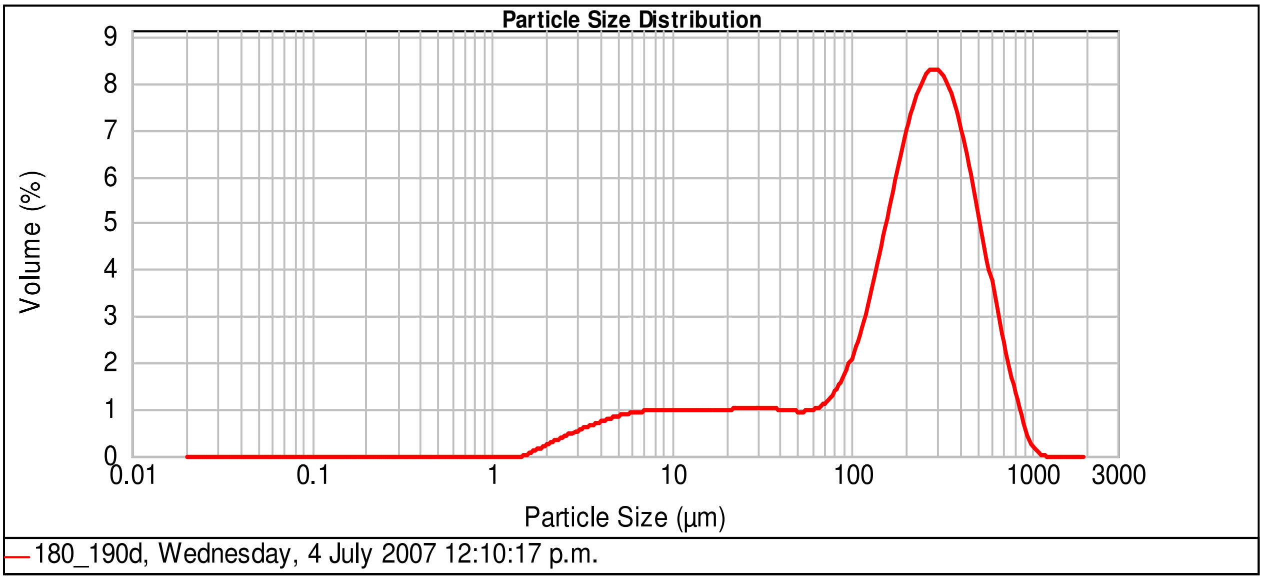
Result units:
Volume

Specific Surface Area:
0.159 m²/g

Surface Weighted Mean D[3,2]:
37.787 um

Vol. Weighted Mean D[4,3]:
253.023 um

d(0.1): 13.835 um **d(0.5): 226.886 um** **d(0.9): 517.096 um**



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.20
2.000	
	2.12
3.900	

Size (µm)	Volume In %
3.900	
	3.98
7.800	
	4.47
15.600	
	4.51
31.000	
	1.18
37.000	
	1.13
44.000	
	1.17
53.000	

Size (µm)	Volume In %
53.000	
	1.09
63.000	
	1.13
74.000	
	1.55
88.000	
	2.24
105.000	
	3.24
125.000	
	4.64
149.000	

Size (µm)	Volume In %
149.000	
	6.07
177.000	
	7.48
210.000	
	8.80
250.000	
	9.83
300.000	
	8.21
350.000	
	8.83
420.000	

Size (µm)	Volume In %
420.000	
	6.97
500.000	
	4.98
590.000	
	3.65
710.000	
	1.79
840.000	
	0.64
1000.000	
	0.09
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
170_180d

Sample Source & type:
A18

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 11:58:37 a.m.

Analysed:
Wednesday, 4 July 2007 11:58:38 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
2.160 %

Sensitivity:
Enhanced

Obscuration:
10.55 %

Result Emulation:
Off

Concentration:
0.0877 %Vol

Specific Surface Area:
0.083 m²/g

Span :
1.625

Surface Weighted Mean D[3,2]:
72.316 um

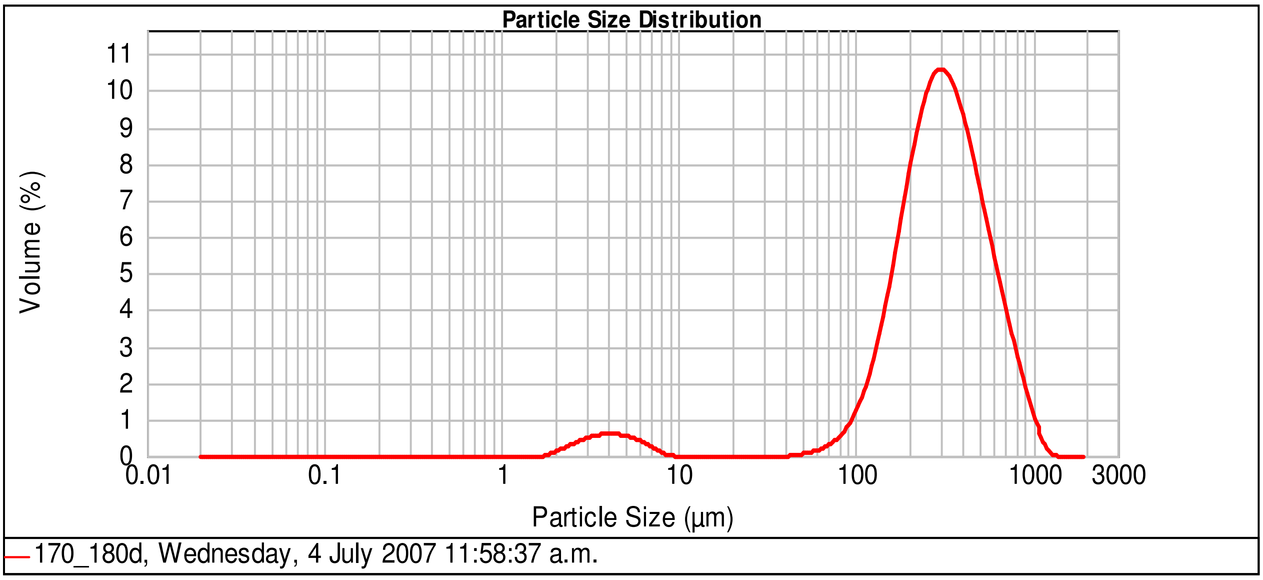
Uniformity:
0.506

Vol. Weighted Mean D[4,3]:
342.039 um

Result units:
Volume

d(0.1): 134.526 um **d(0.5):** 299.840 um **d(0.9):** 621.731 um

---



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	2.04	53.000	0.15	149.000	6.06	420.000	9.21	2000.000	0.00
0.120	0.00	7.800	0.05	63.000	0.29	177.000	8.36	500.000	6.91	4000.000	
0.241	0.00	15.600	0.00	74.000	0.62	210.000	10.63	590.000	5.67		
0.490	0.00	31.000	0.00	88.000	1.26	250.000	12.43	710.000	3.40		
0.980	0.04	37.000	0.00	105.000	2.32	300.000	10.56	840.000	1.96		
2.000	1.76	44.000	0.05	125.000	3.99	350.000	11.46	1000.000	0.79		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

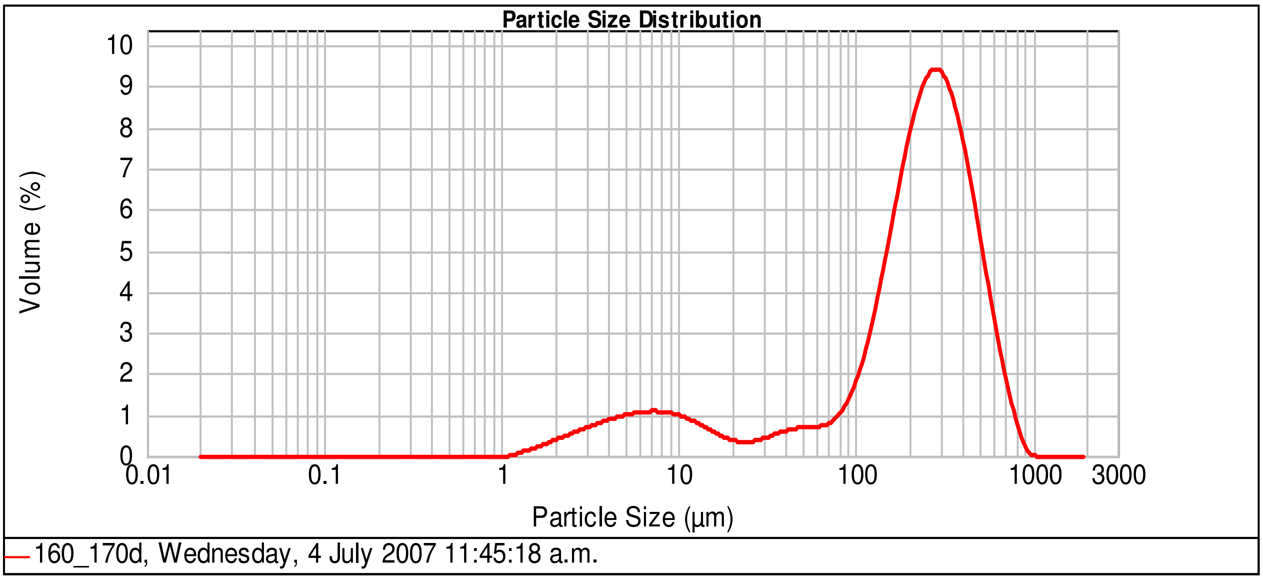
Result Analysis Report

Sample Name: 160_170d	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 4 July 2007 11:45:18 a.m.
Sample Source & type: A17	**Measured by:** gmdr1	**Analysed:** Wednesday, 4 July 2007 11:45:19 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 11.31 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.898 %	**Result Emulation:** Off

Concentration: 0.0415 %Vol	**Span :** 2.037	**Uniformity:** 0.588	**Result units:** Volume
Specific Surface Area: 0.188 m²/g	**Surface Weighted Mean D[3,2]:** 31.895 um	**Vol. Weighted Mean D[4,3]:** 251.268 um	

d(0.1): 10.347 um **d(0.5):** 233.920 um **d(0.9):** 486.927 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.70
2.000	2.77
3.900	

Size (μm)	Volume In %
3.900	4.61
7.800	4.04
15.600	1.82
31.000	0.59
37.000	0.70
44.000	0.83
53.000	

Size (μm)	Volume In %
53.000	0.80
63.000	0.82
74.000	1.18
88.000	1.92
105.000	3.12
125.000	4.84
149.000	

Size (μm)	Volume In %
149.000	6.68
177.000	8.48
210.000	10.08
250.000	11.21
300.000	9.16
350.000	9.50
420.000	

Size (μm)	Volume In %
420.000	7.10
500.000	4.69
590.000	3.05
710.000	1.15
840.000	0.17
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
140_150d_repeat

SOP Name:
Marine Sediment

Measured:
Wednesday, 4 July 2007 11:34:19 a.m.

Sample Source & type:
A16

Measured by:
gmdr1

Analysed:
Wednesday, 4 July 2007 11:34:20 a.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
11.93 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.761 %

Result Emulation:
Off

Concentration:
0.0358 %Vol

Span :
2.511

Uniformity:
0.894

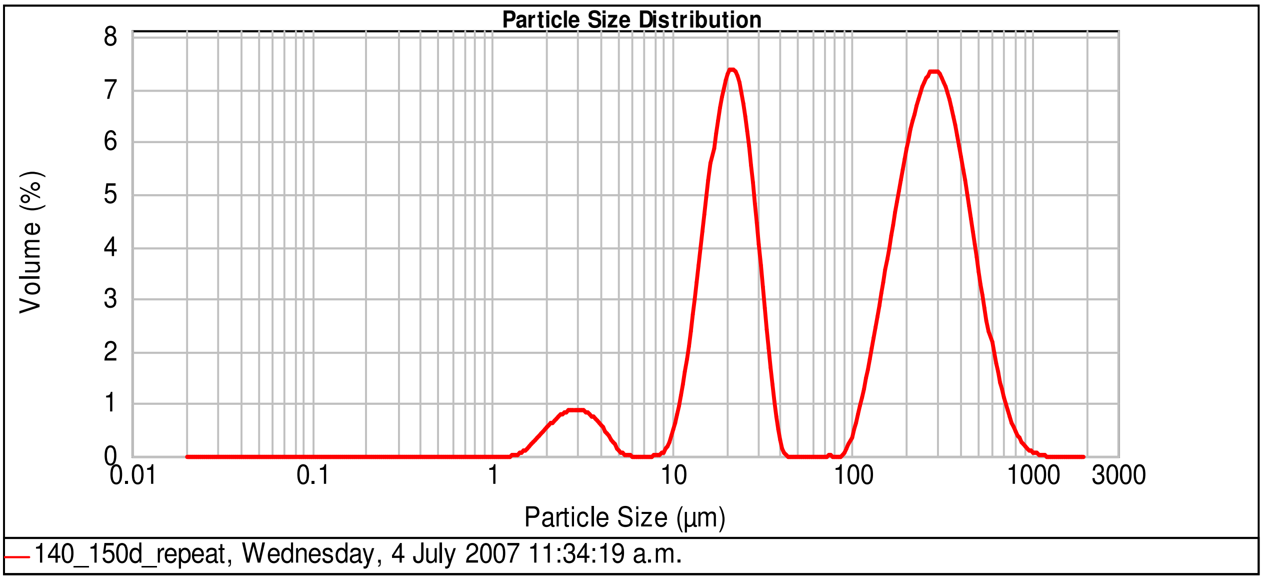
Result units:
Volume

Specific Surface Area:
0.229 m²/g

Surface Weighted Mean D[3,2]:
26.175 um

Vol. Weighted Mean D[4,3]:
187.717 um

d(0.1): 14.975 um **d(0.5): 167.641 um** **d(0.9): 435.878 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.57
2.000	3.37
3.900	

Size (μm)	Volume In %
3.900	0.68
7.800	6.60
15.600	28.20
31.000	2.67
37.000	0.32
44.000	0.00
53.000	

Size (μm)	Volume In %
53.000	0.00
63.000	0.00
74.000	0.00
88.000	0.26
105.000	1.40
125.000	2.96
149.000	

Size (μm)	Volume In %
149.000	4.60
177.000	6.17
210.000	7.62
250.000	8.71
300.000	7.20
350.000	7.39
420.000	

Size (μm)	Volume In %
420.000	5.27
500.000	3.21
590.000	1.88
710.000	0.69
840.000	0.21
1000.000	0.03
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

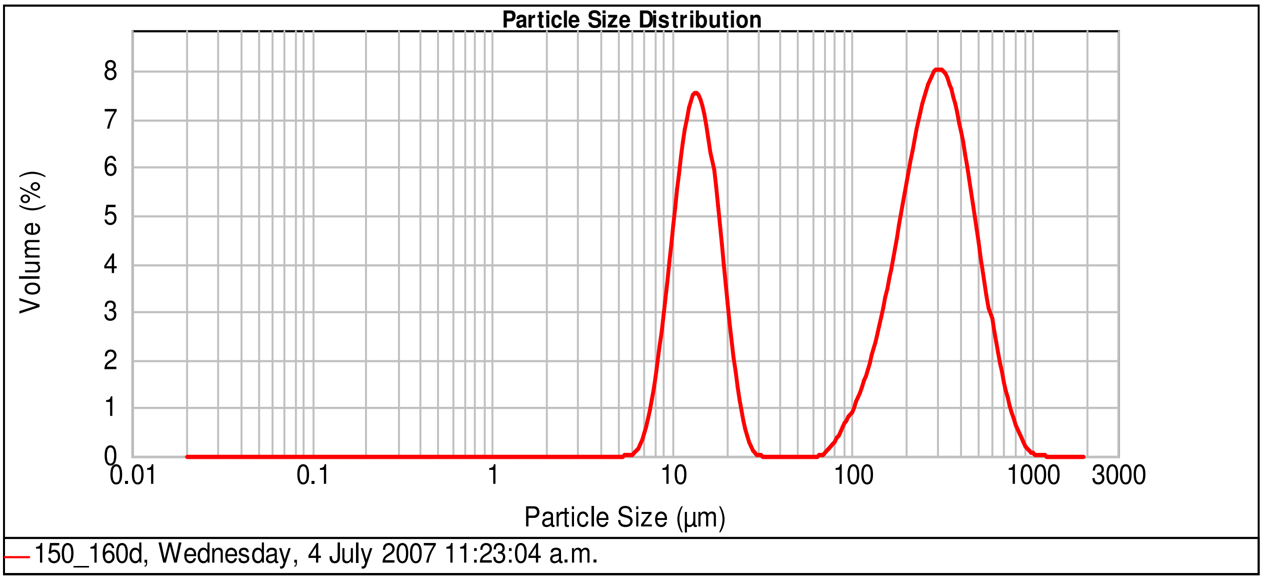
Result Analysis Report

Sample Name:	SOP Name:	Measured:
150_160d	Marine Sediment	Wednesday, 4 July 2007 11:23:04 a.m.
Sample Source & type:	**Measured by:**	**Analysed:**
A16	gmdr1	Wednesday, 4 July 2007 11:23:05 a.m.
Sample bulk lot ref:	**Result Source:**	
	Measurement	

Particle Name:	Accessory Name:	Analysis model:	Sensitivity:
Marine Sediment	None	General purpose	Enhanced
Particle RI:	**Absorption:**	**Size range:**	**Obscuration:**
1.500	0	0.020 to 2000.000 um	12.41 %
Dispersant Name:	**Dispersant RI:**	**Weighted Residual:**	**Result Emulation:**
Water	1.330	1.163 %	Off

Concentration:	Span :	Uniformity:	Result units:
0.0561 %Vol	2.298	0.793	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.18 m²/g	33.318 um	210.277 um	

d(0.1): 11.507 um **d(0.5): 198.799 um** **d(0.9): 468.298 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.00
3.900	

Size (μm)	Volume In %
3.900	0.69
7.800	23.82
15.600	11.55
31.000	0.00
37.000	0.00
44.000	0.00
53.000	

Size (μm)	Volume In %
53.000	0.00
63.000	0.02
74.000	0.33
88.000	0.93
105.000	1.72
125.000	2.85
149.000	

Size (μm)	Volume In %
149.000	4.25
177.000	5.92
210.000	7.73
250.000	9.32
300.000	8.04
350.000	8.59
420.000	

Size (μm)	Volume In %
420.000	6.40
500.000	4.09
590.000	2.53
710.000	0.96
840.000	0.24
1000.000	0.02
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

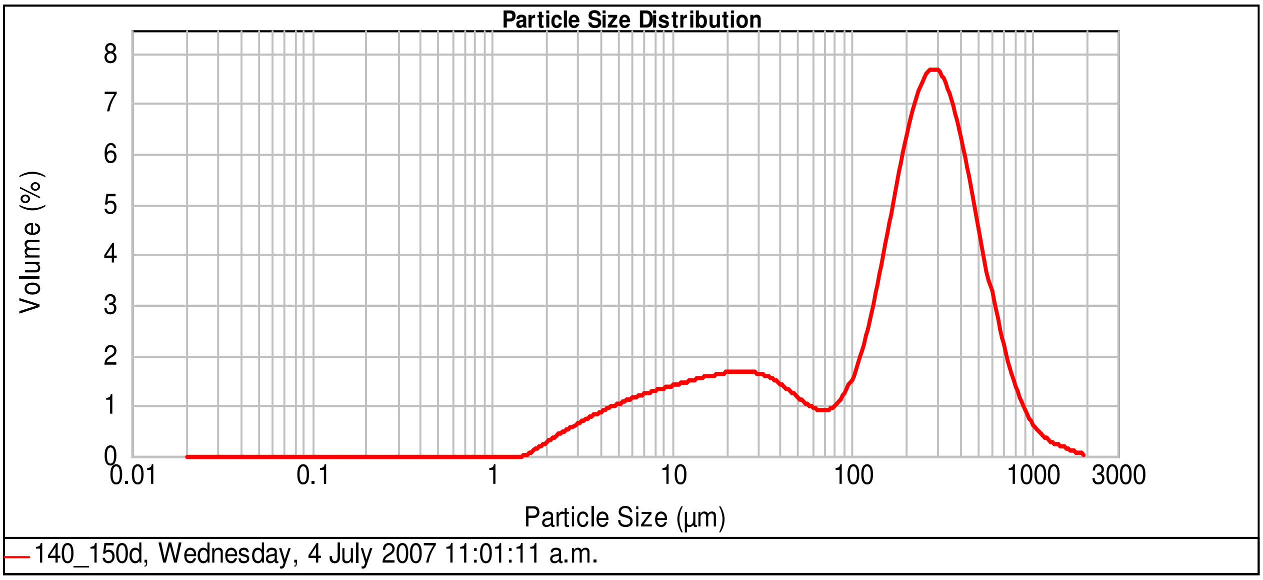
Result Analysis Report

Sample Name: 140_150d	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 4 July 2007 11:01:11 a.m.
Sample Source & type: A15	**Measured by:** gmdr1	**Analysed:** Wednesday, 4 July 2007 11:01:12 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 12.96 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.465 %	**Result Emulation:** Off

Concentration: 0.0483 %Vol	**Span :** 2.431	**Uniformity:** 0.795	**Result units:** Volume
Specific Surface Area: 0.195 m²/g	**Surface Weighted Mean D[3,2]:** 30.796 um	**Vol. Weighted Mean D[4,3]:** 246.612 um	

d(0.1): 10.236 um **d(0.5):** 211.871 um **d(0.9):** 525.287 um



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	4.91	53.000	1.15	149.000	5.29	420.000	6.17	2000.000	0.00
0.120	0.00	7.800	6.49	63.000	0.96	177.000	6.77	500.000	4.33	4000.000	
0.241	0.00	15.600	7.39	74.000	1.13	210.000	8.11	590.000	3.22		
0.490	0.00	31.000	1.82	88.000	1.61	250.000	9.11	710.000	1.75		
0.980	0.21	37.000	1.61	105.000	2.48	300.000	7.55	840.000	1.02		
2.000	2.49	44.000	1.48	125.000	3.82	350.000	7.99	1000.000	1.13		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

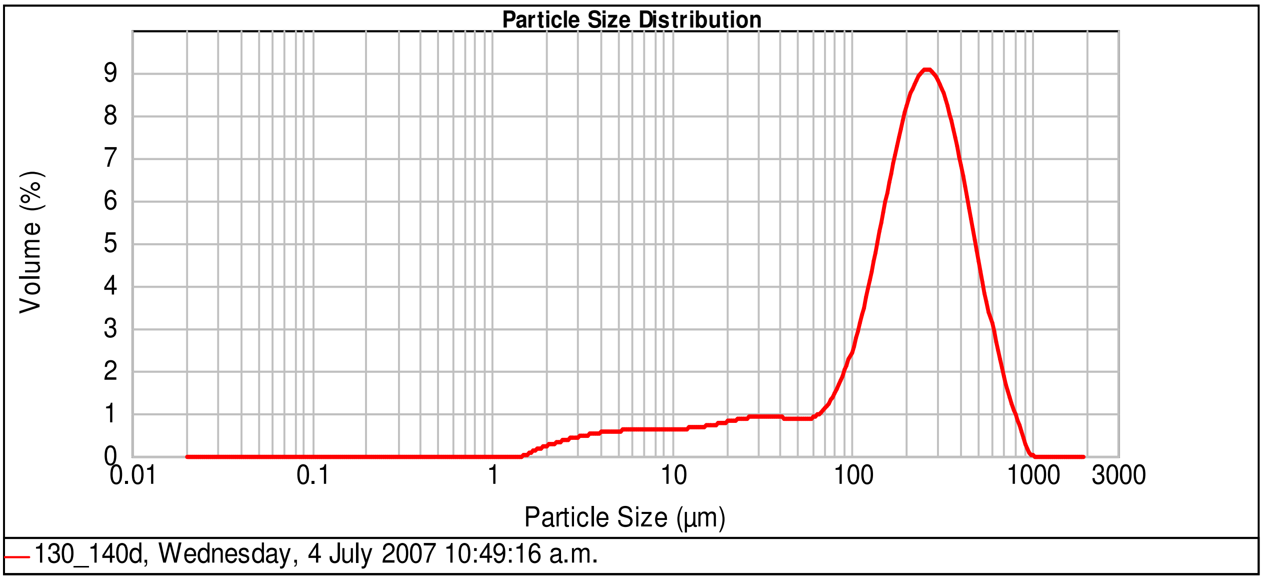
Result Analysis Report

Sample Name: 130_140d	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 4 July 2007 10:49:16 a.m.
Sample Source & type: A14	**Measured by:** gmdr1	**Analysed:** Wednesday, 4 July 2007 10:49:17 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 17.63 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.404 %	**Result Emulation:** Off

Concentration: 0.1001 %Vol	**Span :** 2.051	**Uniformity:** 0.6	**Result units:** Volume
Specific Surface Area: 0.129 m²/g	**Surface Weighted Mean D[3,2]:** 46.394 um	**Vol. Weighted Mean D[4,3]:** 247.844 um	

d(0.1): 24.854 um **d(0.5):** 223.496 um **d(0.9):** 483.228 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.22
2.000	1.76
3.900	

Size (μm)	Volume In %
3.900	2.71
7.800	2.91
15.600	3.71
31.000	1.07
37.000	1.02
44.000	1.05
53.000	

Size (μm)	Volume In %
53.000	0.99
63.000	1.09
74.000	1.64
88.000	2.58
105.000	3.90
125.000	5.65
149.000	

Size (μm)	Volume In %
149.000	7.34
177.000	8.84
210.000	10.06
250.000	10.77
300.000	8.57
350.000	8.74
420.000	

Size (μm)	Volume In %
420.000	6.48
500.000	4.32
590.000	2.94
710.000	1.31
840.000	0.32
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
120_130d

Sample Source & type:
A13

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 10:30:05 a.m.

Analysed:
Wednesday, 4 July 2007 10:30:06 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.302 %

Sensitivity:
Enhanced

Obscuration:
13.68 %

Result Emulation:
Off

Concentration:
0.0433 %Vol

Specific Surface Area:
0.225 m²/g

Span :
2.549

Surface Weighted Mean D[3,2]:
26.631 um

Uniformity:
0.809

Vol. Weighted Mean D[4,3]:
209.156 um

Result units:
Volume

d(0.1): 8.177 um **d(0.5):** 177.895 um **d(0.9):** 461.696 um

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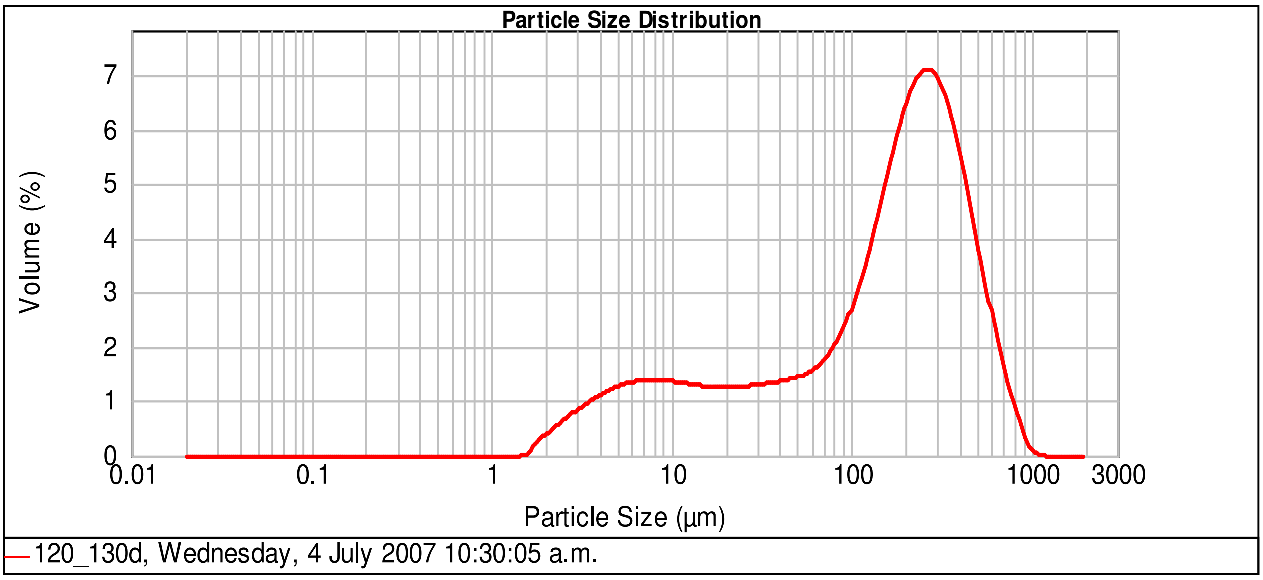


Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.35
2.000	3.32
3.900	

Size (μm)	Volume In %
3.900	5.90
7.800	6.12
15.600	5.72
31.000	1.54
37.000	1.56
44.000	1.74
53.000	

Size (μm)	Volume In %
53.000	1.73
63.000	1.79
74.000	2.29
88.000	2.96
105.000	3.81
125.000	4.95
149.000	

Size (μm)	Volume In %
149.000	6.03
177.000	7.03
210.000	7.89
250.000	8.45
300.000	6.77
350.000	7.00
420.000	

Size (μm)	Volume In %
420.000	5.29
500.000	3.61
590.000	2.53
710.000	1.19
840.000	0.39
1000.000	0.04
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
110_120d

Sample Source & type:
A12

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 10:12:18 a.m.

Analysed:
Wednesday, 4 July 2007 10:12:19 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.410 %

Sensitivity:
Enhanced

Obscuration:
14.75 %

Result Emulation:
Off

Concentration:
0.0530 %Vol

Specific Surface Area:
0.2 m²/g

Span :
2.393

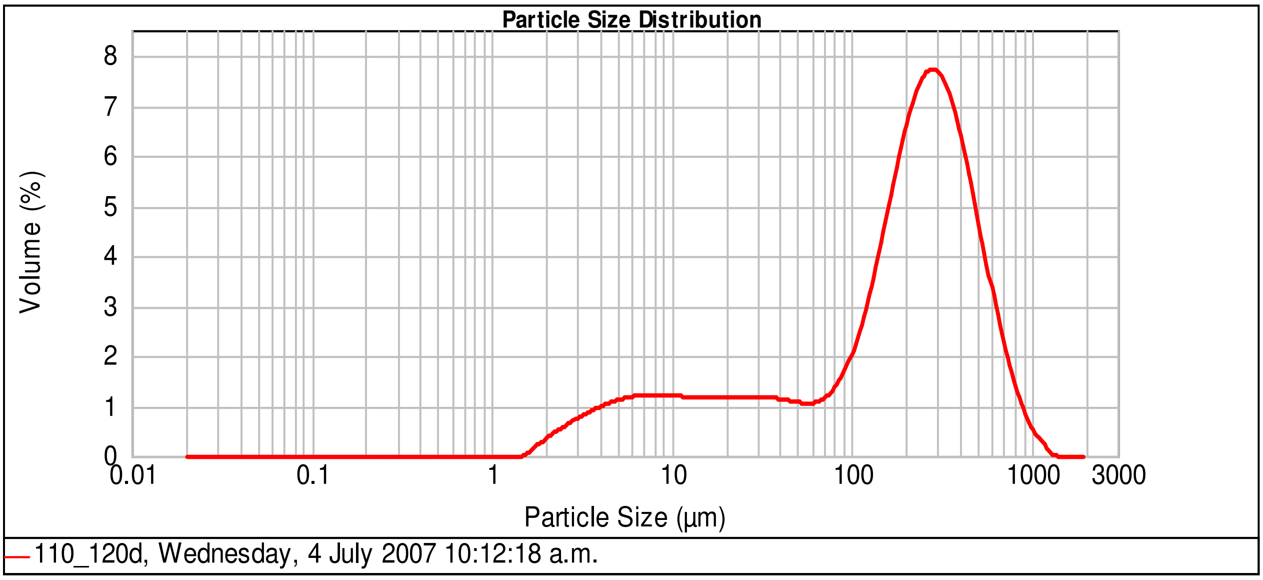
Surface Weighted Mean D[3,2]:
30.045 um

Uniformity:
0.748

Vol. Weighted Mean D[4,3]:
243.513 um

Result units:
Volume

d(0.1): 9.532 um **d(0.5): 212.262 um** **d(0.9): 517.370 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.30
2.000	2.95
3.900	

Size (μm)	Volume In %
3.900	5.15
7.800	5.41
15.600	5.27
31.000	1.36
37.000	1.29
44.000	1.32
53.000	

Size (μm)	Volume In %
53.000	1.19
63.000	1.18
74.000	1.54
88.000	2.17
105.000	3.10
125.000	4.42
149.000	

Size (μm)	Volume In %
149.000	5.78
177.000	7.09
210.000	8.30
250.000	9.19
300.000	7.59
350.000	8.07
420.000	

Size (μm)	Volume In %
420.000	6.30
500.000	4.48
590.000	3.35
710.000	1.79
840.000	0.95
1000.000	0.47
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
100_110d

Sample Source & type:
A11

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 9:55:04 a.m.

Analysed:
Wednesday, 4 July 2007 9:55:05 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.397 %

Sensitivity:
Enhanced

Obscuration:
13.19 %

Result Emulation:
Off

Concentration:
0.0867 %Vol

Specific Surface Area:
0.114 m²/g

Span :
2.016

Surface Weighted Mean D[3,2]:
52.670 um

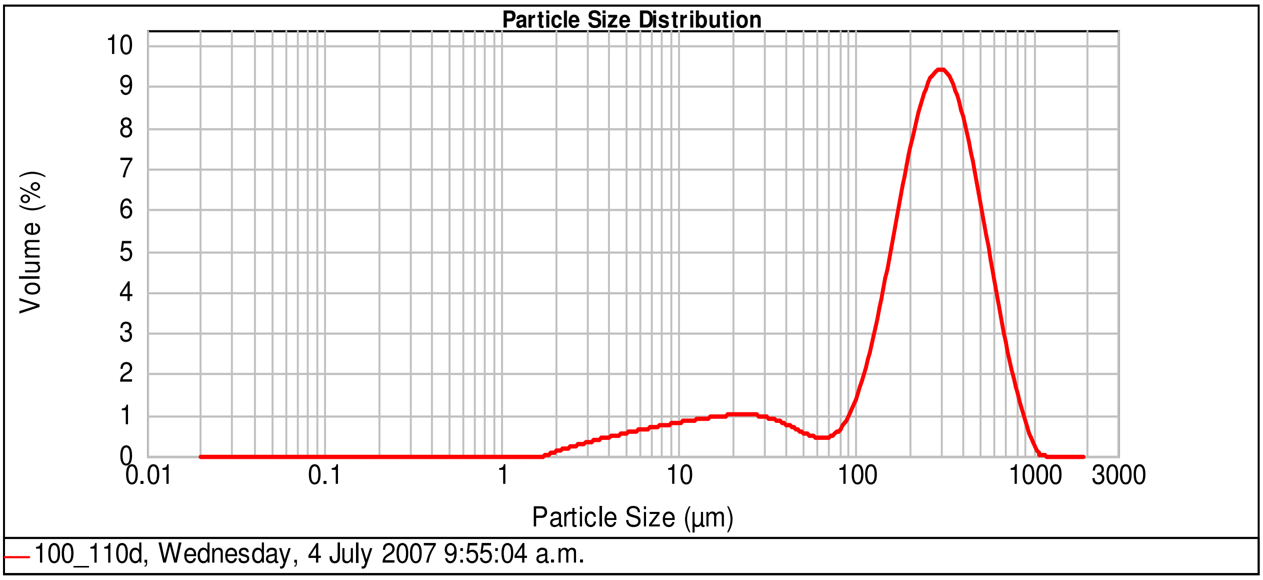
Uniformity:
0.581

Vol. Weighted Mean D[4,3]:
278.967 um

Result units:
Volume

d(0.1): 21.996 um **d(0.5):** 255.498 um **d(0.9):** 537.164 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.04
2.000	1.25
3.900	

Size (µm)	Volume In %
3.900	2.69
7.800	3.82
15.600	4.43
31.000	1.04
37.000	0.87
44.000	0.73
53.000	

Size (µm)	Volume In %
53.000	0.52
63.000	0.47
74.000	0.75
88.000	1.44
105.000	2.59
125.000	4.27
149.000	

Size (µm)	Volume In %
149.000	6.12
177.000	7.97
210.000	9.72
250.000	11.10
300.000	9.37
350.000	10.13
420.000	

Size (µm)	Volume In %
420.000	7.99
500.000	5.68
590.000	4.15
710.000	2.02
840.000	0.78
1000.000	0.07
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
90_100d

Sample Source & type:
A10

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 9:43:14 a.m.

Analysed:
Wednesday, 4 July 2007 9:43:15 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.277 %

Sensitivity:
Enhanced

Obscuration:
11.93 %

Result Emulation:
Off

Concentration:
0.0286 %Vol

Specific Surface Area:
0.294 m^2/g

Span :
3.012

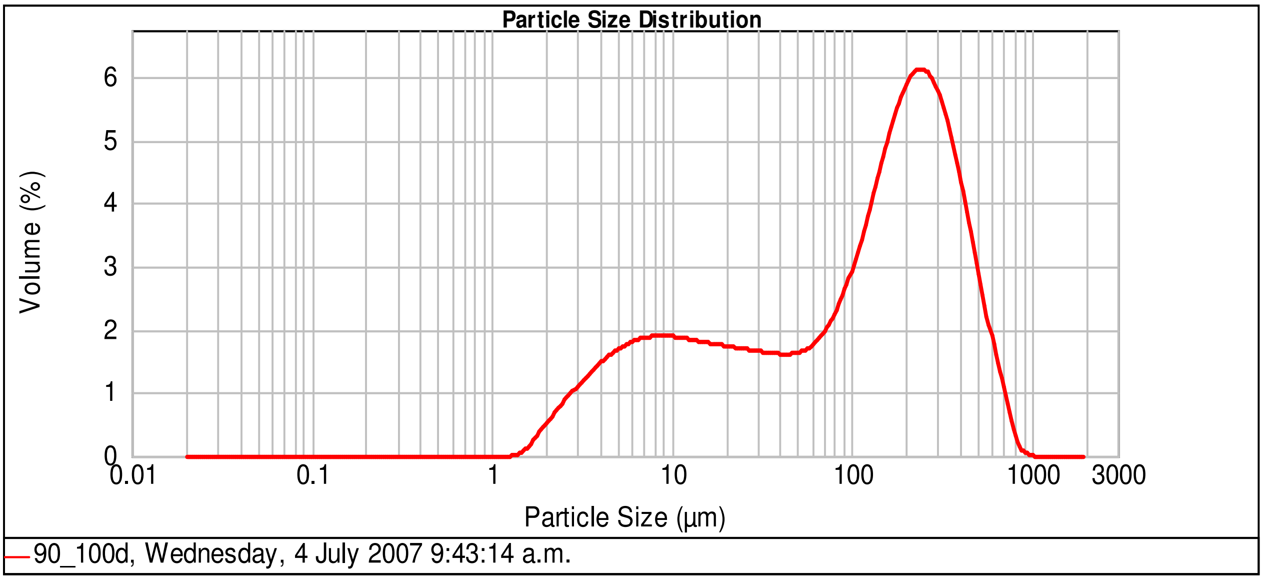
Surface Weighted Mean D[3,2]:
20.437 um

Uniformity:
0.984

Vol. Weighted Mean D[4,3]:
171.160 um

Result units:
Volume

d(0.1): 6.242 um **d(0.5): 133.283 um** **d(0.9): 407.740 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.54
2.000	4.34
3.900	

Size (μm)	Volume In %
3.900	7.84
7.800	8.46
15.600	7.73
31.000	1.90
37.000	1.83
44.000	1.98
53.000	

Size (μm)	Volume In %
53.000	1.93
63.000	2.00
74.000	2.54
88.000	3.22
105.000	4.00
125.000	4.98
149.000	

Size (μm)	Volume In %
149.000	5.79
177.000	6.46
210.000	6.95
250.000	7.17
300.000	5.57
350.000	5.61
420.000	

Size (μm)	Volume In %
420.000	4.11
500.000	2.70
590.000	1.74
710.000	0.56
840.000	0.06
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
80_90d_repeat

Sample Source & type:
A9

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 9:30:44 a.m.

Analysed:
Wednesday, 4 July 2007 9:30:45 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.381 %

Sensitivity:
Enhanced

Obscuration:
11.60 %

Result Emulation:
Off

Concentration:
0.0474 %Vol

Specific Surface Area:
0.177 m²/g

Span :
2.195

Surface Weighted Mean D[3,2]:
33.982 um

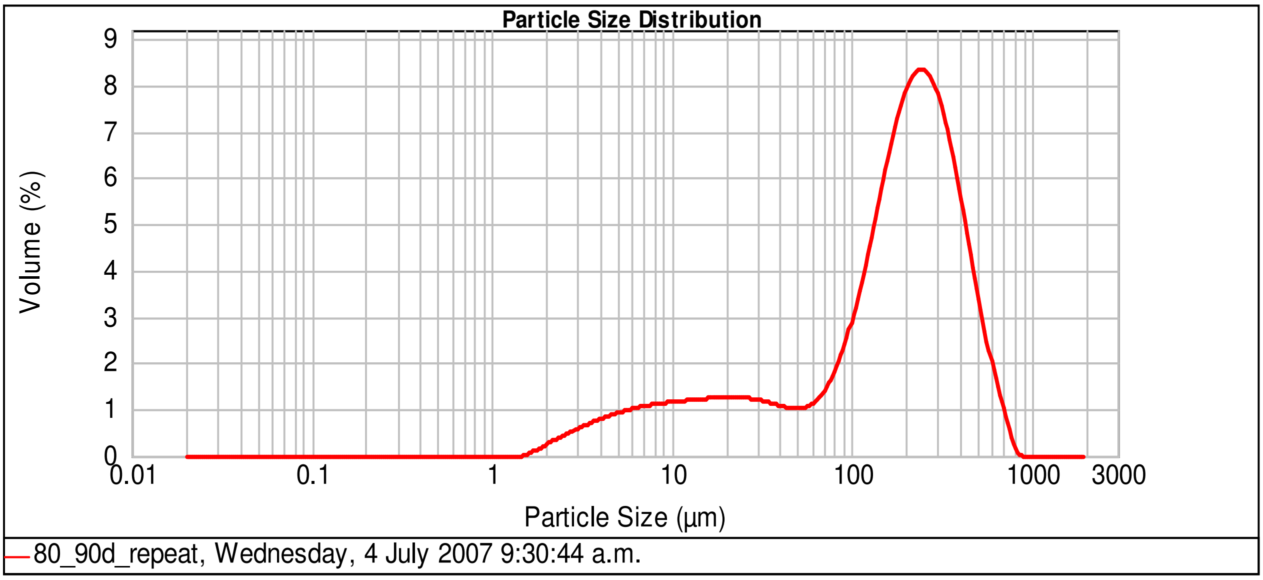
Uniformity:
0.668

Vol. Weighted Mean D[4,3]:
206.366 um

Result units:
Volume

d(0.1): 11.841 um **d(0.5):** 187.378 um **d(0.9):** 423.209 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.19
2.000	2.29
3.900	

Size (µm)	Volume In %
3.900	4.38
7.800	5.33
15.600	5.60
31.000	1.34
37.000	1.22
44.000	1.25
53.000	

Size (µm)	Volume In %
53.000	1.22
63.000	1.38
74.000	2.05
88.000	3.09
105.000	4.40
125.000	6.03
149.000	

Size (µm)	Volume In %
149.000	7.47
177.000	8.63
210.000	9.45
250.000	9.73
300.000	7.45
350.000	7.25
420.000	

Size (µm)	Volume In %
420.000	5.04
500.000	3.06
590.000	1.75
710.000	0.41
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
80_90d

Sample Source & type:
A9

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 9:18:42 a.m.

Analysed:
Wednesday, 4 July 2007 9:18:43 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
6.236 %

Sensitivity:
Enhanced

Obscuration:
18.66 %

Result Emulation:
Off

Concentration:
0.0419 %Vol

Specific Surface Area:
0.369 m²/g

Span :
22.066

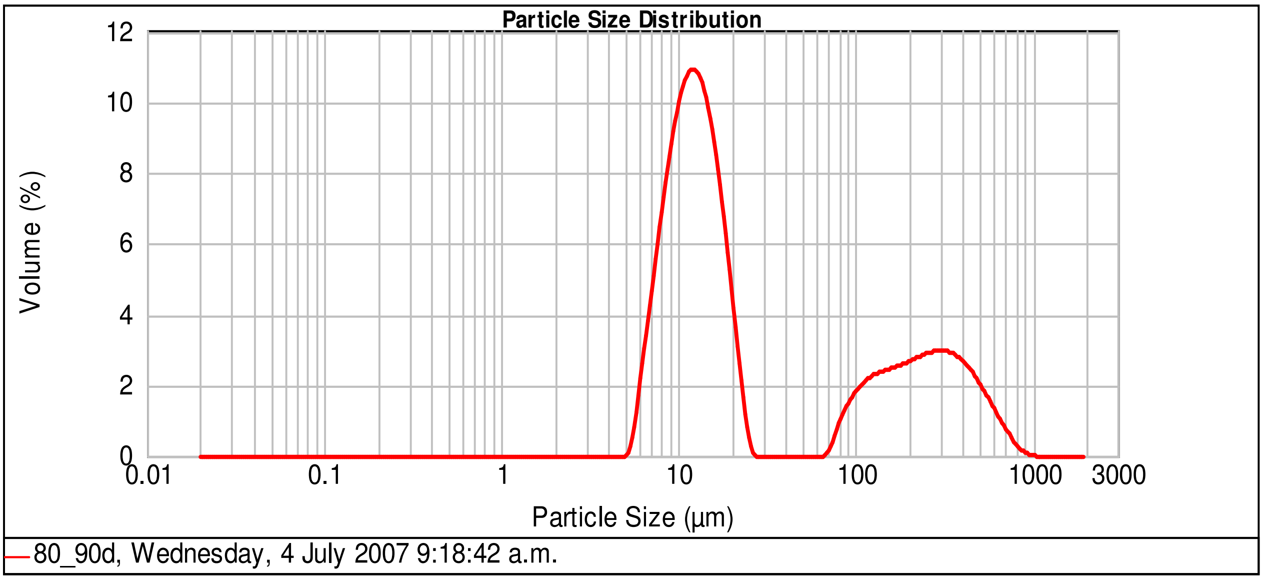
Surface Weighted Mean D[3,2]:
16.272 um

Uniformity:
6.02

Vol. Weighted Mean D[4,3]:
101.141 um

Result units:
Volume

d(0.1): 8.151 um **d(0.5): 15.054 um** **d(0.9): 340.340 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.00
3.900	

Size (µm)	Volume In %
3.900	8.02
7.800	44.15
15.600	14.45
31.000	0.00
37.000	0.00
44.000	0.00
53.000	

Size (µm)	Volume In %
53.000	0.00
63.000	0.09
74.000	1.13
88.000	2.01
105.000	2.47
125.000	2.72
149.000	

Size (µm)	Volume In %
149.000	2.81
177.000	2.96
210.000	3.22
250.000	3.52
300.000	2.98
350.000	3.28
420.000	

Size (µm)	Volume In %
420.000	2.62
500.000	1.83
590.000	1.23
710.000	0.43
840.000	0.08
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
70_80d

Sample Source & type:
A8

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 8:51:50 a.m.

Analysed:
Wednesday, 4 July 2007 8:51:51 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.612 %

Sensitivity:
Enhanced

Obscuration:
18.16 %

Result Emulation:
Off

Concentration:
0.0811 %Vol

Specific Surface Area:
0.168 m²/g

Span :
2.208

Surface Weighted Mean D[3,2]:
35.736 um

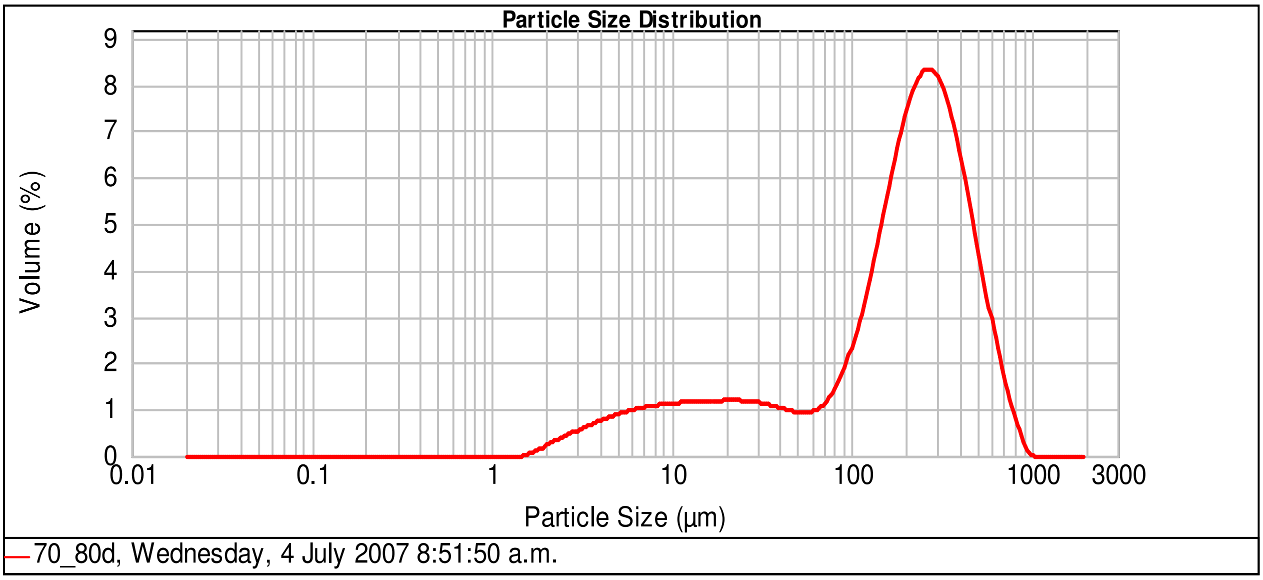
Uniformity:
0.671

Vol. Weighted Mean D[4,3]:
230.474 um

Result units:
Volume

d(0.1): 12.441 um **d(0.5):** 208.361 um **d(0.9):** 472.511 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.18
2.000	2.15
3.900	

Size (μm)	Volume In %
3.900	4.24
7.800	5.16
15.600	5.32
31.000	1.29
37.000	1.17
44.000	1.16
53.000	

Size (μm)	Volume In %
53.000	1.06
63.000	1.13
74.000	1.62
88.000	2.46
105.000	3.62
125.000	5.16
149.000	

Size (μm)	Volume In %
149.000	6.66
177.000	8.03
210.000	9.18
250.000	9.92
300.000	7.97
350.000	8.20
420.000	

Size (μm)	Volume In %
420.000	6.13
500.000	4.09
590.000	2.74
710.000	1.14
840.000	0.23
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
60_70d

Sample Source & type:
A7

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 8:40:36 a.m.

Analysed:
Wednesday, 4 July 2007 8:40:38 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.789 %

Sensitivity:
Enhanced

Obscuration:
12.84 %

Result Emulation:
Off

Concentration:
0.0676 %Vol

Specific Surface Area:
0.137 m²/g

Span :
2.140

Surface Weighted Mean D[3,2]:
43.727 um

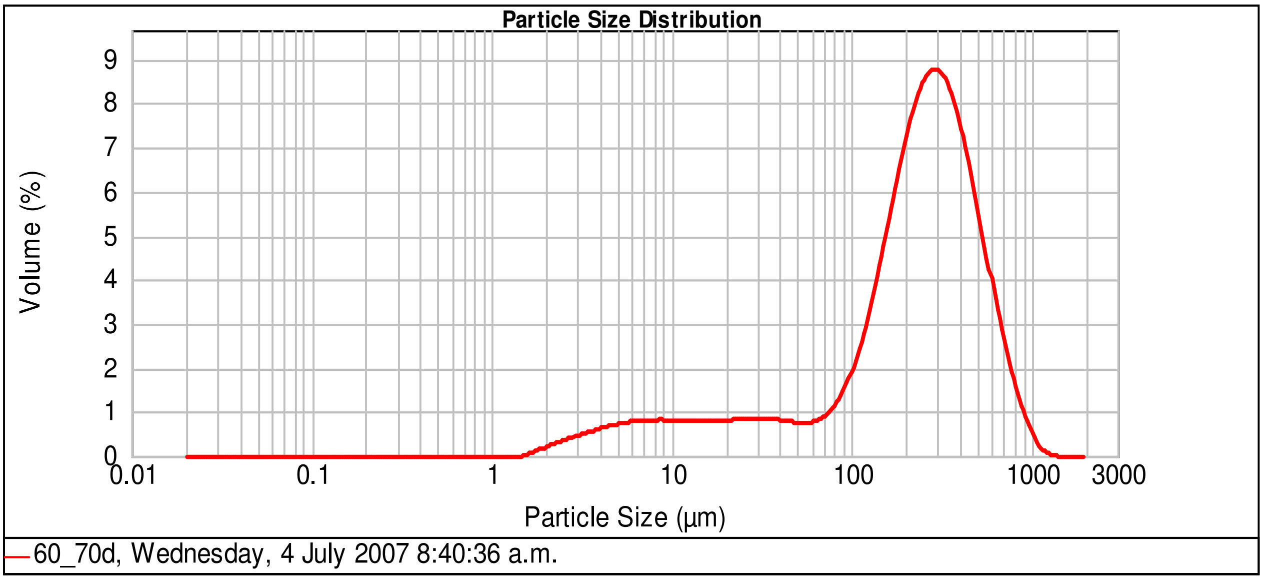
Uniformity:
0.633

Vol. Weighted Mean D[4,3]:
272.129 um

Result units:
Volume

d(0.1): 18.788 um **d(0.5):** 243.231 um **d(0.9):** 539.272 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.18
2.000	1.81
3.900	

Size (μm)	Volume In %
3.900	3.37
7.800	3.67
15.600	3.70
31.000	0.98
37.000	0.92
44.000	0.94
53.000	

Size (μm)	Volume In %
53.000	0.86
63.000	0.90
74.000	1.29
88.000	2.01
105.000	3.09
125.000	4.60
149.000	

Size (μm)	Volume In %
149.000	6.20
177.000	7.77
210.000	9.24
250.000	10.40
300.000	8.70
350.000	9.36
420.000	

Size (μm)	Volume In %
420.000	7.39
500.000	5.29
590.000	3.95
710.000	2.05
840.000	1.03
1000.000	0.32
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
50_60d

Sample Source & type:
A6

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 8:29:12 a.m.

Analysed:
Wednesday, 4 July 2007 8:29:13 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.505 %

Sensitivity:
Enhanced

Obscuration:
11.26 %

Result Emulation:
Off

Concentration:
0.0352 %Vol

Specific Surface Area:
0.227 m²/g

Span :
2.626

Surface Weighted Mean D[3,2]:
26.400 um

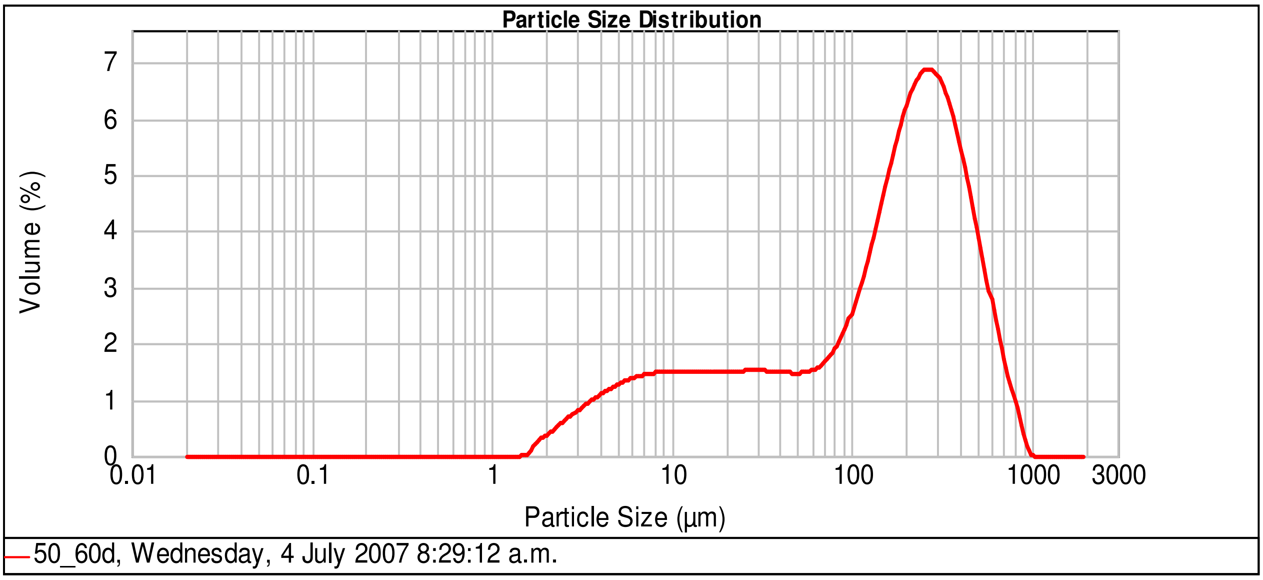
Uniformity:
0.839

Vol. Weighted Mean D[4,3]:
206.594 um

Result units:
Volume

d(0.1): 8.273 um **d(0.5):** 173.926 um **d(0.9):** 464.935 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.32
2.000	3.15
3.900	

Size (µm)	Volume In %
3.900	5.95
7.800	6.76
15.600	6.76
31.000	1.75
37.000	1.69
44.000	1.79
53.000	

Size (µm)	Volume In %
53.000	1.69
63.000	1.70
74.000	2.15
88.000	2.78
105.000	3.61
125.000	4.73
149.000	

Size (µm)	Volume In %
149.000	5.79
177.000	6.76
210.000	7.61
250.000	8.18
300.000	6.62
350.000	6.92
420.000	

Size (µm)	Volume In %
420.000	5.32
500.000	3.71
590.000	2.65
710.000	1.26
840.000	0.33
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

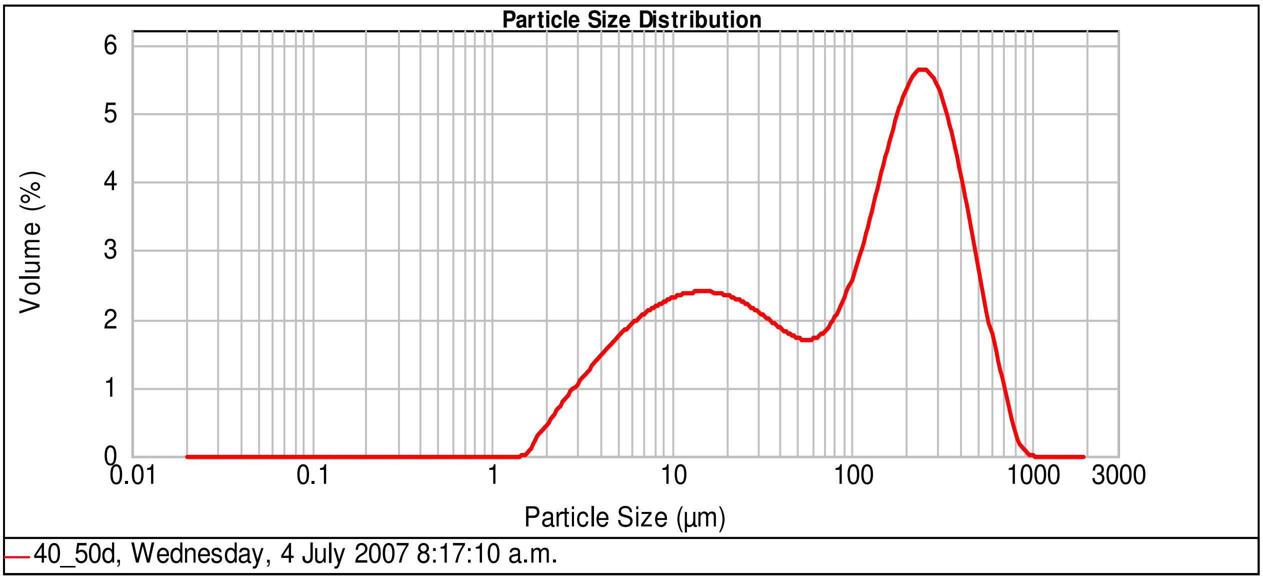
Result Analysis Report

Sample Name:	SOP Name:	Measured:
40_50d	Marine Sediment	Wednesday, 4 July 2007 8:17:10 a.m.
Sample Source & type:	**Measured by:**	**Analysed:**
A5	gmdr1	Wednesday, 4 July 2007 8:17:11 a.m.
Sample bulk lot ref:	**Result Source:**	
	Measurement	

Particle Name:	Accessory Name:	Analysis model:	Sensitivity:
Marine Sediment	None	General purpose	Enhanced
Particle RI:	**Absorption:**	**Size range:**	**Obscuration:**
1.500	0	0.020 to 2000.000 um	13.07 %
Dispersant Name:	**Dispersant RI:**	**Weighted Residual:**	**Result Emulation:**
Water	1.330	0.438 %	Off

Concentration:	Span :	Uniformity:	Result units:
0.0310 %Vol	3.532	1.17	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.304 m²/g	19.761 um	160.268 um	

d(0.1): 6.362 um **d(0.5): 111.386 um** **d(0.9): 399.732 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.37
2.000	4.12
3.900	

Size (μm)	Volume In %
3.900	8.27
7.800	10.50
15.600	10.23
31.000	2.31
37.000	2.10
44.000	2.11
53.000	

Size (μm)	Volume In %
53.000	1.91
63.000	1.86
74.000	2.27
88.000	2.83
105.000	3.52
125.000	4.42
149.000	

Size (μm)	Volume In %
149.000	5.19
177.000	5.85
210.000	6.37
250.000	6.63
300.000	5.19
350.000	5.24
420.000	

Size (μm)	Volume In %
420.000	3.86
500.000	2.54
590.000	1.65
710.000	0.56
840.000	0.09
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
30_40d

Sample Source & type:
A4

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 8:04:18 a.m.

Analysed:
Wednesday, 4 July 2007 8:04:20 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.543 %

Sensitivity:
Enhanced

Obscuration:
12.92 %

Result Emulation:
Off

Concentration:
0.0330 %Vol

Specific Surface Area:
0.284 m²/g

Span :
3.977

Surface Weighted Mean D[3,2]:
21.090 um

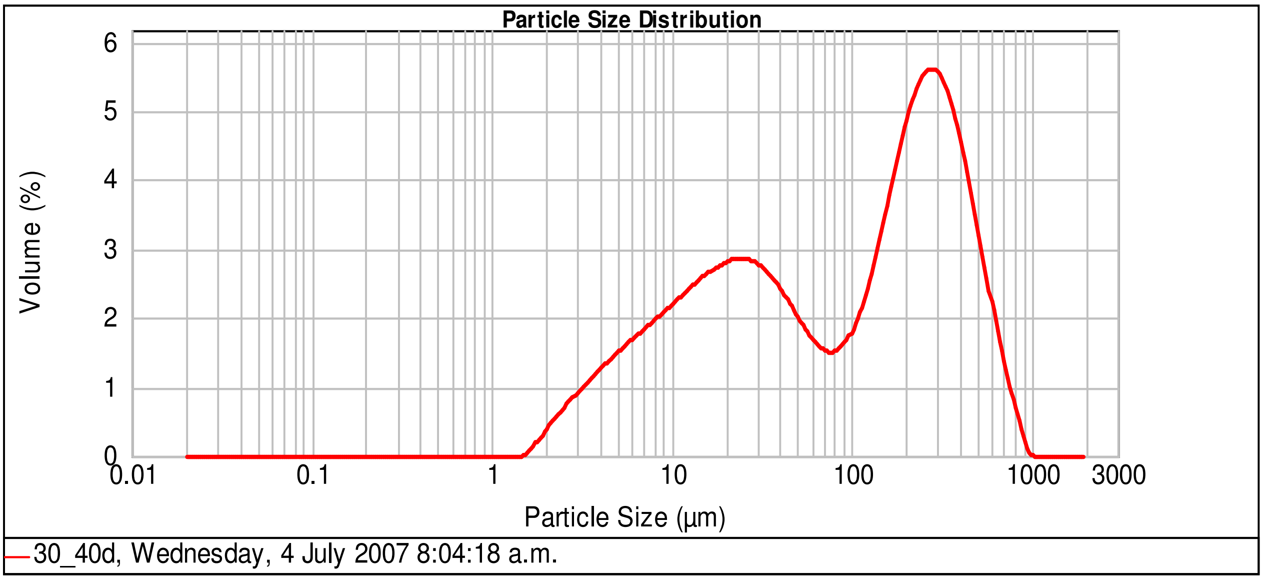
Uniformity:
1.34

Vol. Weighted Mean D[4,3]:
170.192 um

Result units:
Volume

d(0.1): 7.123 um　　**d(0.5):** 106.876 um　　**d(0.9):** 432.124 um

---



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.30
2.000	
	3.59
3.900	

Size (μm)	Volume In %
3.900	
	7.24
7.800	
	10.36
15.600	
	12.56
31.000	
	3.08
37.000	
	2.74
44.000	
	2.55
53.000	

Size (μm)	Volume In %
53.000	
	2.01
63.000	
	1.64
74.000	
	1.72
88.000	
	1.99
105.000	
	2.52
125.000	
	3.39
149.000	

Size (μm)	Volume In %
149.000	
	4.31
177.000	
	5.23
210.000	
	6.06
250.000	
	6.68
300.000	
	5.47
350.000	
	5.76
420.000	

Size (μm)	Volume In %
420.000	
	4.43
500.000	
	3.05
590.000	
	2.14
710.000	
	0.96
840.000	
	0.22
1000.000	
	0.00
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
20_30d

Sample Source & type:
A3

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 4 July 2007 7:52:23 a.m.

Analysed:
Wednesday, 4 July 2007 7:52:24 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.482 %

Sensitivity:
Enhanced

Obscuration:
13.56 %

Result Emulation:
Off

Concentration:
0.0396 %Vol

Specific Surface Area:
0.246 m²/g

Span :
2.779

Surface Weighted Mean D[3,2]:
24.372 um

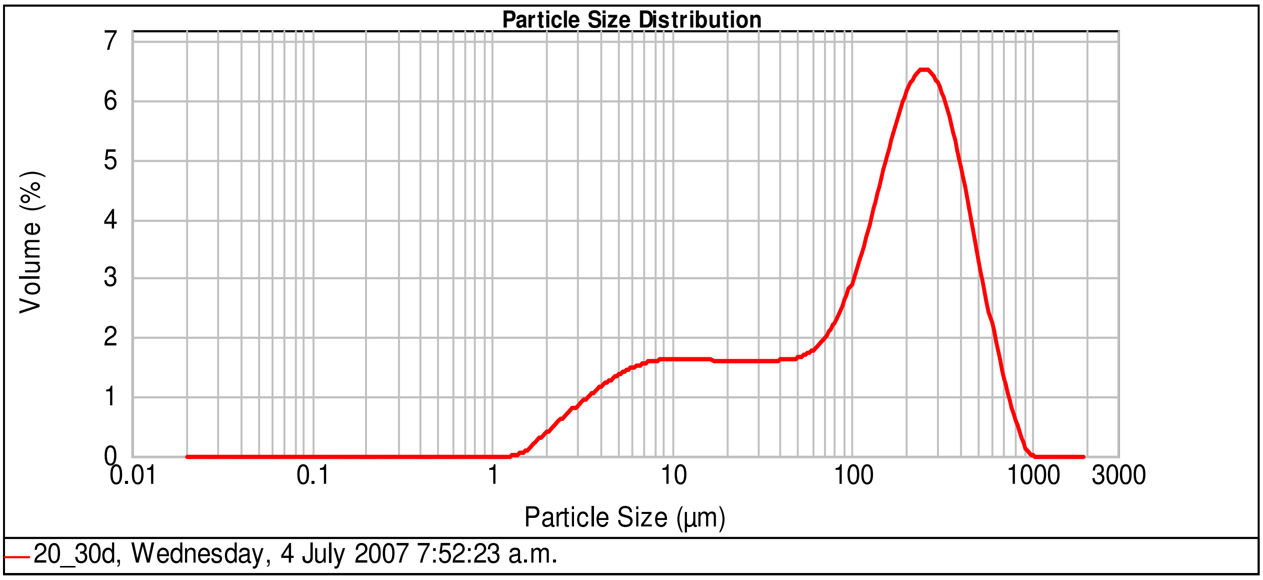
Uniformity:
0.896

Vol. Weighted Mean D[4,3]:
188.214 um

Result units:
Volume

d(0.1): 7.665 um **d(0.5):** 152.961 um **d(0.9):** 432.734 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.42
2.000	3.37
3.900	

Size (μm)	Volume In %
3.900	6.40
7.800	7.37
15.600	7.21
31.000	1.86
37.000	1.83
44.000	2.00
53.000	

Size (μm)	Volume In %
53.000	1.96
63.000	2.02
74.000	2.54
88.000	3.20
105.000	3.99
125.000	5.01
149.000	

Size (μm)	Volume In %
149.000	5.90
177.000	6.69
210.000	7.33
250.000	7.70
300.000	6.09
350.000	6.23
420.000	

Size (μm)	Volume In %
420.000	4.65
500.000	3.12
590.000	2.10
710.000	0.87
840.000	0.17
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
10_20d

SOP Name:
Marine Sediment

Measured:
Wednesday, 4 July 2007 7:40:12 a.m.

Sample Source & type:
A2

Measured by:
gmdr1

Analysed:
Wednesday, 4 July 2007 7:40:13 a.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
11.37 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.476 %

Result Emulation:
Off

Concentration:
0.0264 %Vol

Span :
3.694

Uniformity:
1.21

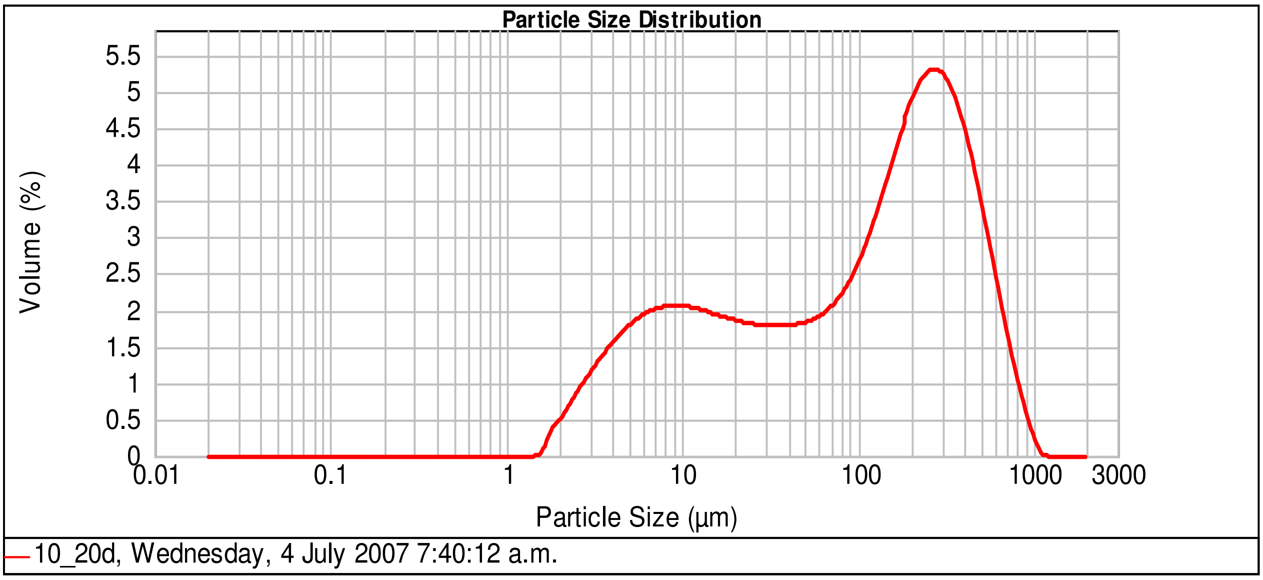
Result units:
Volume

Specific Surface Area:
0.303 m²/g

Surface Weighted Mean D[3,2]:
19.797 um

Vol. Weighted Mean D[4,3]:
182.803 um

d(0.1): 6.072 um **d(0.5):** 123.000 um **d(0.9):** 460.490 um



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.44
2.000	4.47
3.900	

Size (µm)	Volume In %
3.900	8.38
7.800	9.19
15.600	8.31
31.000	2.07
37.000	2.04
44.000	2.22
53.000	

Size (µm)	Volume In %
53.000	2.14
63.000	2.13
74.000	2.53
88.000	2.97
105.000	3.46
125.000	4.13
149.000	

Size (µm)	Volume In %
149.000	4.73
177.000	5.31
210.000	5.87
250.000	6.32
300.000	5.20
350.000	5.60
420.000	

Size (µm)	Volume In %
420.000	4.51
500.000	3.34
590.000	2.59
710.000	1.37
840.000	0.61
1000.000	0.07
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

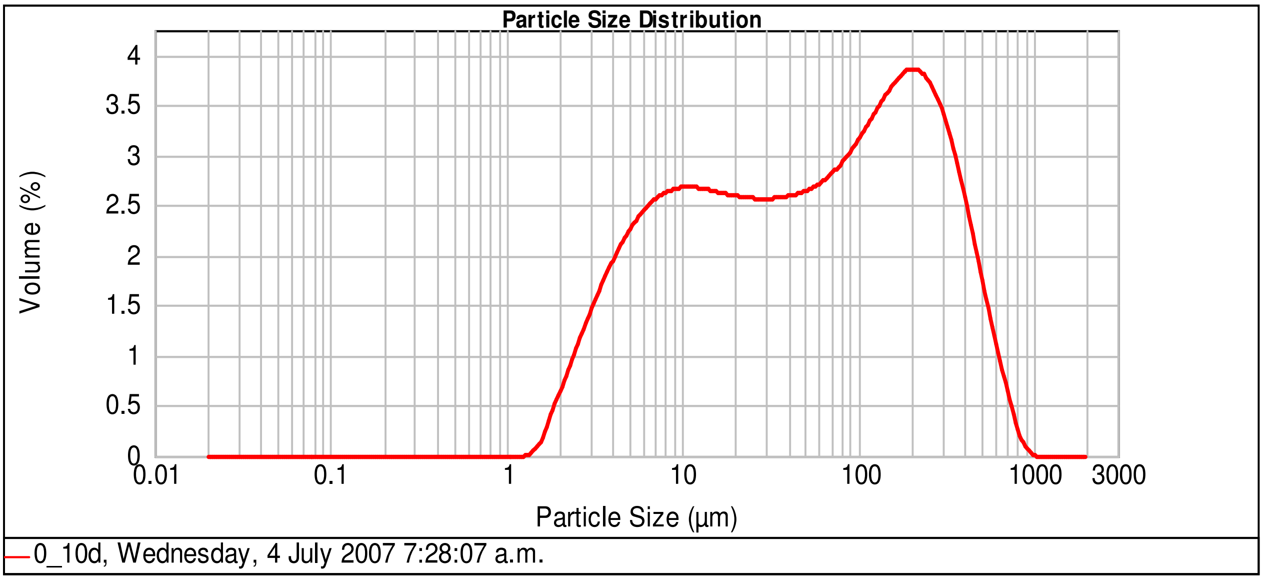
Result Analysis Report

Sample Name: 0_10d	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 4 July 2007 7:28:07 a.m.
Sample Source & type: A1	**Measured by:** gmdr1	**Analysed:** Wednesday, 4 July 2007 7:28:08 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 11.22 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.387 %	**Result Emulation:** Off

Concentration: 0.0204 %Vol	**Span :** 6.084	**Uniformity:** 1.9	**Result units:** Volume
Specific Surface Area: 0.387 m²/g	**Surface Weighted Mean D[3,2]:** 15.519 um	**Vol. Weighted Mean D[4,3]:** 120.294 um	

d(0.1): 5.128 um **d(0.5):** 54.135 um **d(0.9):** 334.507 um



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	10.57	53.000	3.05	149.000	4.21	420.000	2.46	2000.000	0.00
0.120	0.00	7.800	12.08	63.000	2.94	177.000	4.30	500.000	1.65	4000.000	
0.241	0.00	15.600	11.63	74.000	3.32	210.000	4.37	590.000	1.12		
0.490	0.00	31.000	2.98	88.000	3.59	250.000	4.34	710.000	0.42		
0.980	0.64	37.000	2.94	105.000	3.79	300.000	3.32	840.000	0.09		
2.000	5.59	44.000	3.20	125.000	4.07	350.000	3.33	1000.000	0.00		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
930_950e

Sample Source & type:
B2

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 6:02:58 p.m.

Analysed:
Wednesday, 27 June 2007 6:02:59 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.350 %

Sensitivity:
Enhanced

Obscuration:
14.17 %

Result Emulation:
Off

Concentration:
0.0482 %Vol

Specific Surface Area:
0.223 m²/g

Span :
4.224

Surface Weighted Mean D[3,2]:
26.950 um

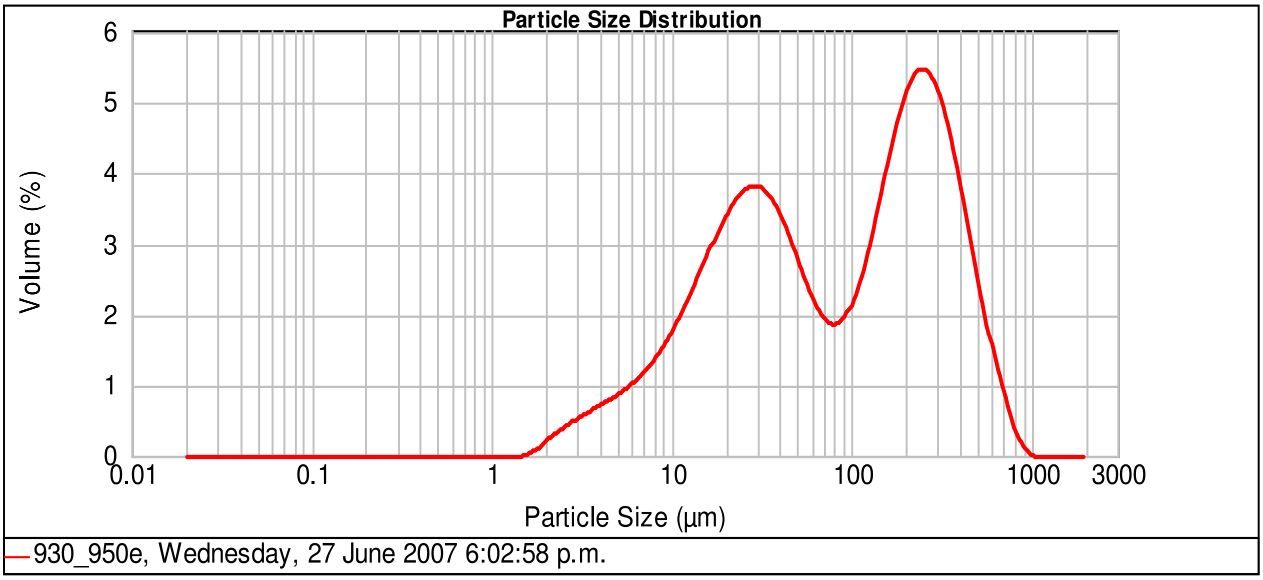
Uniformity:
1.4

Vol. Weighted Mean D[4,3]:
153.857 um

Result units:
Volume

d(0.1): 10.828 um **d(0.5):** 88.931 um **d(0.9):** 386.455 um

---



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.14
2.000	
	2.06
3.900	

Size (μm)	Volume In %
3.900	
	4.39
7.800	
	9.01
15.600	
	15.68
31.000	
	4.30
37.000	
	3.85
44.000	
	3.54
53.000	

Size (μm)	Volume In %
53.000	
	2.69
63.000	
	2.11
74.000	
	2.11
88.000	
	2.38
105.000	
	2.98
125.000	
	3.93
149.000	

Size (μm)	Volume In %
149.000	
	4.83
177.000	
	5.61
210.000	
	6.19
250.000	
	6.42
300.000	
	4.97
350.000	
	4.92
420.000	

Size (μm)	Volume In %
420.000	
	3.53
500.000	
	2.26
590.000	
	1.45
710.000	
	0.54
840.000	
	0.13
1000.000	
	0.00
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
880_900e

Sample Source & type:
A45

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 5:51:50 p.m.

Analysed:
Wednesday, 27 June 2007 5:51:52 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.444 %

Sensitivity:
Enhanced

Obscuration:
13.55 %

Result Emulation:
Off

Concentration:
0.0779 %Vol

Specific Surface Area:
0.13 m²/g

Span :
2.803

Surface Weighted Mean D[3,2]:
46.325 um

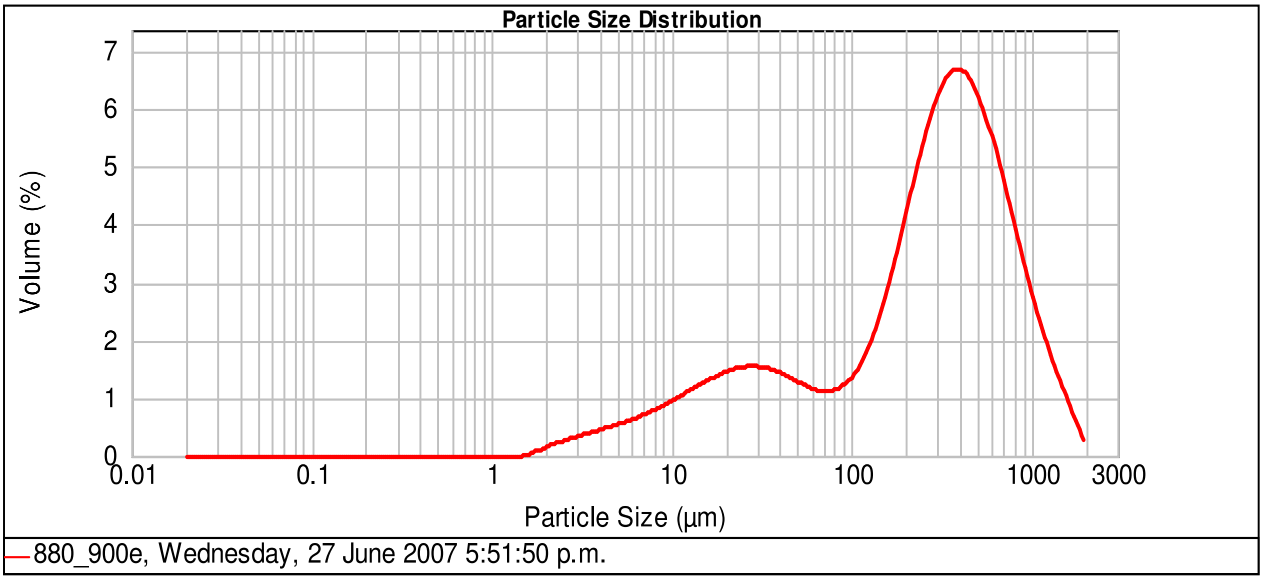
Uniformity:
0.874

Vol. Weighted Mean D[4,3]:
373.148 um

Result units:
Volume

d(0.1): 17.812 um **d(0.5):** 293.956 um **d(0.9):** 841.835 um

---



Size (μm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.12
3.900	1.34

Size (μm)	Volume In %
3.900	
7.800	2.72
15.600	4.66
31.000	6.62
37.000	1.75
44.000	1.62
53.000	1.60

Size (μm)	Volume In %
53.000	
63.000	1.35
74.000	1.18
88.000	1.29
105.000	1.51
125.000	1.91
149.000	2.60

Size (μm)	Volume In %
149.000	
177.000	3.45
210.000	4.46
250.000	5.66
300.000	6.98
350.000	6.50
420.000	7.96

Size (μm)	Volume In %
420.000	
500.000	7.42
590.000	6.45
710.000	6.21
840.000	4.58
1000.000	3.69
2000.000	6.36

Size (μm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

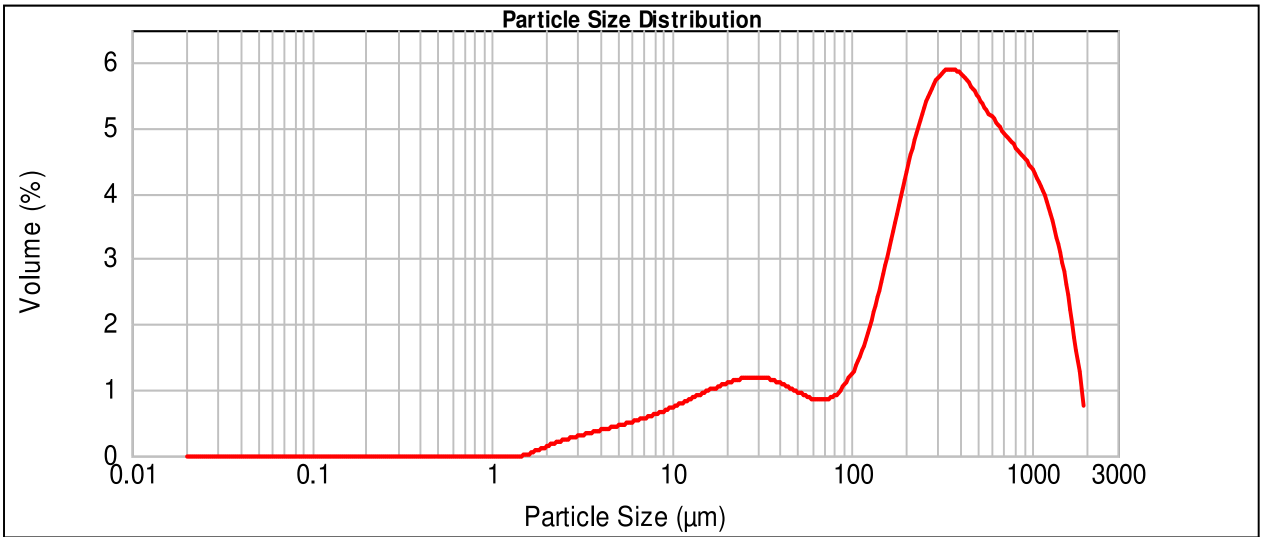
Result Analysis Report

Sample Name: 780_800e	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 27 June 2007 5:40:26 p.m.
Sample Source & type: A44	**Measured by:** gmdr1	**Analysed:** Wednesday, 27 June 2007 5:40:27 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 13.18 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 1.935 %	**Result Emulation:** Off

Concentration: 0.0903 %Vol	**Span :** 3.242	**Uniformity:** 0.948	**Result units:** Volume
Specific Surface Area: 0.108 m²/g	**Surface Weighted Mean D[3,2]:** 55.659 um	**Vol. Weighted Mean D[4,3]:** 470.393 um	

d(0.1): 23.689 um **d(0.5): 340.735 um** **d(0.9): 1128.250 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.12
2.000	1.17
3.900	

Size (μm)	Volume In %
3.900	2.21
7.800	3.55
15.600	5.04
31.000	1.36
37.000	1.25
44.000	1.21
53.000	

Size (μm)	Volume In %
53.000	1.01
63.000	0.89
74.000	1.03
88.000	1.34
105.000	1.88
125.000	2.70
149.000	

Size (μm)	Volume In %
149.000	3.61
177.000	4.59
210.000	5.61
250.000	6.60
300.000	5.89
350.000	6.98
420.000	

Size (μm)	Volume In %
420.000	6.44
500.000	5.77
590.000	6.07
710.000	5.22
840.000	5.14
1000.000	13.34
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
700_720e

Sample Source & type:
A43

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 3:07:15 p.m.

Analysed:
Wednesday, 27 June 2007 3:07:16 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.675 %

Sensitivity:
Enhanced

Obscuration:
15.87 %

Result Emulation:
Off

Concentration:
0.1415 %Vol

Specific Surface Area:
0.0839 m²/g

Span :
2.447

Surface Weighted Mean D[3,2]:
71.493 um

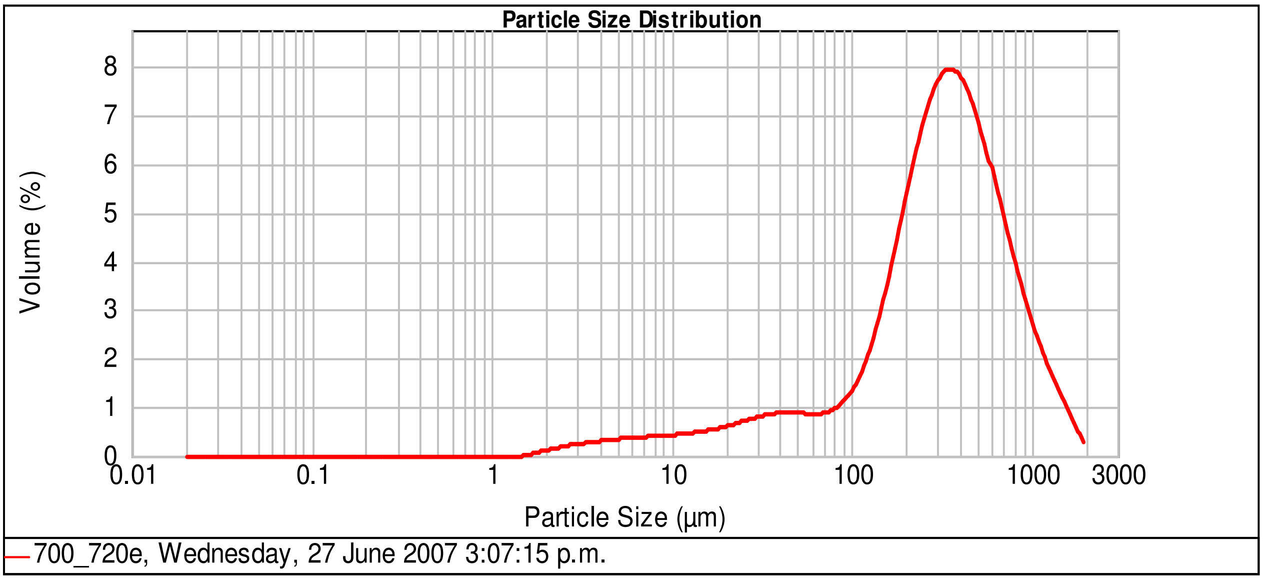
Uniformity:
0.733

Vol. Weighted Mean D[4,3]:
402.211 um

Result units:
Volume

d(0.1): 46.804 um **d(0.5):** 323.372 um **d(0.9):** 838.216 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.10
2.000	0.95
3.900	

Size (μm)	Volume In %
3.900	1.62
7.800	2.03
15.600	2.96
31.000	0.98
37.000	1.00
44.000	1.08
53.000	

Size (μm)	Volume In %
53.000	0.98
63.000	0.92
74.000	1.10
88.000	1.45
105.000	2.06
125.000	3.06
149.000	

Size (μm)	Volume In %
149.000	4.28
177.000	5.67
210.000	7.20
250.000	8.74
300.000	7.93
350.000	9.40
420.000	

Size (μm)	Volume In %
420.000	8.40
500.000	7.02
590.000	6.50
710.000	4.63
840.000	3.66
1000.000	6.29
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
680_700e

Sample Source & type:
A42

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 2:54:24 p.m.

Analysed:
Wednesday, 27 June 2007 2:54:25 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.644 %

Sensitivity:
Enhanced

Obscuration:
13.97 %

Result Emulation:
Off

Concentration:
0.0979 %Vol

Specific Surface Area:
0.105 m²/g

Span :
2.835

Surface Weighted Mean D[3,2]:
57.327 um

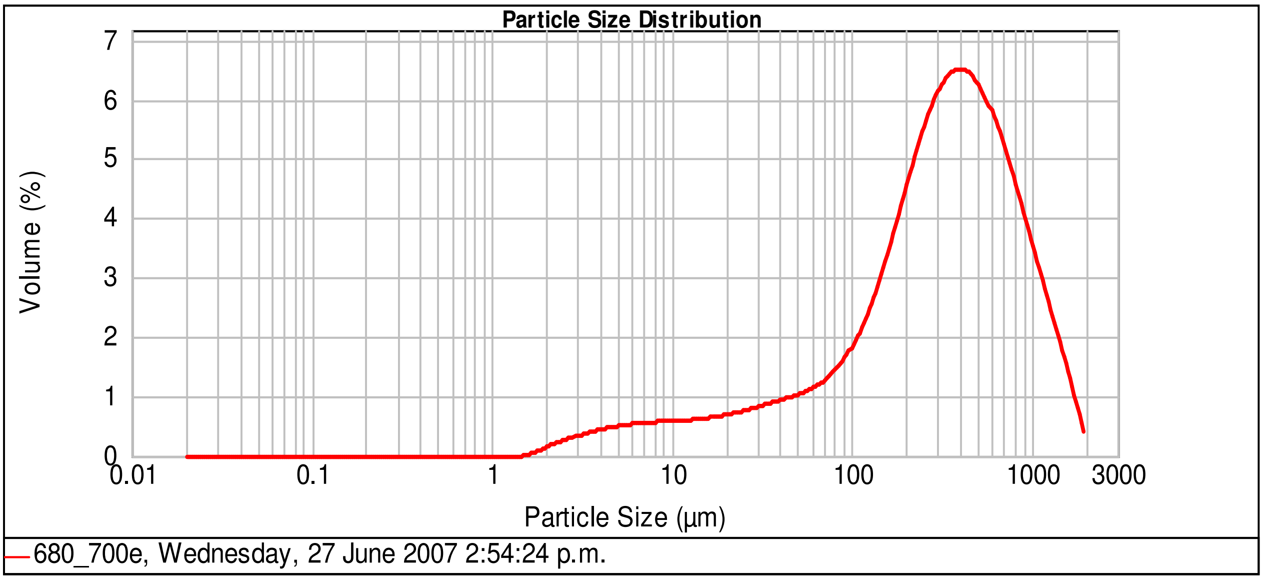
Uniformity:
0.853

Vol. Weighted Mean D[4,3]:
425.495 um

Result units:
Volume

d(0.1): 32.625 um **d(0.5):** 326.128 um **d(0.9):** 957.298 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.11
2.000	1.31
3.900	

Size (µm)	Volume In %
3.900	2.34
7.800	2.70
15.600	3.25
31.000	1.01
37.000	1.07
44.000	1.24
53.000	

Size (µm)	Volume In %
53.000	1.25
63.000	1.30
74.000	1.61
88.000	2.01
105.000	2.51
125.000	3.23
149.000	

Size (µm)	Volume In %
149.000	4.00
177.000	4.86
210.000	5.86
250.000	6.95
300.000	6.34
350.000	7.74
420.000	

Size (µm)	Volume In %
420.000	7.32
500.000	6.58
590.000	6.67
710.000	5.25
840.000	4.54
1000.000	8.95
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
600_620e

Sample Source & type:
A41

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 2:42:44 p.m.

Analysed:
Wednesday, 27 June 2007 2:42:45 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.346 %

Sensitivity:
Enhanced

Obscuration:
12.55 %

Result Emulation:
Off

Concentration:
0.0383 %Vol

Specific Surface Area:
0.242 m²/g

Span :
4.692

Surface Weighted Mean D[3,2]:
24.747 um

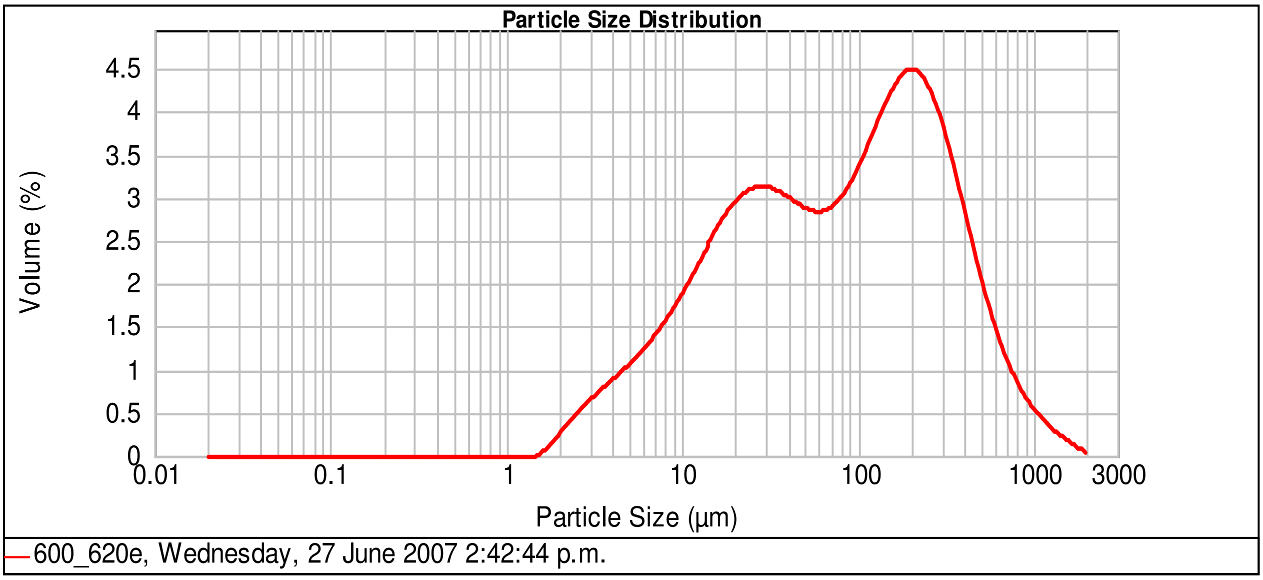
Uniformity:
1.58

Vol. Weighted Mean D[4,3]:
161.905 um

Result units:
Volume

d(0.1): 9.314 um **d(0.5):** 83.759 um **d(0.9):** 402.285 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.20
2.000	2.54
3.900	

Size (μm)	Volume In %
3.900	5.33
7.800	9.38
15.600	13.38
31.000	3.58
37.000	3.40
44.000	3.53
53.000	

Size (μm)	Volume In %
53.000	3.21
63.000	3.03
74.000	3.42
88.000	3.80
105.000	4.16
125.000	4.62
149.000	

Size (μm)	Volume In %
149.000	4.88
177.000	5.01
210.000	5.05
250.000	4.93
300.000	3.69
350.000	3.65
420.000	

Size (μm)	Volume In %
420.000	2.74
500.000	1.96
590.000	1.59
710.000	1.02
840.000	0.75
1000.000	1.16
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
580_600e

Sample Source & type:
A40

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 2:29:51 p.m.

Analysed:
Wednesday, 27 June 2007 2:29:52 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.295 %

Sensitivity:
Enhanced

Obscuration:
14.51 %

Result Emulation:
Off

Concentration:
0.0326 %Vol

Specific Surface Area:
0.328 m²/g

Span :
4.279

Surface Weighted Mean D[3,2]:
18.319 um

Uniformity:
1.4

Vol. Weighted Mean D[4,3]:
87.866 um

Result units:
Volume

d(0.1): 6.718 um **d(0.5):** 48.932 um **d(0.9):** 216.102 um

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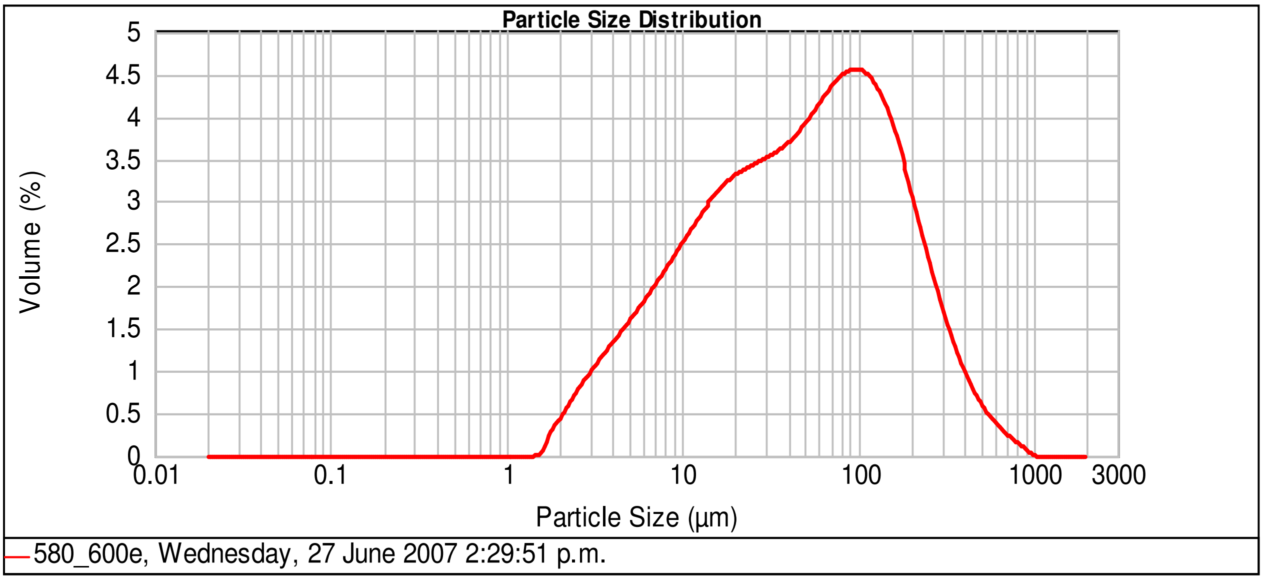


Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.37
2.000	3.85
3.900	

Size (μm)	Volume In %
3.900	7.80
7.800	12.00
15.600	15.00
31.000	4.13
37.000	4.19
44.000	4.72
53.000	

Size (μm)	Volume In %
53.000	4.63
63.000	4.54
74.000	5.08
88.000	5.26
105.000	5.10
125.000	4.84
149.000	

Size (μm)	Volume In %
149.000	4.28
177.000	3.66
210.000	3.06
250.000	2.48
300.000	1.57
350.000	1.34
420.000	

Size (μm)	Volume In %
420.000	0.87
500.000	0.55
590.000	0.39
710.000	0.20
840.000	0.07
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

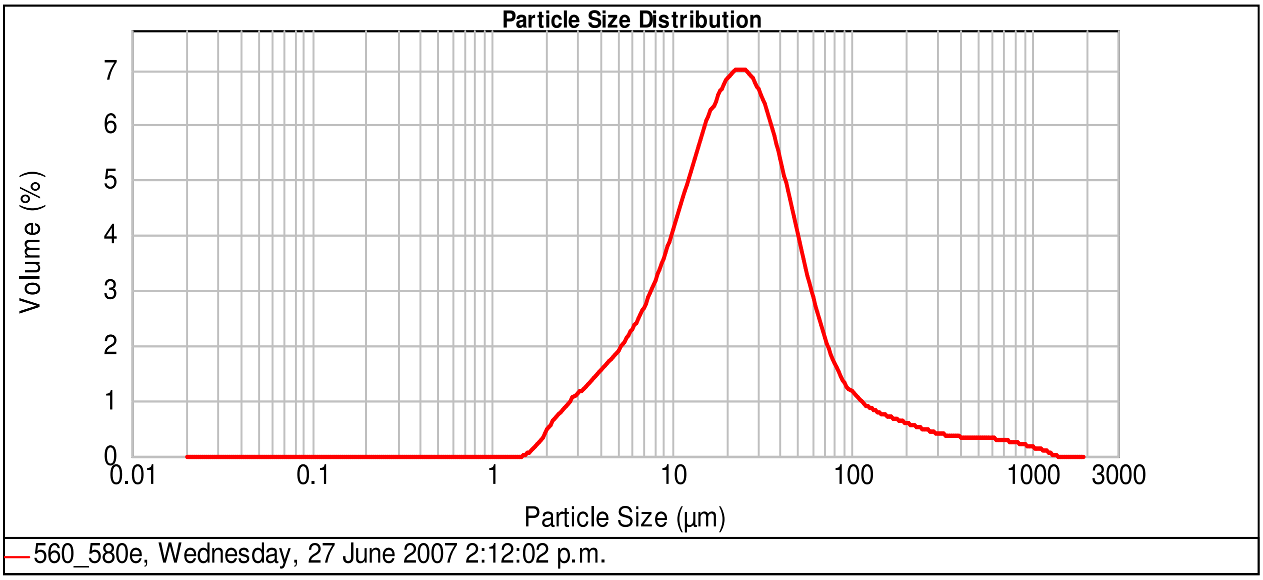
Result Analysis Report

Sample Name: 560_580e	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 27 June 2007 2:12:02 p.m.
Sample Source & type: A39	**Measured by:** gmdr1	**Analysed:** Wednesday, 27 June 2007 2:12:03 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 11.56 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.515 %	**Result Emulation:** Off

Concentration: 0.0196 %Vol	**Span :** 3.209	**Uniformity:** 1.58	**Result units:** Volume
Specific Surface Area: 0.435 m²/g	**Surface Weighted Mean D[3,2]:** 13.808 um	**Vol. Weighted Mean D[4,3]:** 47.084 um	

d(0.1): 6.037 um **d(0.5): 22.259 um** **d(0.9): 77.468 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.31
2.000	4.37
3.900	

Size (µm)	Volume In %
3.900	9.74
7.800	20.25
15.600	30.27
31.000	7.19
37.000	6.04
44.000	5.19
53.000	

Size (µm)	Volume In %
53.000	3.61
63.000	2.46
74.000	1.92
88.000	1.42
105.000	1.09
125.000	0.92
149.000	

Size (µm)	Volume In %
149.000	0.79
177.000	0.69
210.000	0.61
250.000	0.54
300.000	0.39
350.000	0.42
420.000	

Size (µm)	Volume In %
420.000	0.38
500.000	0.35
590.000	0.36
710.000	0.28
840.000	0.23
1000.000	0.18
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
540_560e

Sample Source & type:
A38

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 2:00:28 p.m.

Analysed:
Wednesday, 27 June 2007 2:00:29 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.382 %

Sensitivity:
Enhanced

Obscuration:
18.18 %

Result Emulation:
Off

Concentration:
0.0382 %Vol

Specific Surface Area:
0.364 m²/g

Span :
3.823

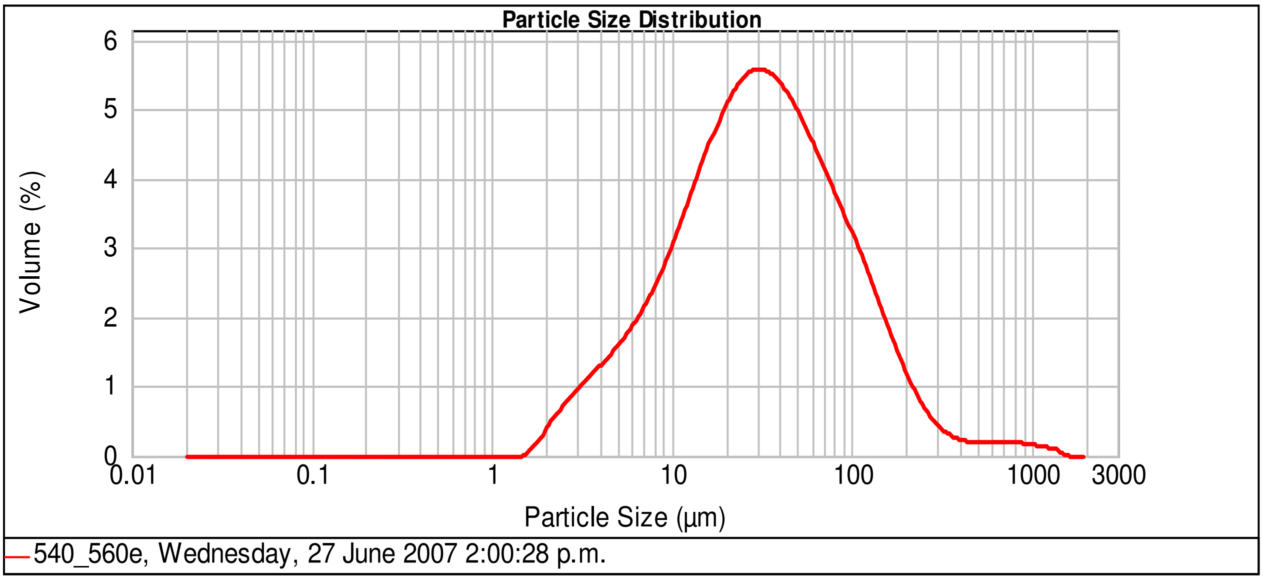
Surface Weighted Mean D[3,2]:
16.488 um

Uniformity:
1.44

Vol. Weighted Mean D[4,3]:
59.547 um

Result units:
Volume

d(0.1): 6.805 um **d(0.5): 30.773 um** **d(0.9): 124.450 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.27
2.000	3.73
3.900	

Size (µm)	Volume In %
3.900	7.98
7.800	15.06
15.600	23.23
31.000	6.42
37.000	6.08
44.000	6.15
53.000	

Size (µm)	Volume In %
53.000	5.27
63.000	4.47
74.000	4.33
88.000	3.86
105.000	3.23
125.000	2.65
149.000	

Size (µm)	Volume In %
149.000	2.01
177.000	1.46
210.000	1.02
250.000	0.68
300.000	0.37
350.000	0.31
420.000	

Size (µm)	Volume In %
420.000	0.24
500.000	0.21
590.000	0.24
710.000	0.22
840.000	0.20
1000.000	0.31
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
520_540e

Sample Source & type:
A37

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 1:47:40 p.m.

Analysed:
Wednesday, 27 June 2007 1:47:41 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.374 %

Sensitivity:
Enhanced

Obscuration:
11.68 %

Result Emulation:
Off

Concentration:
0.0248 %Vol

Specific Surface Area:
0.345 m²/g

Span :
3.364

Surface Weighted Mean D[3,2]:
17.372 um

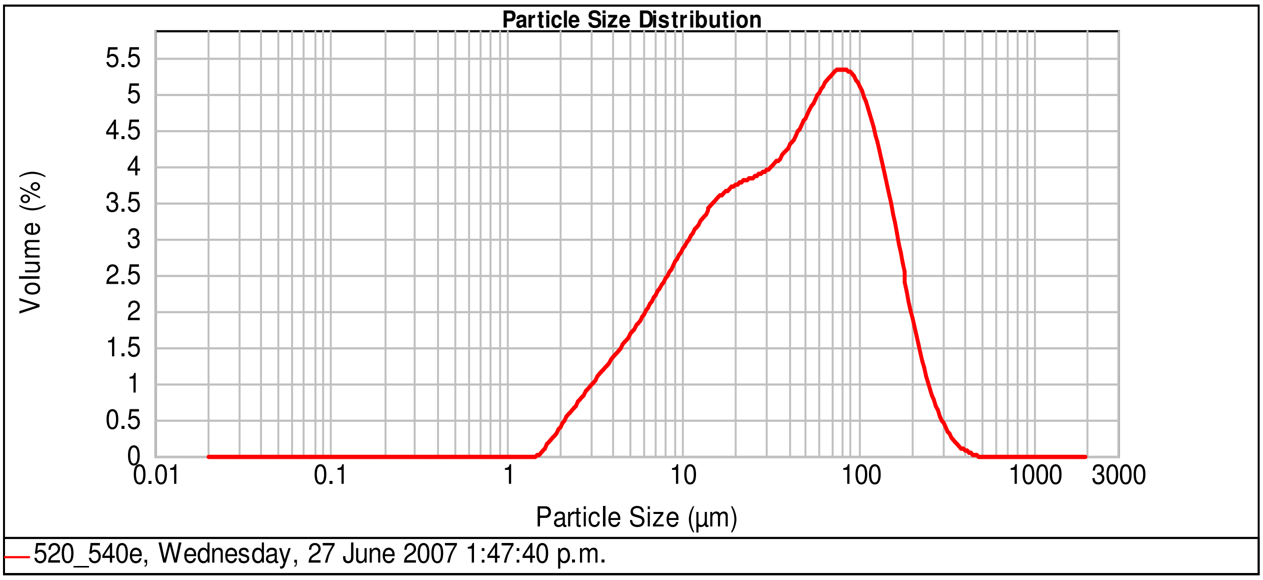
Uniformity:
1.08

Vol. Weighted Mean D[4,3]:
60.699 um

Result units:
Volume

d(0.1): 6.666 um **d(0.5):** 40.578 um **d(0.9):** 143.183 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.30
2.000	3.75
3.900	

Size (µm)	Volume In %
3.900	8.27
7.800	13.60
15.600	16.88
31.000	4.66
37.000	4.82
44.000	5.57
53.000	

Size (µm)	Volume In %
53.000	5.58
63.000	5.48
74.000	6.04
88.000	5.99
105.000	5.40
125.000	4.61
149.000	

Size (µm)	Volume In %
149.000	3.52
177.000	2.48
210.000	1.60
250.000	0.90
300.000	0.35
350.000	0.15
420.000	

Size (µm)	Volume In %
420.000	0.02
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

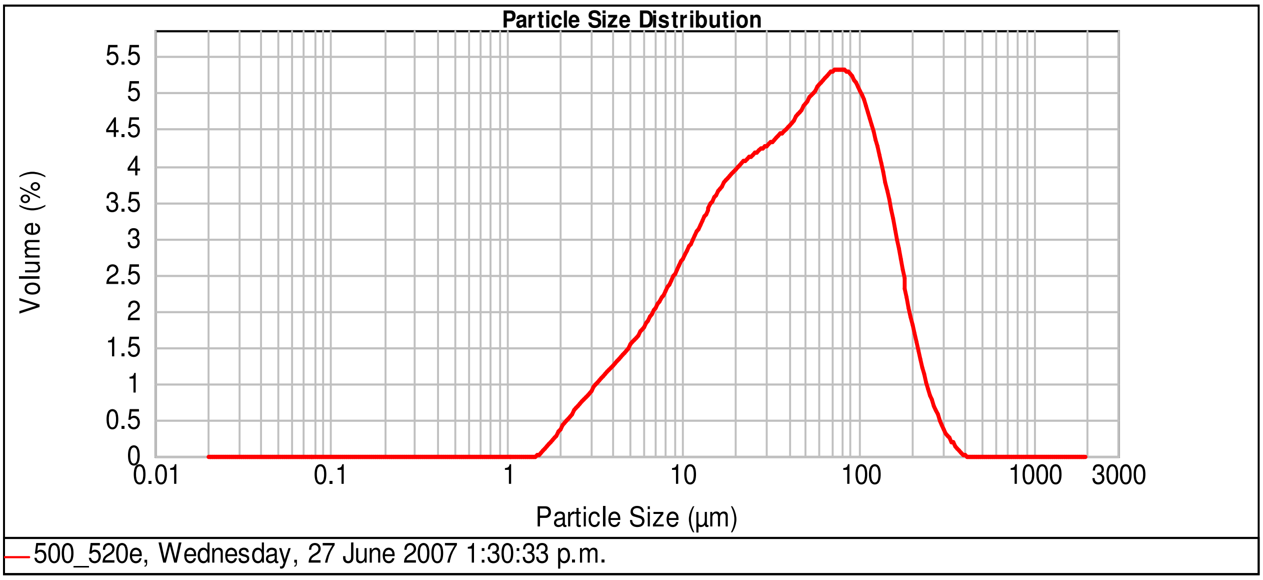
Result Analysis Report

Sample Name: 500_520e	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 27 June 2007 1:30:33 p.m.
Sample Source & type: A36	**Measured by:** gmdr1	**Analysed:** Wednesday, 27 June 2007 1:30:34 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 15.38 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.362 %	**Result Emulation:** Off

Concentration: 0.0348 %Vol	**Span :** 3.293	**Uniformity:** 1.04	**Result units:** Volume
Specific Surface Area: 0.332 m²/g	**Surface Weighted Mean D[3,2]:** 18.065 um	**Vol. Weighted Mean D[4,3]:** 59.669 um	

d(0.1): 7.121 um **d(0.5): 40.326 um** **d(0.9): 139.916 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.27
2.000	3.45
3.900	

Size (μm)	Volume In %
3.900	7.56
7.800	13.22
15.600	17.93
31.000	5.05
37.000	5.14
44.000	5.82
53.000	

Size (μm)	Volume In %
53.000	5.71
63.000	5.53
74.000	6.02
88.000	5.94
105.000	5.33
125.000	4.53
149.000	

Size (μm)	Volume In %
149.000	3.43
177.000	2.38
210.000	1.50
250.000	0.81
300.000	0.28
350.000	0.07
420.000	

Size (μm)	Volume In %
420.000	0.00
500.000	0.00
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
480_500

Sample Source & type:
A35

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 1:12:09 p.m.

Analysed:
Wednesday, 27 June 2007 1:12:10 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
2.091 %

Sensitivity:
Enhanced

Obscuration:
17.65 %

Result Emulation:
Off

Concentration:
0.0373 %Vol

Specific Surface Area:
0.355 m²/g

Span :
3.731

Surface Weighted Mean D[3,2]:
16.898 um

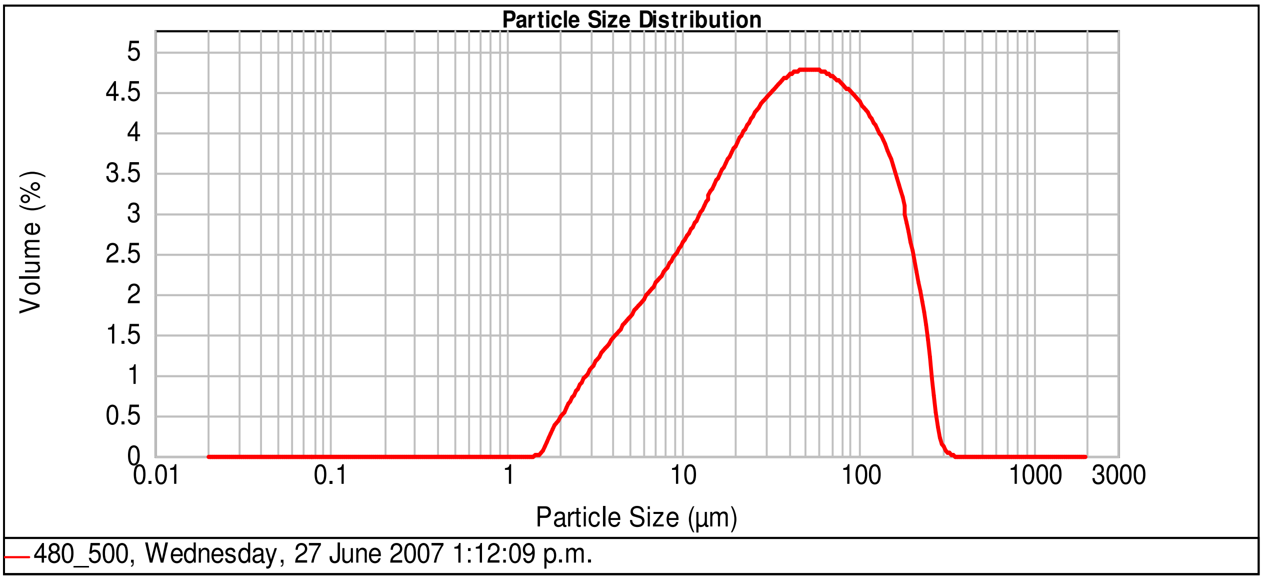
Uniformity:
1.12

Vol. Weighted Mean D[4,3]:
60.362 um

Result units:
Volume

d(0.1): 6.359 um **d(0.5):** 38.759 um **d(0.9):** 150.977 um

---



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.38
2.000	
	4.16
3.900	

Size (µm)	Volume In %
3.900	
	8.32
7.800	
	12.70
15.600	
	17.76
31.000	
	5.27
37.000	
	5.32
44.000	
	5.81
53.000	

Size (µm)	Volume In %
53.000	
	5.39
63.000	
	4.95
74.000	
	5.21
88.000	
	5.12
105.000	
	4.80
125.000	
	4.49
149.000	

Size (µm)	Volume In %
149.000	
	3.92
177.000	
	3.19
210.000	
	2.30
250.000	
	0.86
300.000	
	0.06
350.000	
	0.00
420.000	

Size (µm)	Volume In %
420.000	
	0.00
500.000	
	0.00
590.000	
	0.00
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
460_480e

Sample Source & type:
A34

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 12:53:37 p.m.

Analysed:
Wednesday, 27 June 2007 12:53:39 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.798 %

Sensitivity:
Enhanced

Obscuration:
15.15 %

Result Emulation:
Off

Concentration:
0.0392 %Vol

Specific Surface Area:
0.286 m²/g

Span :
2.907

Surface Weighted Mean D[3,2]:
20.987 um

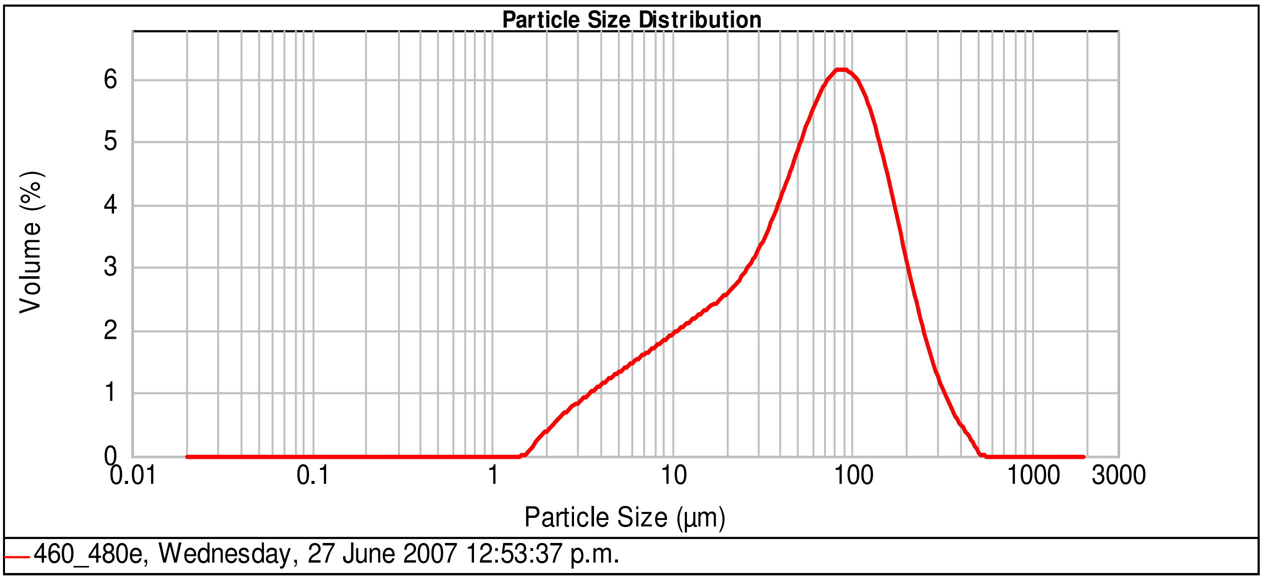
Uniformity:
0.925

Vol. Weighted Mean D[4,3]:
80.396 um

Result units:
Volume

d(0.1): 7.769 um **d(0.5):** 59.556 um **d(0.9):** 180.925 um

---



Size (µm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.35
3.900	3.33

Size (µm)	Volume In %
3.900	
7.800	6.36
15.600	9.10
31.000	12.33
37.000	4.13
44.000	4.65
53.000	5.74

Size (µm)	Volume In %
53.000	
63.000	6.03
74.000	6.12
88.000	6.91
105.000	7.06
125.000	6.60
149.000	5.91

Size (µm)	Volume In %
149.000	
177.000	4.83
210.000	3.73
250.000	2.76
300.000	1.93
350.000	1.05
420.000	0.73

Size (µm)	Volume In %
420.000	
500.000	0.33
590.000	0.01
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	0.00

Size (µm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
440_460e

Sample Source & type:
A33

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 12:29:57 p.m.

Analysed:
Wednesday, 27 June 2007 12:29:58 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.180 %

Sensitivity:
Enhanced

Obscuration:
14.04 %

Result Emulation:
Off

Concentration:
0.0302 %Vol

Specific Surface Area:
0.336 m²/g

Span :
2.854

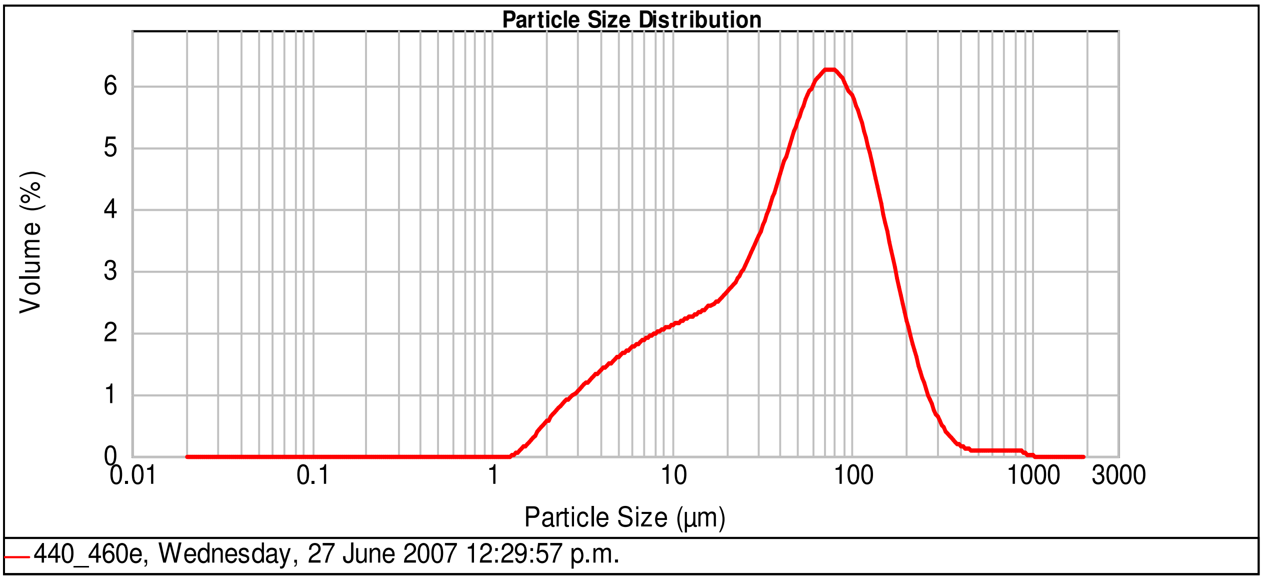
Surface Weighted Mean D[3,2]:
17.854 um

Uniformity:
0.94

Vol. Weighted Mean D[4,3]:
69.528 um

Result units:
Volume

d(0.1): 6.392 um **d(0.5):** 51.173 um **d(0.9):** 152.438 um



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.66
2.000	
	4.20
3.900	

Size (μm)	Volume In %
3.900	
	7.60
7.800	
	9.82
15.600	
	12.84
31.000	
	4.55
37.000	
	5.20
44.000	
	6.42
53.000	

Size (μm)	Volume In %
53.000	
	6.62
63.000	
	6.52
74.000	
	7.07
88.000	
	6.85
105.000	
	6.04
125.000	
	5.06
149.000	

Size (μm)	Volume In %
149.000	
	3.83
177.000	
	2.71
210.000	
	1.80
250.000	
	1.07
300.000	
	0.47
350.000	
	0.26
420.000	

Size (μm)	Volume In %
420.000	
	0.11
500.000	
	0.08
590.000	
	0.10
710.000	
	0.10
840.000	
	0.05
1000.000	
	0.00
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
420_440e

Sample Source & type:
A32

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 12:15:29 p.m.

Analysed:
Wednesday, 27 June 2007 12:15:31 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.232 %

Sensitivity:
Enhanced

Obscuration:
17.44 %

Result Emulation:
Off

Concentration:
0.0450 %Vol

Specific Surface Area:
0.289 m²/g

Span :
2.882

Surface Weighted Mean D[3,2]:
20.778 um

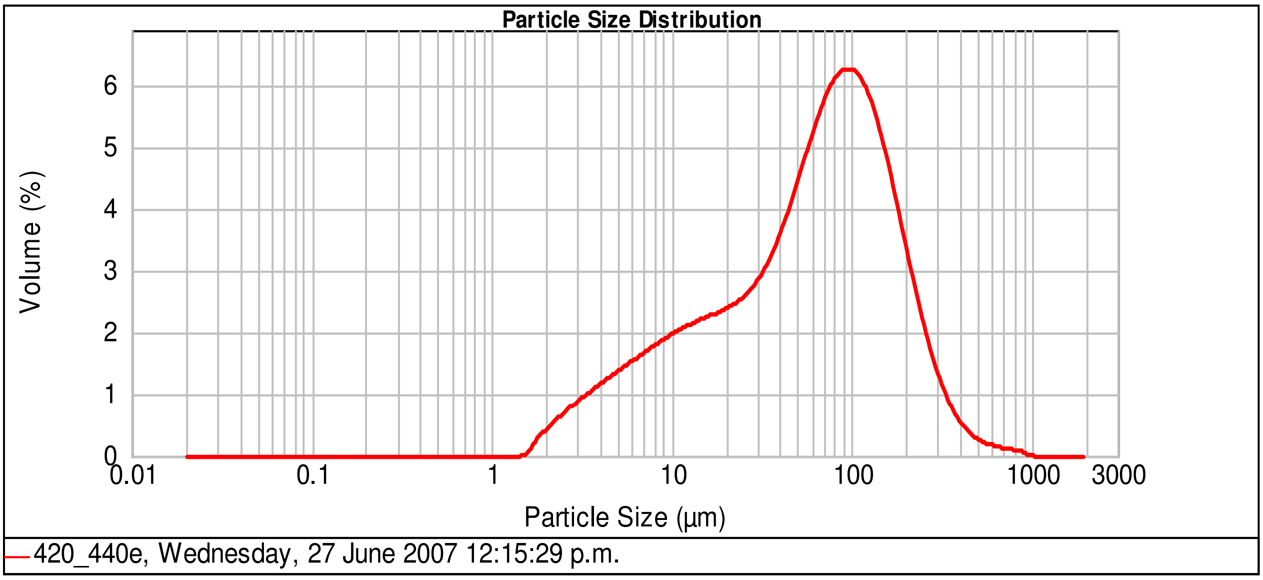
Uniformity:
0.951

Vol. Weighted Mean D[4,3]:
86.892 um

Result units:
Volume

d(0.1): 7.478 um **d(0.5):** 63.816 um **d(0.9):** 191.403 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.38
2.000	3.49
3.900	

Size (µm)	Volume In %
3.900	6.62
7.800	9.20
15.600	11.23
31.000	3.62
37.000	4.12
44.000	5.23
53.000	

Size (µm)	Volume In %
53.000	5.68
63.000	5.95
74.000	6.91
88.000	7.24
105.000	6.91
125.000	6.28
149.000	

Size (µm)	Volume In %
149.000	5.18
177.000	4.03
210.000	2.98
250.000	2.07
300.000	1.10
350.000	0.78
420.000	

Size (µm)	Volume In %
420.000	0.43
500.000	0.25
590.000	0.18
710.000	0.12
840.000	0.05
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

Result Analysis Report

Sample Name:
400_420e

Sample Source & type:
A31

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 12:01:09 p.m.

Analysed:
Wednesday, 27 June 2007 12:01:10 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.252 %

Sensitivity:
Enhanced

Obscuration:
18.36 %

Result Emulation:
Off

Concentration:
0.0435 %Vol

Specific Surface Area:
0.317 m²/g

Span :
3.132

Surface Weighted Mean D[3,2]:
18.917 um

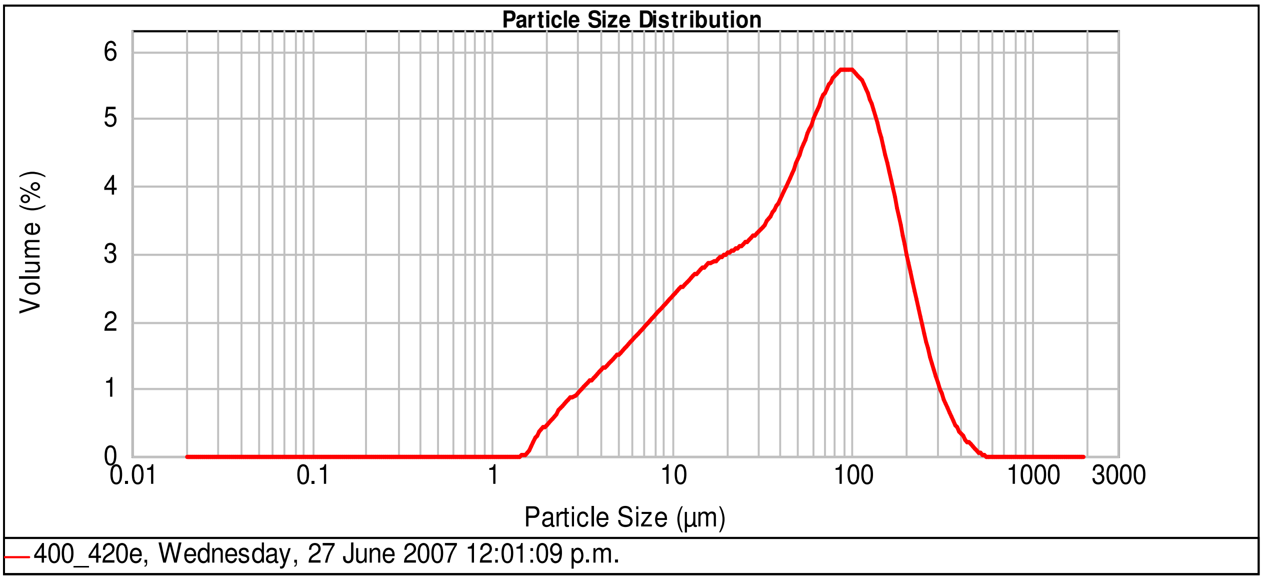
Uniformity:
1.01

Vol. Weighted Mean D[4,3]:
75.016 um

Result units:
Volume

d(0.1): 6.968 um **d(0.5):** 53.287 um **d(0.9):** 173.886 um

---



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	7.32	53.000	5.43	149.000	4.68	420.000	0.21	2000.000	0.00
0.120	0.00	7.800	11.09	63.000	5.55	177.000	3.61	500.000	0.01	4000.000	
0.241	0.00	15.600	13.75	74.000	6.36	210.000	2.62	590.000	0.00		
0.490	0.00	31.000	4.03	88.000	6.61	250.000	1.74	710.000	0.00		
0.980	0.40	37.000	4.33	105.000	6.28	300.000	0.85	840.000	0.00		
2.000	3.72	44.000	5.20	125.000	5.70	350.000	0.53	1000.000	0.00		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
380_400e

Sample Source & type:
A30

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 11:43:22 a.m.

Analysed:
Wednesday, 27 June 2007 11:43:23 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.369 %

Sensitivity:
Enhanced

Obscuration:
19.51 %

Result Emulation:
Off

Concentration:
0.0506 %Vol

Specific Surface Area:
0.287 m^2/g

Span :
3.190

Surface Weighted Mean D[3,2]:
20.871 um

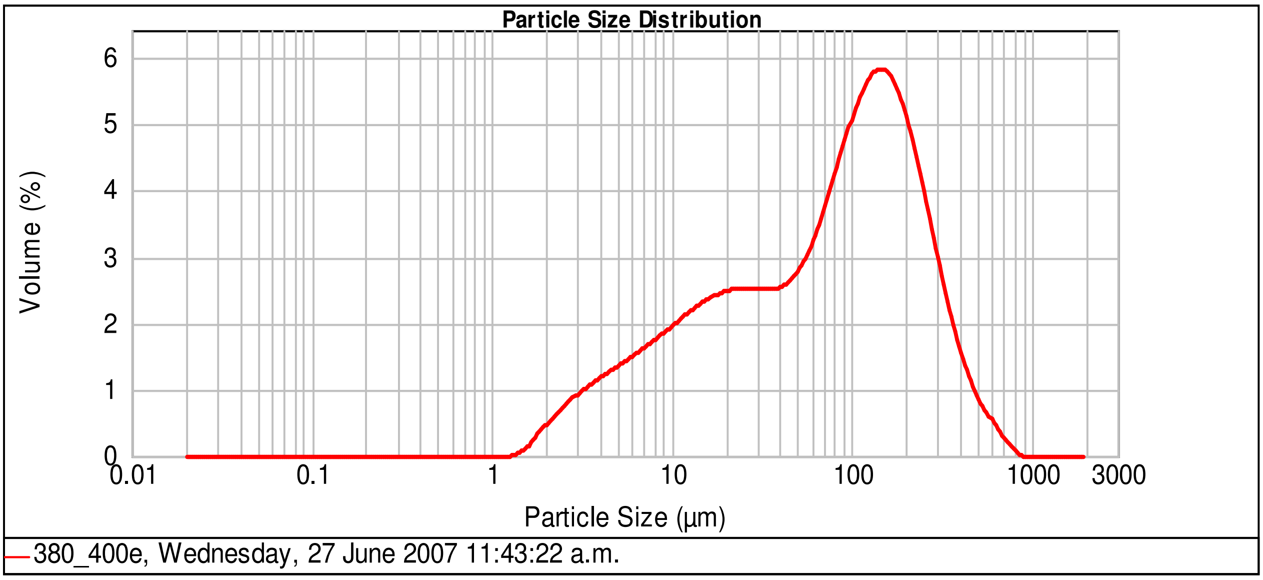
Uniformity:
1.05

Vol. Weighted Mean D[4,3]:
114.266 um

Result units:
Volume

d(0.1): 7.331 um   **d(0.5):** 81.573 um   **d(0.9):** 267.534 um

---



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.060	0.00	3.900	6.50	53.000	3.47	149.000	6.45	420.000	1.32	2000.000	0.00
0.120	0.00	7.800	9.24	63.000	3.77	177.000	5.89	500.000	0.78	4000.000	
0.241	0.00	15.600	11.14	74.000	4.79	210.000	5.13	590.000	0.48		
0.490	0.00	31.000	2.90	88.000	5.69	250.000	4.21	710.000	0.14		
0.980	0.52	37.000	2.89	105.000	6.28	300.000	2.63	840.000	0.00		
2.000	3.67	44.000	3.31	125.000	6.67	350.000	2.15	1000.000	0.00		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
360_380e

Sample Source & type:
A29

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 11:09:28 a.m.

Analysed:
Wednesday, 27 June 2007 11:09:29 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.257 %

Sensitivity:
Enhanced

Obscuration:
19.23 %

Result Emulation:
Off

Concentration:
0.0674 %Vol

Specific Surface Area:
0.209 m²/g

Span :
2.744

Surface Weighted Mean D[3,2]:
28.681 um

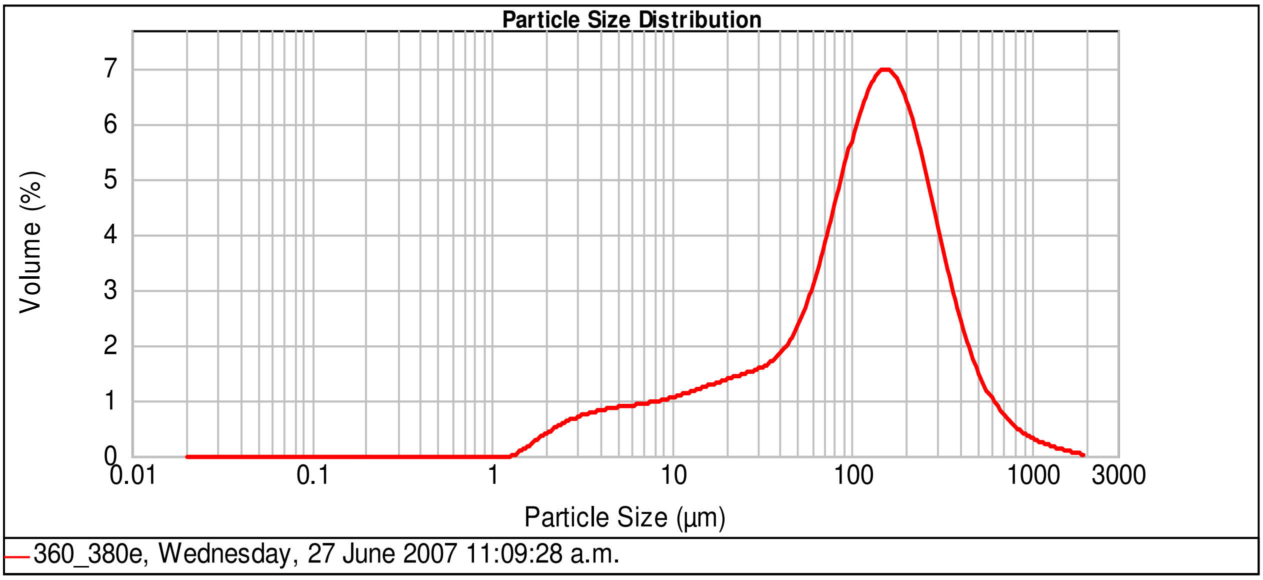
Uniformity:
0.903

Vol. Weighted Mean D[4,3]:
163.084 um

Result units:
Volume

d(0.1): 11.419 um　　**d(0.5):** 121.415 um　　**d(0.9):** 344.636 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.53
2.000	2.82
3.900	

Size (μm)	Volume In %
3.900	4.07
7.800	4.98
15.600	6.40
31.000	1.92
37.000	2.11
44.000	2.73
53.000	

Size (μm)	Volume In %
53.000	3.21
63.000	3.79
74.000	5.11
88.000	6.35
105.000	7.24
125.000	7.90
149.000	

Size (μm)	Volume In %
149.000	7.83
177.000	7.34
210.000	6.61
250.000	5.66
300.000	3.73
350.000	3.27
420.000	

Size (μm)	Volume In %
420.000	2.17
500.000	1.41
590.000	1.06
710.000	0.64
840.000	0.45
1000.000	0.66
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

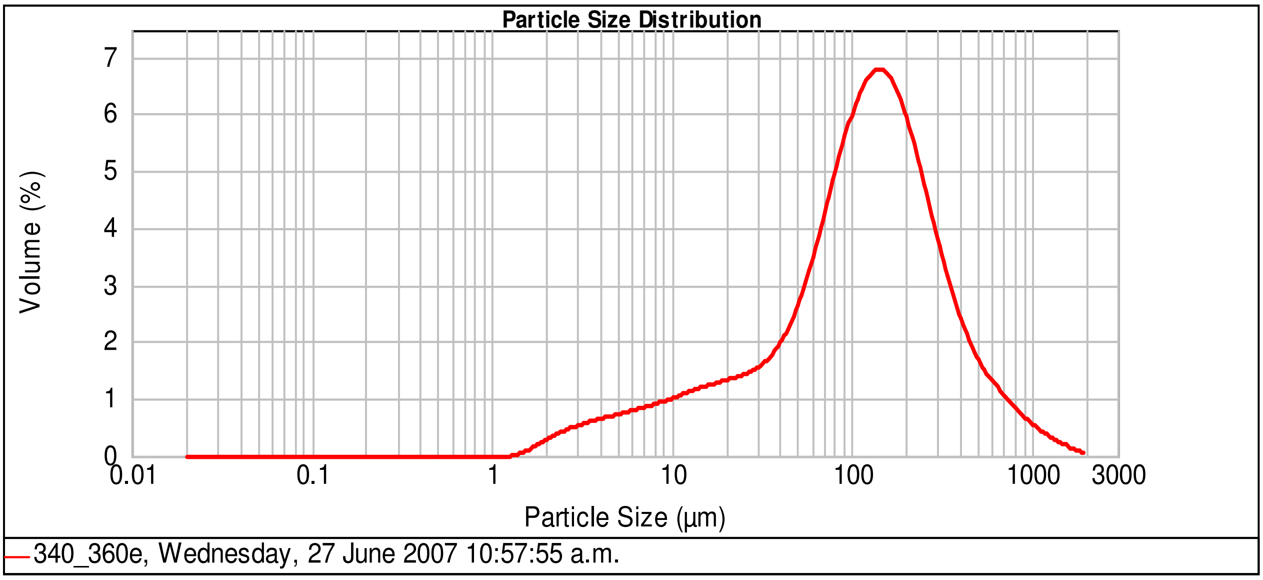
Result Analysis Report

Sample Name: 340_360e	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 27 June 2007 10:57:55 a.m.
Sample Source & type: A28	**Measured by:** gmdr1	**Analysed:** Wednesday, 27 June 2007 10:57:56 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 14.24 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.245 %	**Result Emulation:** Off

Concentration: 0.0577 %Vol	**Span :** 3.039	**Uniformity:** 1	**Result units:** Volume
Specific Surface Area: 0.18 m²/g	**Surface Weighted Mean D[3,2]:** 33.320 um	**Vol. Weighted Mean D[4,3]:** 175.978 um	

d(0.1): 14.255 um **d(0.5):** 120.148 um **d(0.9):** 379.405 um



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.33
2.000	2.12
3.900	

Size (µm)	Volume In %
3.900	3.47
7.800	4.79
15.600	6.20
31.000	1.96
37.000	2.26
44.000	3.04
53.000	

Size (µm)	Volume In %
53.000	3.62
63.000	4.24
74.000	5.58
88.000	6.71
105.000	7.38
125.000	7.78
149.000	

Size (µm)	Volume In %
149.000	7.48
177.000	6.84
210.000	6.05
250.000	5.16
300.000	3.46
350.000	3.16
420.000	

Size (µm)	Volume In %
420.000	2.28
500.000	1.67
590.000	1.43
710.000	0.99
840.000	0.76
1000.000	1.21
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

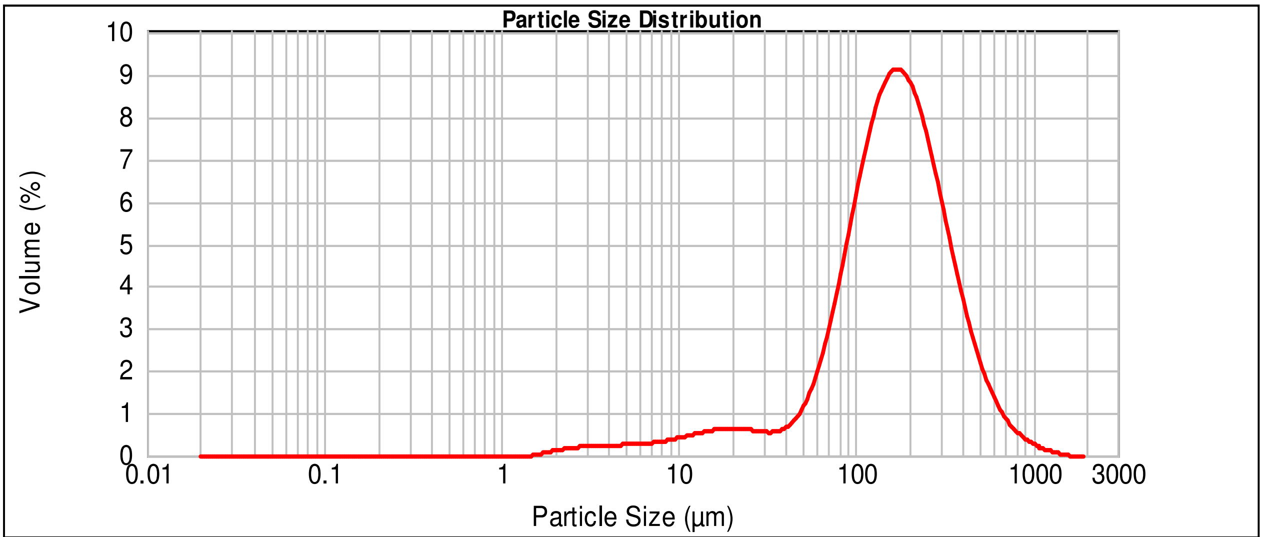
Result Analysis Report

Sample Name: 320_340e	**SOP Name:** Marine Sediment	**Measured:** Wednesday, 27 June 2007 10:31:27 a.m.
Sample Source & type: A27	**Measured by:** gmdr1	**Analysed:** Wednesday, 27 June 2007 10:31:28 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 14.71 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.320 %	**Result Emulation:** Off

Concentration: 0.1205 %Vol	**Span :** 2.000	**Uniformity:** 0.64	**Result units:** Volume
Specific Surface Area: 0.0925 m^2/g	**Surface Weighted Mean D[3,2]:** 64.859 um	**Vol. Weighted Mean D[4,3]:** 199.850 um	

d(0.1): 54.747 um **d(0.5):** 163.528 um **d(0.9):** 381.838 um



320_340e, Wednesday, 27 June 2007 10:31:27 a.m.

Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	1.22	53.000	2.00	149.000	10.24	420.000	3.07	2000.000	0.00
0.120	0.00	7.800	2.09	63.000	2.99	177.000	9.99	500.000	1.90	4000.000	
0.241	0.00	15.600	2.77	74.000	4.79	210.000	9.26	590.000	1.31		
0.490	0.00	31.000	0.64	88.000	6.76	250.000	8.12	710.000	0.69		
0.980	0.11	37.000	0.75	105.000	8.43	300.000	5.42	840.000	0.41		
2.000	0.85	44.000	1.26	125.000	9.83	350.000	4.73	1000.000	0.35		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
300_320e

Sample Source & type:
A26

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 10:19:55 a.m.

Analysed:
Wednesday, 27 June 2007 10:19:56 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.341 %

Sensitivity:
Enhanced

Obscuration:
14.14 %

Result Emulation:
Off

Concentration:
0.1011 %Vol

Specific Surface Area:
0.104 m²/g

Span :
1.865

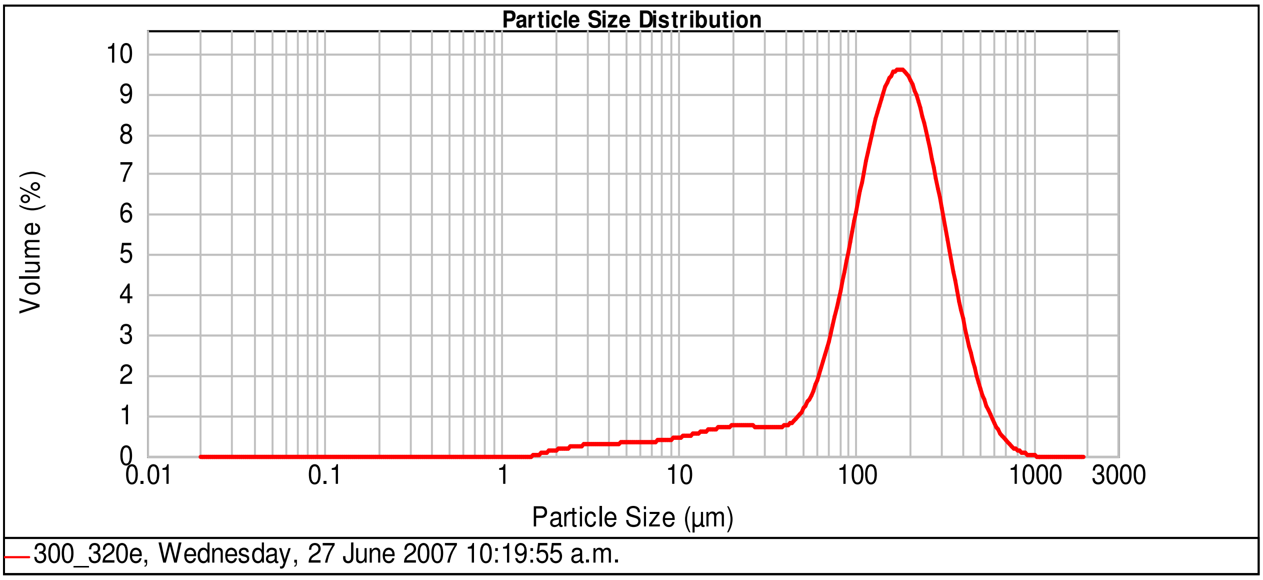
Surface Weighted Mean D[3,2]:
57.538 um

Uniformity:
0.571

Vol. Weighted Mean D[4,3]:
182.261 um

Result units:
Volume

d(0.1): 44.154 um **d(0.5):** 159.550 um **d(0.9):** 341.759 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.14
2.000	1.07
3.900	

Size (μm)	Volume In %
3.900	1.51
7.800	2.30
15.600	3.28
31.000	0.81
37.000	0.87
44.000	1.29
53.000	

Size (μm)	Volume In %
53.000	1.92
63.000	2.83
74.000	4.59
88.000	6.62
105.000	8.47
125.000	10.10
149.000	

Size (μm)	Volume In %
149.000	10.72
177.000	10.56
210.000	9.79
250.000	8.45
300.000	5.44
350.000	4.45
420.000	

Size (μm)	Volume In %
420.000	2.56
500.000	1.32
590.000	0.67
710.000	0.21
840.000	0.06
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
280_300e

Sample Source & type:
A25

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 10:07:43 a.m.

Analysed:
Wednesday, 27 June 2007 10:07:44 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.344 %

Sensitivity:
Enhanced

Obscuration:
17.07 %

Result Emulation:
Off

Concentration:
0.0900 %Vol

Specific Surface Area:
0.141 m²/g

Span :
2.058

Surface Weighted Mean D[3,2]:
42.478 um

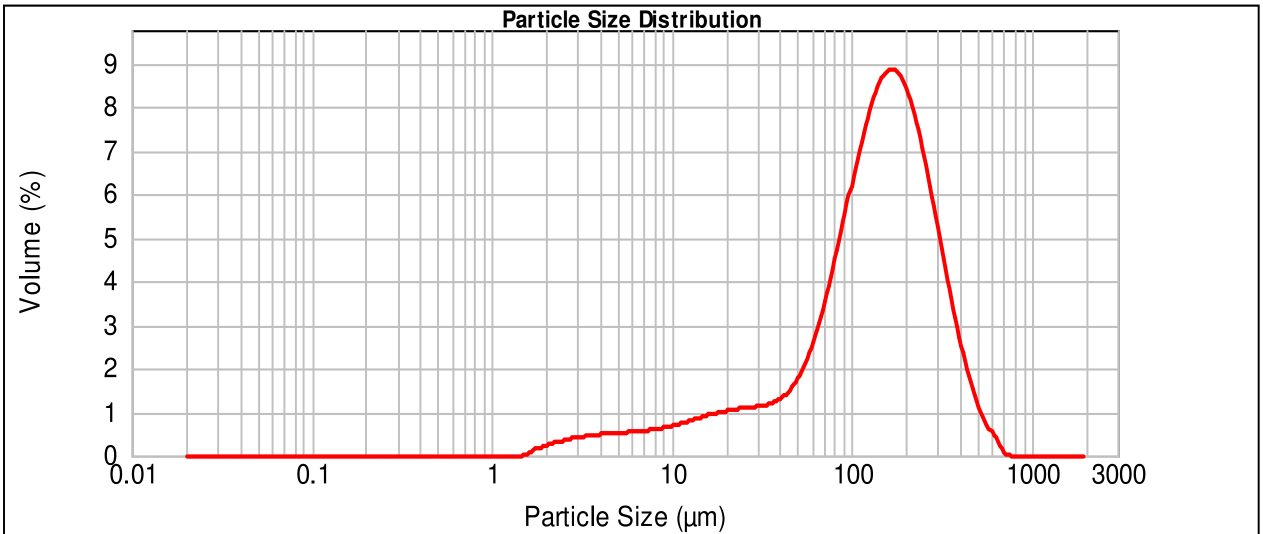
Uniformity:
0.615

Vol. Weighted Mean D[4,3]:
160.458 um

Result units:
Volume

d(0.1): 22.499 um **d(0.5):** 141.353 um **d(0.9):** 313.459 um

---



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.22
2.000	
	1.65
3.900	

Size (µm)	Volume In %
3.900	
	2.42
7.800	
	3.33
15.600	
	4.69
31.000	
	1.35
37.000	
	1.49
44.000	
	2.01
53.000	

Size (µm)	Volume In %
53.000	
	2.59
63.000	
	3.39
74.000	
	5.03
88.000	
	6.82
105.000	
	8.35
125.000	
	9.64
149.000	

Size (µm)	Volume In %
149.000	
	9.97
177.000	
	9.59
210.000	
	8.69
250.000	
	7.31
300.000	
	4.58
350.000	
	3.61
420.000	

Size (µm)	Volume In %
420.000	
	1.98
500.000	
	0.93
590.000	
	0.36
710.000	
	0.00
840.000	
	0.00
1000.000	
	0.00
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
260_280e

Sample Source & type:
A24

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 9:53:05 a.m.

Analysed:
Wednesday, 27 June 2007 9:53:06 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.361 %

Sensitivity:
Enhanced

Obscuration:
16.01 %

Result Emulation:
Off

Concentration:
0.0623 %Vol

Specific Surface Area:
0.188 m²/g

Span :
2.075

Surface Weighted Mean D[3,2]:
31.947 um

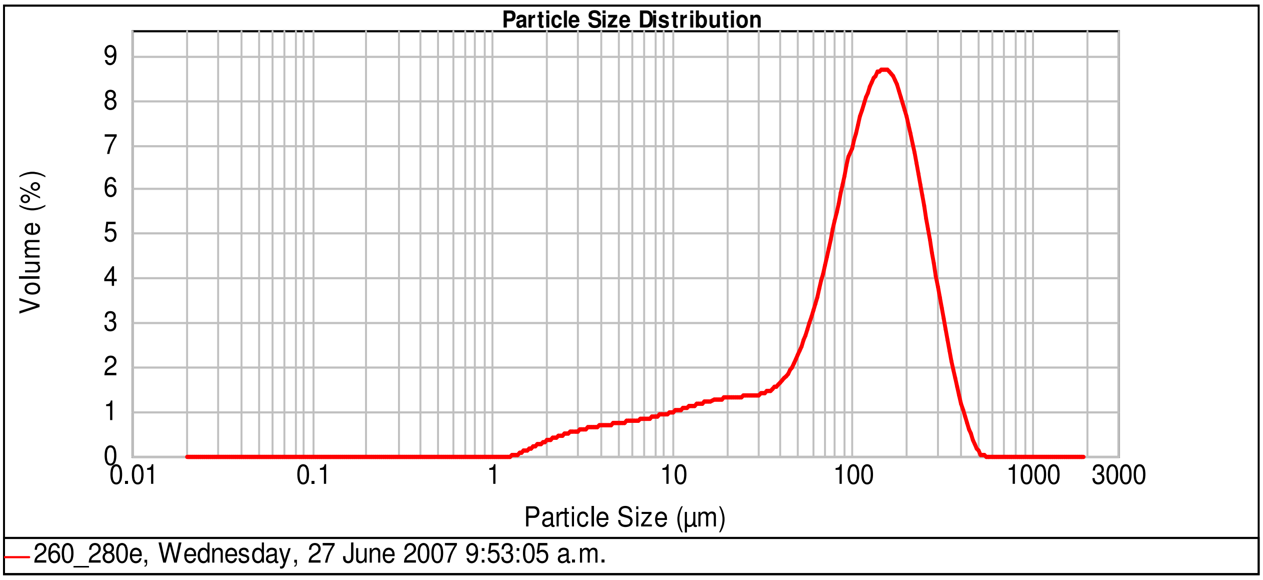
Uniformity:
0.625

Vol. Weighted Mean D[4,3]:
131.016 um

Result units:
Volume

d(0.1): 13.926 um **d(0.5):** 118.531 um **d(0.9):** 259.834 um

---



Size (μm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.44
3.900	2.29

Size (μm)	Volume In %
3.900	
7.800	3.46
15.600	4.69
31.000	5.89
37.000	1.67
44.000	1.88
53.000	2.58

Size (μm)	Volume In %
53.000	
63.000	3.28
74.000	4.15
88.000	5.92
105.000	7.66
125.000	8.94
149.000	9.84

Size (μm)	Volume In %
149.000	
177.000	9.67
210.000	8.80
250.000	7.45
300.000	5.70
350.000	3.12
420.000	1.95

Size (μm)	Volume In %
420.000	
500.000	0.62
590.000	0.01
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	0.00

Size (μm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
240_260e

Sample Source & type:
A23

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 9:26:13 a.m.

Analysed:
Wednesday, 27 June 2007 9:26:14 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.348 %

Sensitivity:
Enhanced

Obscuration:
11.64 %

Result Emulation:
Off

Concentration:
0.0747 %Vol

Specific Surface Area:
0.114 m²/g

Span :
2.140

Surface Weighted Mean D[3,2]:
52.819 um

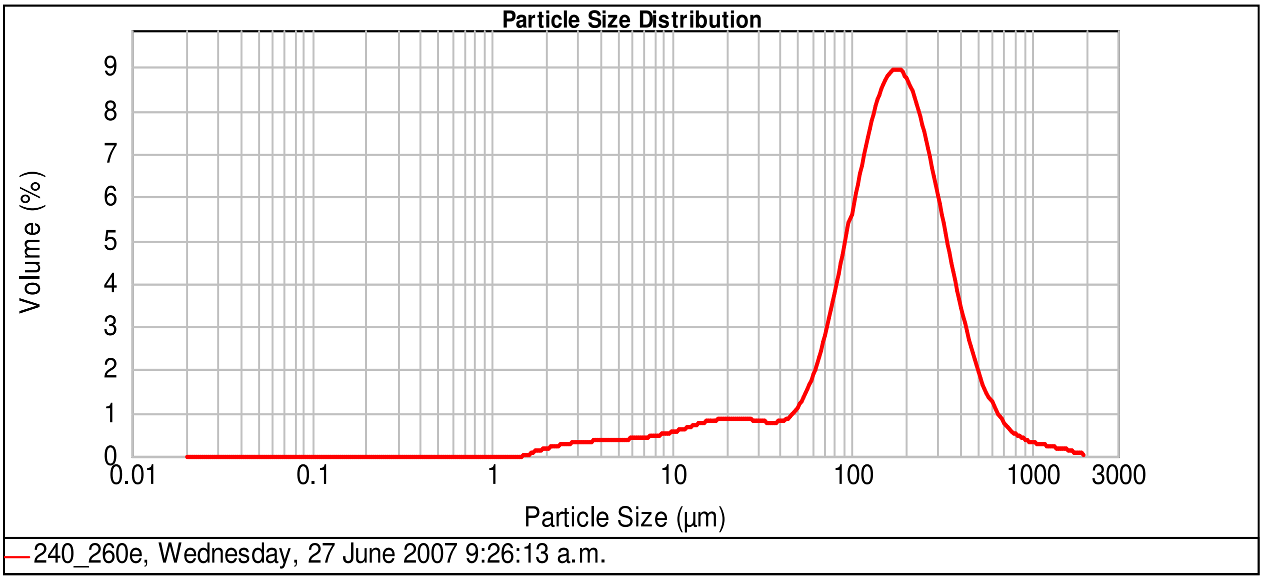
Uniformity:
0.683

Vol. Weighted Mean D[4,3]:
201.220 um

Result units:
Volume

d(0.1): 32.571 um **d(0.5):** 163.165 um **d(0.9):** 381.812 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.16
2.000	1.23
3.900	

Size (μm)	Volume In %
3.900	1.78
7.800	2.74
15.600	3.83
31.000	0.90
37.000	0.91
44.000	1.25
53.000	

Size (μm)	Volume In %
53.000	1.80
63.000	2.62
74.000	4.23
88.000	6.12
105.000	7.84
125.000	9.37
149.000	

Size (μm)	Volume In %
149.000	9.97
177.000	9.88
210.000	9.27
250.000	8.18
300.000	5.44
350.000	4.69
420.000	

Size (μm)	Volume In %
420.000	2.97
500.000	1.76
590.000	1.17
710.000	0.63
840.000	0.43
1000.000	0.81
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
220_240e

Sample Source & type:
A22

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 9:12:45 a.m.

Analysed:
Wednesday, 27 June 2007 9:12:47 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.343 %

Sensitivity:
Enhanced

Obscuration:
18.07 %

Result Emulation:
Off

Concentration:
0.0686 %Vol

Specific Surface Area:
0.194 m²/g

Span :
2.109

Surface Weighted Mean D[3,2]:
30.874 um

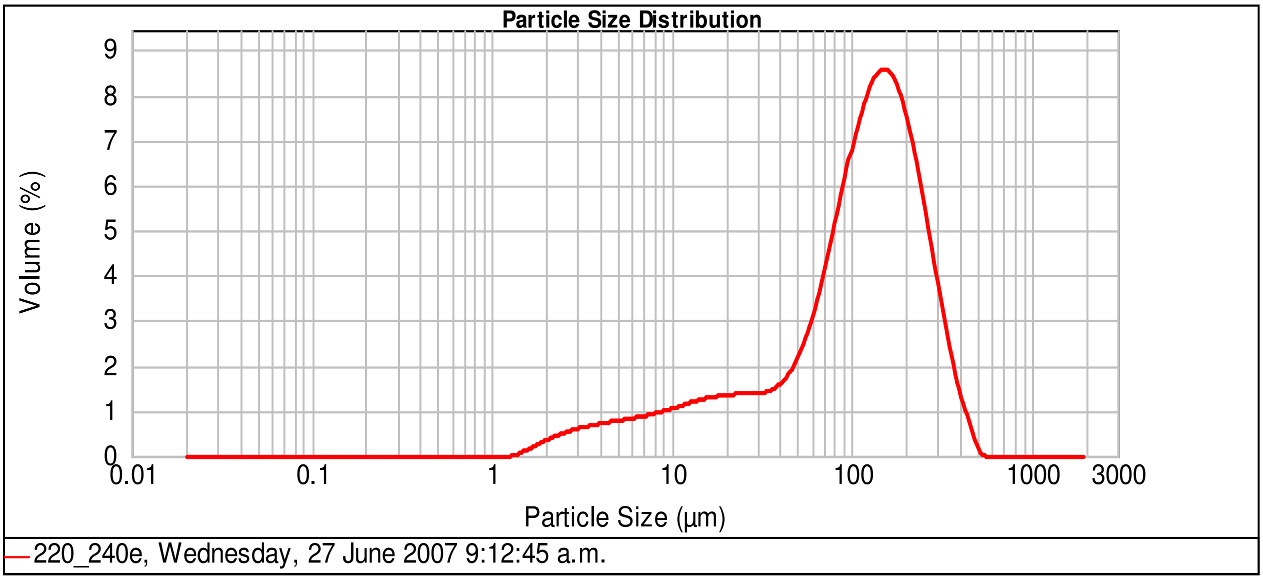
Uniformity:
0.638

Vol. Weighted Mean D[4,3]:
131.403 um

Result units:
Volume

d(0.1): 12.934 um　　**d(0.5):** 118.456 um　　**d(0.9):** 262.791 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.45
2.000	2.41
3.900	

Size (μm)	Volume In %
3.900	3.67
7.800	4.97
15.600	6.08
31.000	1.65
37.000	1.83
44.000	2.48
53.000	

Size (μm)	Volume In %
53.000	3.16
63.000	4.03
74.000	5.78
88.000	7.52
105.000	8.81
125.000	9.71
149.000	

Size (μm)	Volume In %
149.000	9.56
177.000	8.71
210.000	7.40
250.000	5.71
300.000	3.18
350.000	2.08
420.000	

Size (μm)	Volume In %
420.000	0.79
500.000	0.02
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
200_220e

Sample Source & type:
A21

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Wednesday, 27 June 2007 8:57:58 a.m.

Analysed:
Wednesday, 27 June 2007 8:57:59 a.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
4.400 %

Sensitivity:
Enhanced

Obscuration:
11.87 %

Result Emulation:
Off

Concentration:
0.0574 %Vol

Specific Surface Area:
0.148 m²/g

Span :
1.896

Surface Weighted Mean D[3,2]:
40.604 um

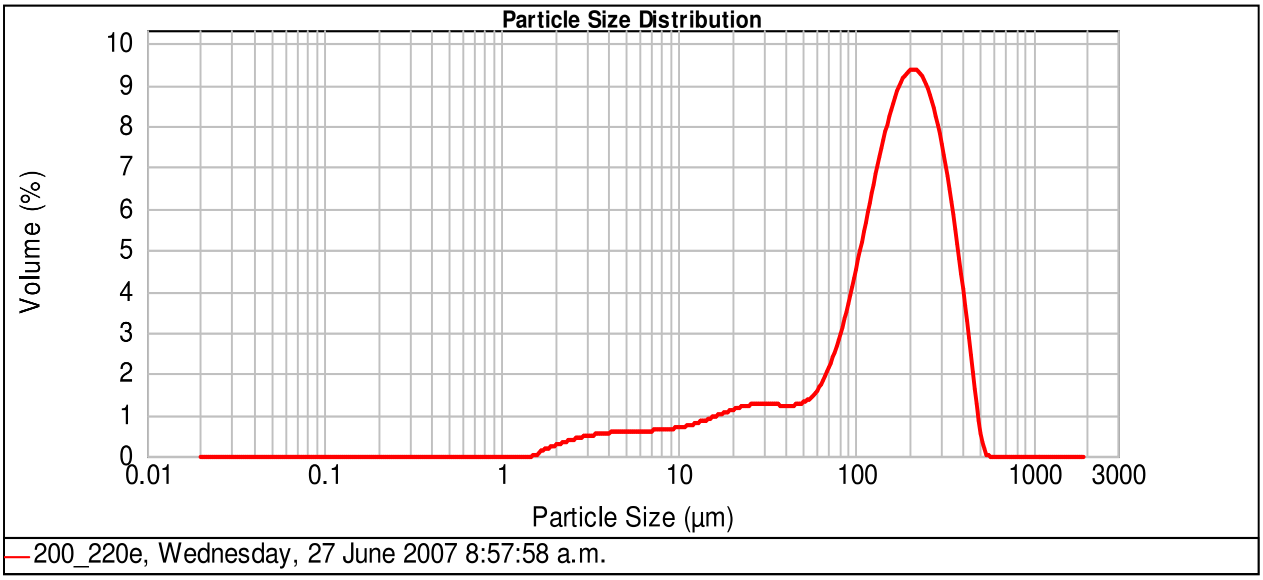
Uniformity:
0.559

Vol. Weighted Mean D[4,3]:
172.654 um

Result units:
Volume

d(0.1): 20.212 um **d(0.5):** 163.366 um **d(0.9):** 329.891 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.25
2.000	1.90
3.900	

Size (μm)	Volume In %
3.900	2.71
7.800	3.38
15.600	5.17
31.000	1.45
37.000	1.39
44.000	1.55
53.000	

Size (μm)	Volume In %
53.000	1.71
63.000	2.14
74.000	3.32
88.000	4.90
105.000	6.62
125.000	8.46
149.000	

Size (μm)	Volume In %
149.000	9.69
177.000	10.38
210.000	10.55
250.000	9.99
300.000	6.86
350.000	5.47
420.000	

Size (μm)	Volume In %
420.000	2.06
500.000	0.04
590.000	0.00
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
190_200e

Sample Source & type:
A20

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 7:05:42 p.m.

Analysed:
Tuesday, 26 June 2007 7:05:43 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.695 %

Sensitivity:
Enhanced

Obscuration:
12.25 %

Result Emulation:
Off

Concentration:
0.0785 %Vol

Specific Surface Area:
0.114 m²/g

Span :
2.036

Surface Weighted Mean D[3,2]:
52.599 um

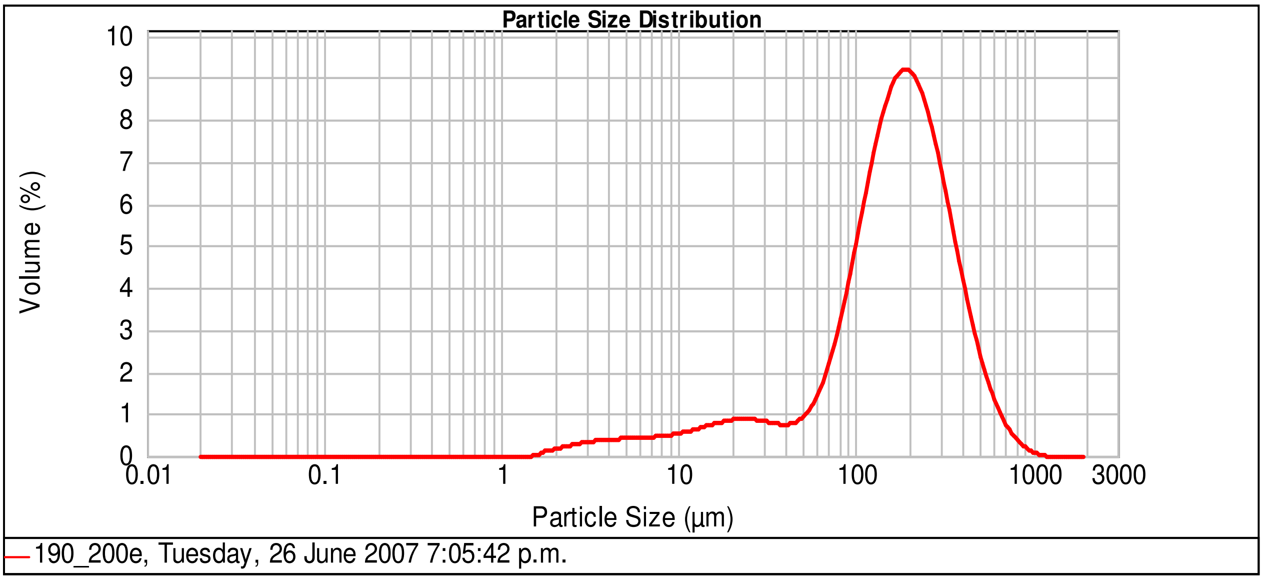
Uniformity:
0.609

Vol. Weighted Mean D[4,3]:
198.446 um

Result units:
Volume

d(0.1): 32.005 um **d(0.5):** 171.580 um **d(0.9):** 381.311 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.15
2.000	1.29
3.900	

Size (µm)	Volume In %
3.900	1.91
7.800	2.68
15.600	3.79
31.000	0.90
37.000	0.85
44.000	1.07
53.000	

Size (µm)	Volume In %
53.000	1.47
63.000	2.17
74.000	3.63
88.000	5.49
105.000	7.32
125.000	9.09
149.000	

Size (µm)	Volume In %
149.000	10.03
177.000	10.27
210.000	9.94
250.000	9.01
300.000	6.14
350.000	5.39
420.000	

Size (µm)	Volume In %
420.000	3.43
500.000	2.00
590.000	1.22
710.000	0.52
840.000	0.19
1000.000	0.04
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

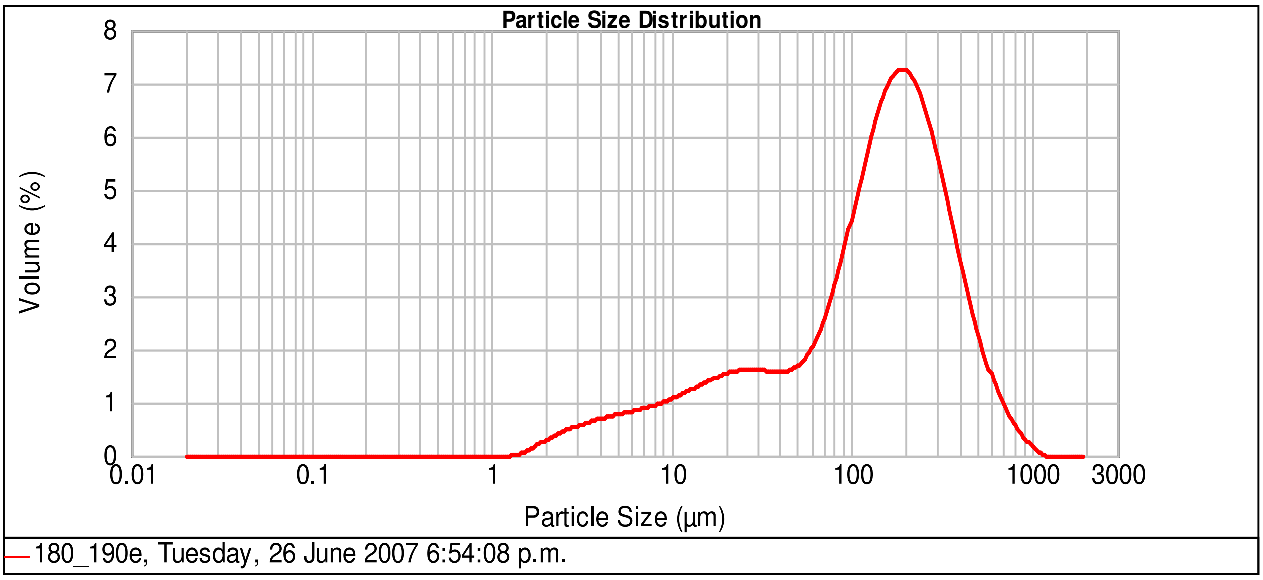
Result Analysis Report

Sample Name: 180_190e	**SOP Name:** Marine Sediment	**Measured:** Tuesday, 26 June 2007 6:54:08 p.m.
Sample Source & type: A19	**Measured by:** gmdr1	**Analysed:** Tuesday, 26 June 2007 6:54:09 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 14.41 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.561 %	**Result Emulation:** Off

Concentration: 0.0577 %Vol	**Span :** 2.544	**Uniformity:** 0.798	**Result units:** Volume
Specific Surface Area: 0.182 m²/g	**Surface Weighted Mean D[3,2]:** 32.978 um	**Vol. Weighted Mean D[4,3]:** 180.427 um	

d(0.1): 13.282 um **d(0.5): 147.112 um** **d(0.9): 387.462 um**



Size (μm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.34
2.000	
	2.22
3.900	

Size (μm)	Volume In %
3.900	
	3.67
7.800	
	5.18
15.600	
	6.98
31.000	
	1.84
37.000	
	1.79
44.000	
	2.01
53.000	

Size (μm)	Volume In %
53.000	
	2.17
63.000	
	2.54
74.000	
	3.60
88.000	
	4.86
105.000	
	6.09
125.000	
	7.30
149.000	

Size (μm)	Volume In %
149.000	
	7.94
177.000	
	8.12
210.000	
	7.94
250.000	
	7.37
300.000	
	5.21
350.000	
	4.81
420.000	

Size (μm)	Volume In %
420.000	
	3.29
500.000	
	2.11
590.000	
	1.46
710.000	
	0.74
840.000	
	0.36
1000.000	
	0.09
2000.000	

Size (μm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
170_180e

Sample Source & type:
A18

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 6:42:29 p.m.

Analysed:
Tuesday, 26 June 2007 6:42:30 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.487 %

Sensitivity:
Enhanced

Obscuration:
12.79 %

Result Emulation:
Off

Concentration:
0.0410 %Vol

Specific Surface Area:
0.227 m²/g

Span :
3.089

Surface Weighted Mean D[3,2]:
26.488 um

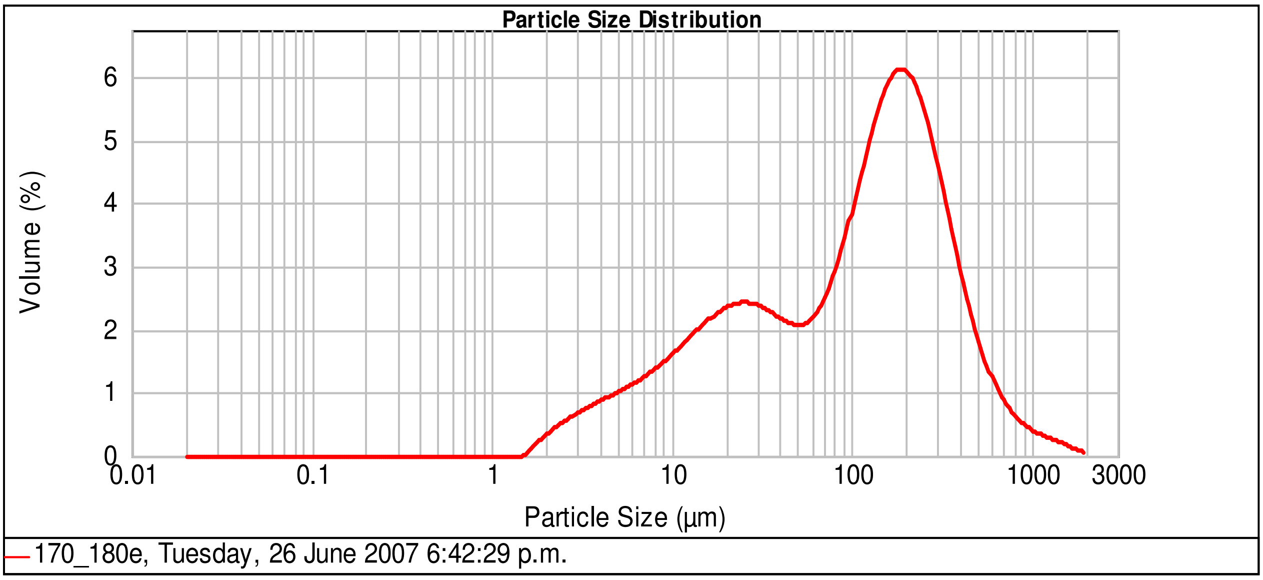
Uniformity:
1.07

Vol. Weighted Mean D[4,3]:
169.186 um

Result units:
Volume

d(0.1): 9.762 um **d(0.5):** 119.133 um **d(0.9):** 377.715 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.29
2.000	2.68
3.900	

Size (μm)	Volume In %
3.900	4.90
7.800	7.78
15.600	10.56
31.000	2.67
37.000	2.46
44.000	2.53
53.000	

Size (μm)	Volume In %
53.000	2.41
63.000	2.52
74.000	3.29
88.000	4.24
105.000	5.21
125.000	6.20
149.000	

Size (μm)	Volume In %
149.000	6.71
177.000	6.83
210.000	6.63
250.000	6.09
300.000	4.24
350.000	3.85
420.000	

Size (μm)	Volume In %
420.000	2.62
500.000	1.70
590.000	1.26
710.000	0.76
840.000	0.55
1000.000	1.02
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
160_170e

Sample Source & type:
A17

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 6:30:23 p.m.

Analysed:
Tuesday, 26 June 2007 6:30:24 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.557 %

Sensitivity:
Enhanced

Obscuration:
13.02 %

Result Emulation:
Off

Concentration:
0.0521 %Vol

Specific Surface Area:
0.181 m²/g

Span :
2.427

Surface Weighted Mean D[3,2]:
33.061 um

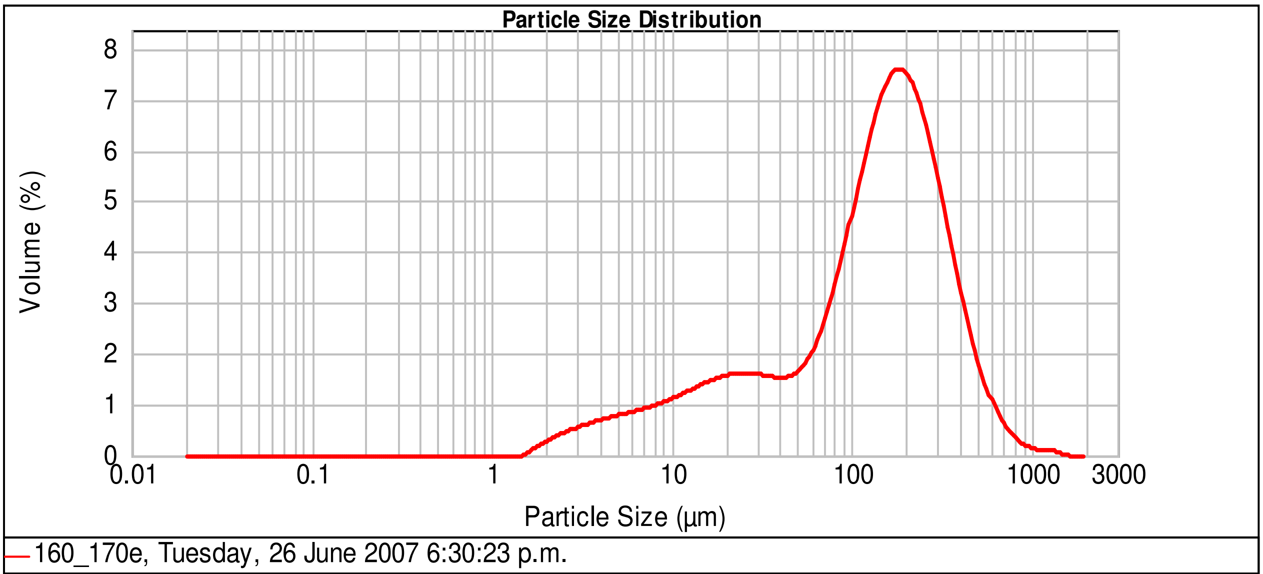
Uniformity:
0.771

Vol. Weighted Mean D[4,3]:
171.493 um

Result units:
Volume

d(0.1): 13.051 um **d(0.5):** 142.264 um **d(0.9):** 358.376 um

---



Size (μm)	Volume In %
0.060	
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.00
2.000	0.25
3.900	2.21

Size (μm)	Volume In %
3.900	
7.800	3.75
15.600	5.38
31.000	7.08
37.000	1.81
44.000	1.74
53.000	1.97

Size (μm)	Volume In %
53.000	
63.000	2.16
74.000	2.60
88.000	3.77
105.000	5.16
125.000	6.49
149.000	7.77

Size (μm)	Volume In %
149.000	
177.000	8.38
210.000	8.46
250.000	8.10
300.000	7.30
350.000	4.96
420.000	4.35

Size (μm)	Volume In %
420.000	
500.000	2.76
590.000	1.61
710.000	1.00
840.000	0.45
1000.000	0.23
2000.000	0.25

Size (μm)	Volume In %
2000.000	
4000.000	0.00

Operator notes:

MASTERSIZER 2000

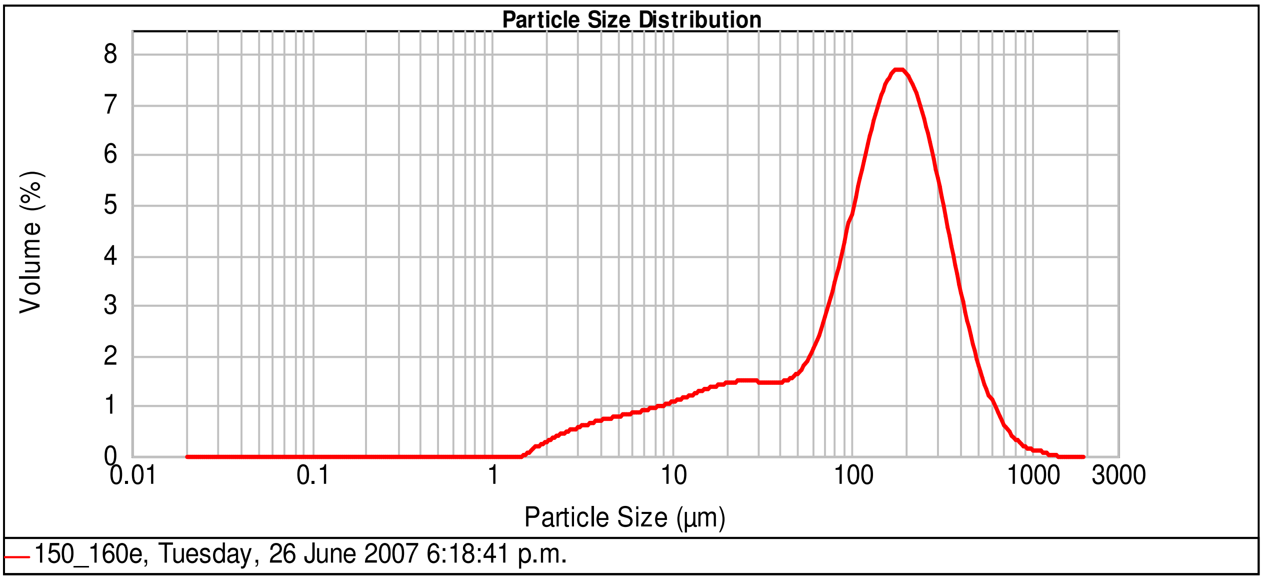
Result Analysis Report

Sample Name: 150_160e	**SOP Name:** Marine Sediment	**Measured:** Tuesday, 26 June 2007 6:18:41 p.m.
Sample Source & type: A16	**Measured by:** gmdr1	**Analysed:** Tuesday, 26 June 2007 6:18:42 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 15.76 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.600 %	**Result Emulation:** Off

Concentration: 0.0645 %Vol	**Span :** 2.396	**Uniformity:** 0.751	**Result units:** Volume
Specific Surface Area: 0.179 m²/g	**Surface Weighted Mean D[3,2]:** 33.443 um	**Vol. Weighted Mean D[4,3]:** 171.703 um	

d(0.1): 13.309 um **d(0.5): 143.804 um** **d(0.9): 357.891 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.26
2.000	2.24
3.900	

Size (μm)	Volume In %
3.900	3.73
7.800	5.10
15.600	6.51
31.000	1.69
37.000	1.66
44.000	1.94
53.000	

Size (μm)	Volume In %
53.000	2.19
63.000	2.67
74.000	3.87
88.000	5.28
105.000	6.62
125.000	7.90
149.000	

Size (μm)	Volume In %
149.000	8.50
177.000	8.57
210.000	8.21
250.000	7.40
300.000	5.02
350.000	4.40
420.000	

Size (μm)	Volume In %
420.000	2.79
500.000	1.63
590.000	1.01
710.000	0.45
840.000	0.21
1000.000	0.13
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
140_150e

SOP Name:
Marine Sediment

Measured:
Tuesday, 26 June 2007 6:06:16 p.m.

Sample Source & type:
A15

Measured by:
gmdr1

Analysed:
Tuesday, 26 June 2007 6:06:17 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
12.55 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.779 %

Result Emulation:
Off

Concentration:
0.0583 %Vol

Span :
2.489

Uniformity:
0.746

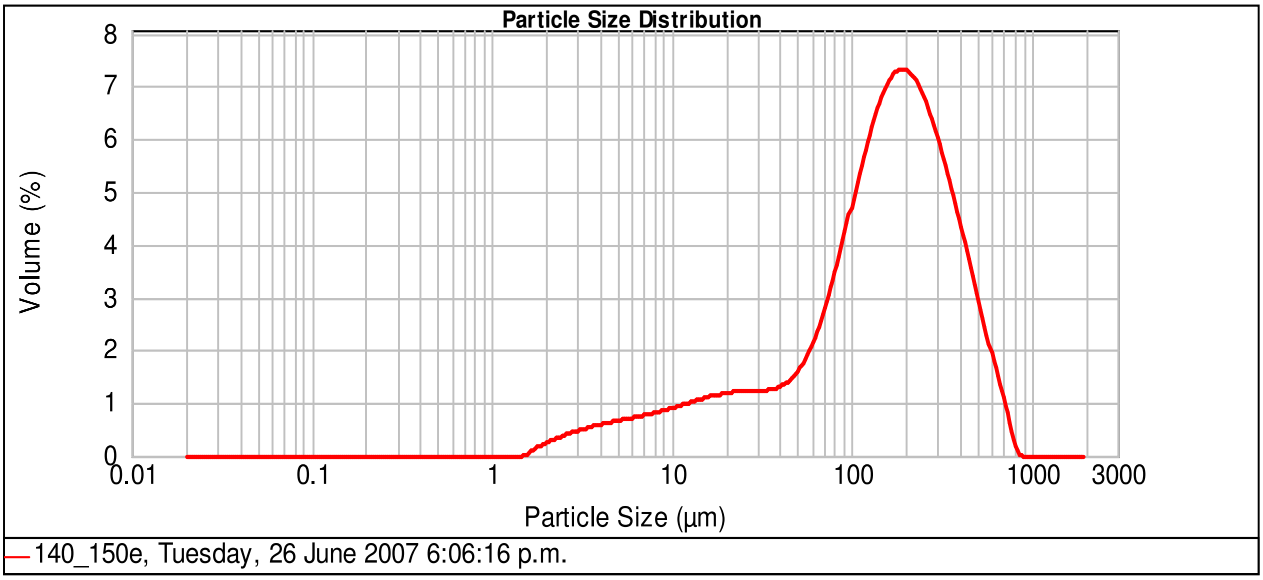
Result units:
Volume

Specific Surface Area:
0.156 m²/g

Surface Weighted Mean D[3,2]:
38.440 um

Vol. Weighted Mean D[4,3]:
190.044 um

d(0.1): 16.605 um **d(0.5): 157.062 um** **d(0.9): 407.458 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.22
2.000	1.89
3.900	

Size (μm)	Volume In %
3.900	3.15
7.800	4.29
15.600	5.37
31.000	1.44
37.000	1.49
44.000	1.86
53.000	

Size (μm)	Volume In %
53.000	2.21
63.000	2.72
74.000	3.90
88.000	5.20
105.000	6.37
125.000	7.49
149.000	

Size (μm)	Volume In %
149.000	8.03
177.000	8.18
210.000	8.06
250.000	7.69
300.000	5.68
350.000	5.60
420.000	

Size (μm)	Volume In %
420.000	4.13
500.000	2.77
590.000	1.78
710.000	0.47
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
130_140e

Sample Source & type:
A14

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 5:54:12 p.m.

Analysed:
Tuesday, 26 June 2007 5:54:13 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.534 %

Sensitivity:
Enhanced

Obscuration:
16.03 %

Result Emulation:
Off

Concentration:
0.0644 %Vol

Specific Surface Area:
0.183 m²/g

Span :
2.801

Surface Weighted Mean D[3,2]:
32.770 um

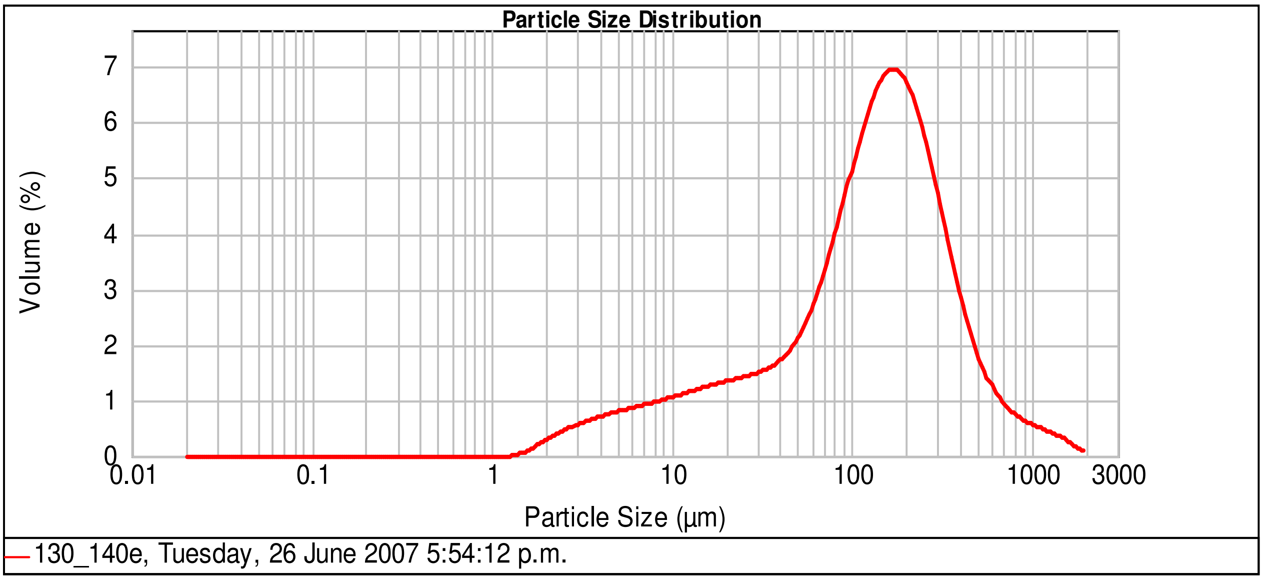
Uniformity:
0.956

Vol. Weighted Mean D[4,3]:
188.447 um

Result units:
Volume

d(0.1): 13.204 um **d(0.5):** 134.956 um **d(0.9):** 391.185 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.33
2.000	2.24
3.900	

Size (μm)	Volume In %
3.900	3.77
7.800	4.97
15.600	6.19
31.000	1.82
37.000	1.96
44.000	2.47
53.000	

Size (μm)	Volume In %
53.000	2.84
63.000	3.31
74.000	4.49
88.000	5.69
105.000	6.69
125.000	7.57
149.000	

Size (μm)	Volume In %
149.000	7.81
177.000	7.63
210.000	7.13
250.000	6.33
300.000	4.28
350.000	3.81
420.000	

Size (μm)	Volume In %
420.000	2.55
500.000	1.68
590.000	1.31
710.000	0.87
840.000	0.72
1000.000	1.55
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
120_130e

Sample Source & type:
A13

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 5:40:38 p.m.

Analysed:
Tuesday, 26 June 2007 5:40:39 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.500 %

Sensitivity:
Enhanced

Obscuration:
11.86 %

Result Emulation:
Off

Concentration:
0.0357 %Vol

Specific Surface Area:
0.238 m²/g

Span :
3.082

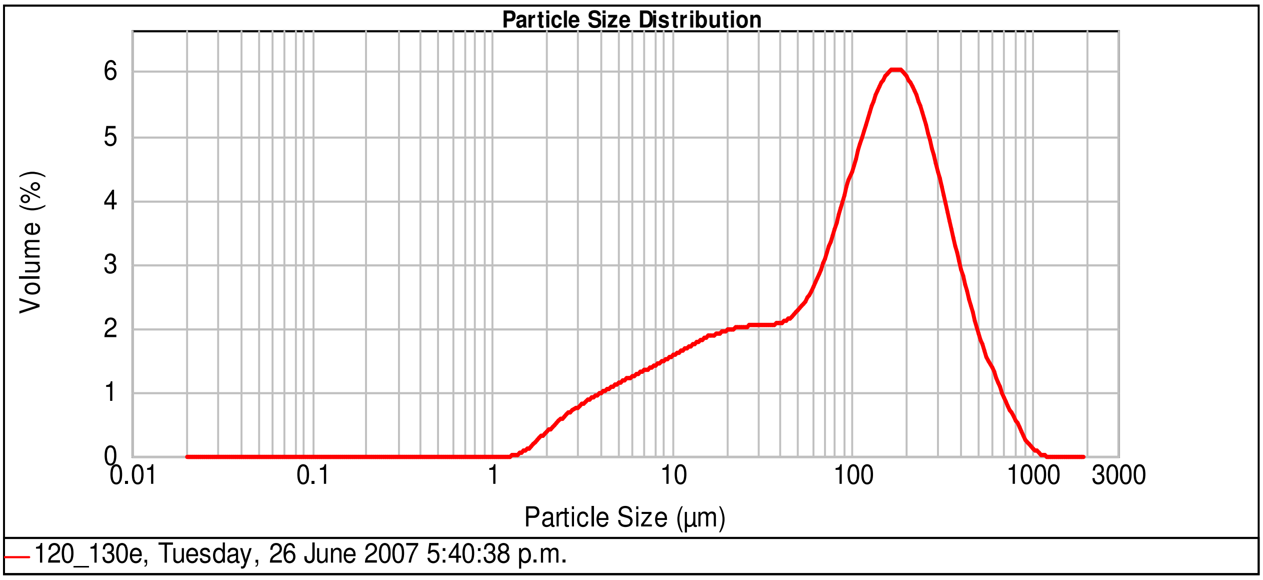
Surface Weighted Mean D[3,2]:
25.232 um

Uniformity:
0.992

Vol. Weighted Mean D[4,3]:
155.921 um

Result units:
Volume

d(0.1): 8.874 um **d(0.5): 114.711 um** **d(0.9): 362.373 um**



Size (µm)	Volume In %
0.060	
	0.00
0.120	
	0.00
0.241	
	0.00
0.490	
	0.00
0.980	
	0.41
2.000	
	3.01
3.900	

Size (µm)	Volume In %
3.900	
	5.37
7.800	
	7.32
15.600	
	8.86
31.000	
	2.36
37.000	
	2.36
44.000	
	2.69
53.000	

Size (µm)	Volume In %
53.000	
	2.82
63.000	
	3.08
74.000	
	3.99
88.000	
	4.93
105.000	
	5.73
125.000	
	6.49
149.000	

Size (µm)	Volume In %
149.000	
	6.75
177.000	
	6.68
210.000	
	6.38
250.000	
	5.85
300.000	
	4.11
350.000	
	3.84
420.000	

Size (µm)	Volume In %
420.000	
	2.71
500.000	
	1.83
590.000	
	1.36
710.000	
	0.72
840.000	
	0.30
1000.000	
	0.06
2000.000	

Size (µm)	Volume In %
2000.000	
	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

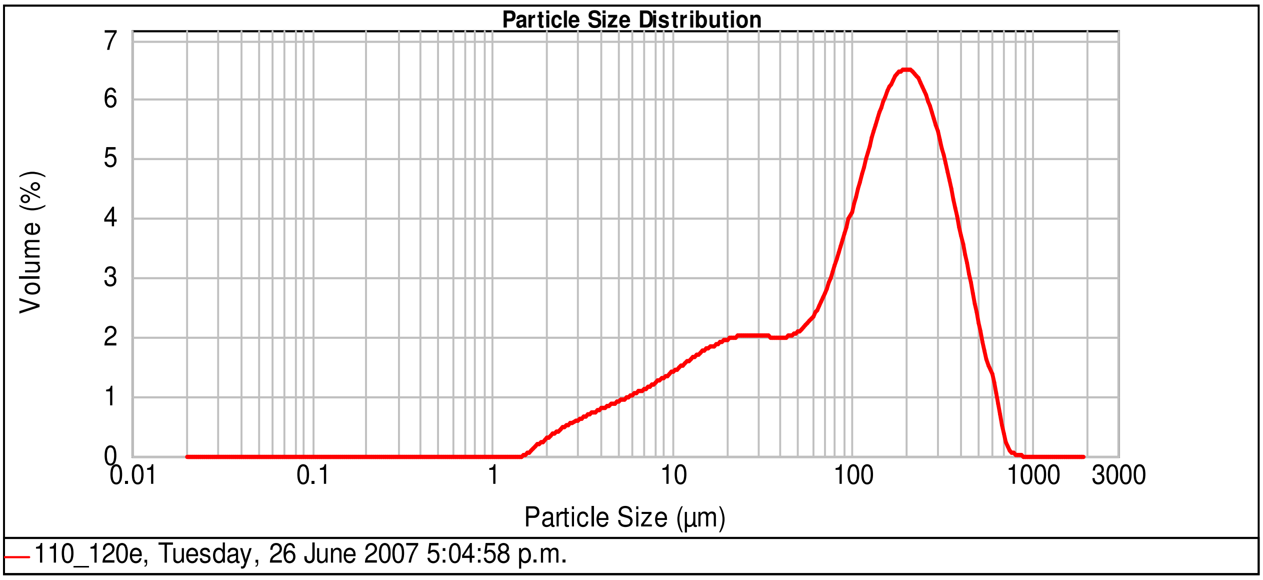
Result Analysis Report

Sample Name: 110_120e	**SOP Name:** Marine Sediment	**Measured:** Tuesday, 26 June 2007 5:04:58 p.m.
Sample Source & type: A12	**Measured by:** gmdr1	**Analysed:** Tuesday, 26 June 2007 5:05:00 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 13.77 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.561 %	**Result Emulation:** Off

Concentration: 0.0495 %Vol	**Span :** 2.731	**Uniformity:** 0.861	**Result units:** Volume
Specific Surface Area: 0.204 m²/g	**Surface Weighted Mean D[3,2]:** 29.397 um	**Vol. Weighted Mean D[4,3]:** 161.431 um	

d(0.1): 10.945 um **d(0.5):** 130.169 um **d(0.9):** 366.392 um



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.25
2.000	2.38
3.900	

Size (μm)	Volume In %
3.900	4.42
7.800	6.75
15.600	8.82
31.000	2.32
37.000	2.26
44.000	2.49
53.000	

Size (μm)	Volume In %
53.000	2.54
63.000	2.74
74.000	3.59
88.000	4.55
105.000	5.48
125.000	6.45
149.000	

Size (μm)	Volume In %
149.000	7.01
177.000	7.26
210.000	7.26
250.000	6.98
300.000	5.11
350.000	4.88
420.000	

Size (μm)	Volume In %
420.000	3.38
500.000	2.03
590.000	0.99
710.000	0.06
840.000	0.00
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
100_110e

Sample Source & type:
A11

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 2:44:30 p.m.

Analysed:
Tuesday, 26 June 2007 2:44:31 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.302 %

Sensitivity:
Enhanced

Obscuration:
13.29 %

Result Emulation:
Off

Concentration:
0.0738 %Vol

Specific Surface Area:
0.132 m²/g

Span :
2.552

Surface Weighted Mean D[3,2]:
45.354 um

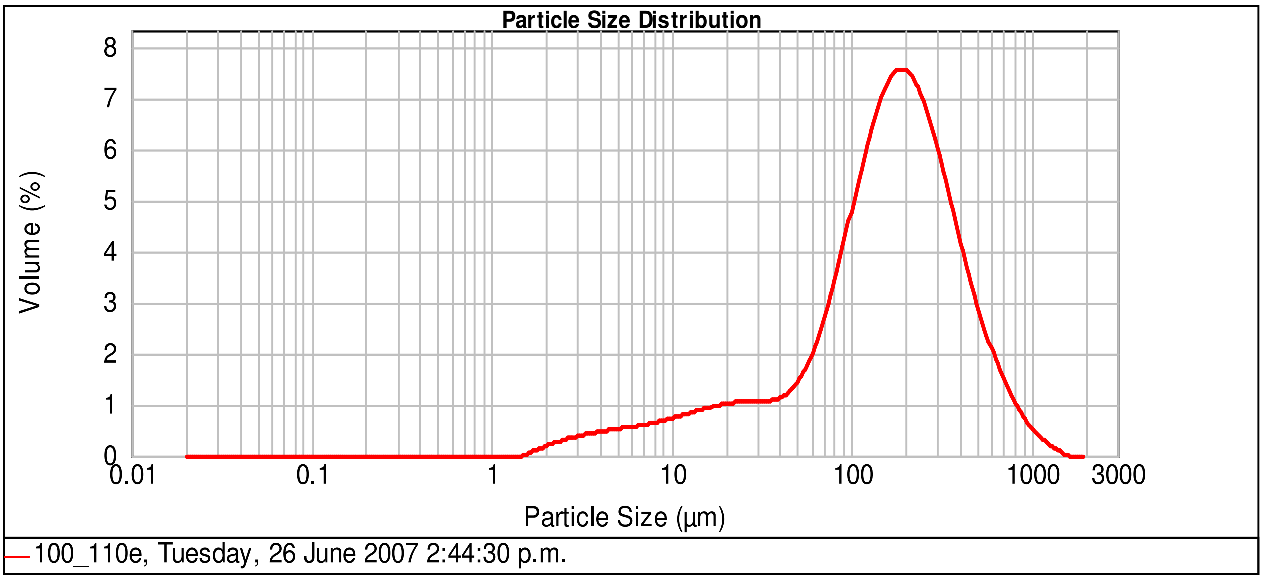
Uniformity:
0.785

Vol. Weighted Mean D[4,3]:
214.084 um

Result units:
Volume

d(0.1): 22.269 um   **d(0.5):** 167.257 um   **d(0.9):** 449.177 um

---



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060		3.900		53.000		149.000		420.000		2000.000	
	0.00		2.49		2.05		8.30		3.95		0.00
0.120		7.800		63.000		177.000		500.000		4000.000	
	0.00		3.52		2.62		8.45		2.76		
0.241		15.600		74.000		210.000		590.000			
	0.00		4.59		3.86		8.28		2.15		
0.490		31.000		88.000		250.000		710.000			
	0.00		1.24		5.24		7.79		1.28		
0.980		37.000		105.000		300.000		840.000			
	0.17		1.30		6.51		5.63		0.82		
2.000		44.000		125.000		350.000		1000.000			
	1.51		1.66		7.72		5.42		0.70		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
90_100e

Sample Source & type:

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 2:32:30 p.m.

Analysed:
Tuesday, 26 June 2007 2:32:31 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.198 %

Sensitivity:
Enhanced

Obscuration:
12.43 %

Result Emulation:
Off

Concentration:
0.0561 %Vol

Specific Surface Area:
0.161 m²/g

Span :
2.799

Surface Weighted Mean D[3,2]:
37.289 um

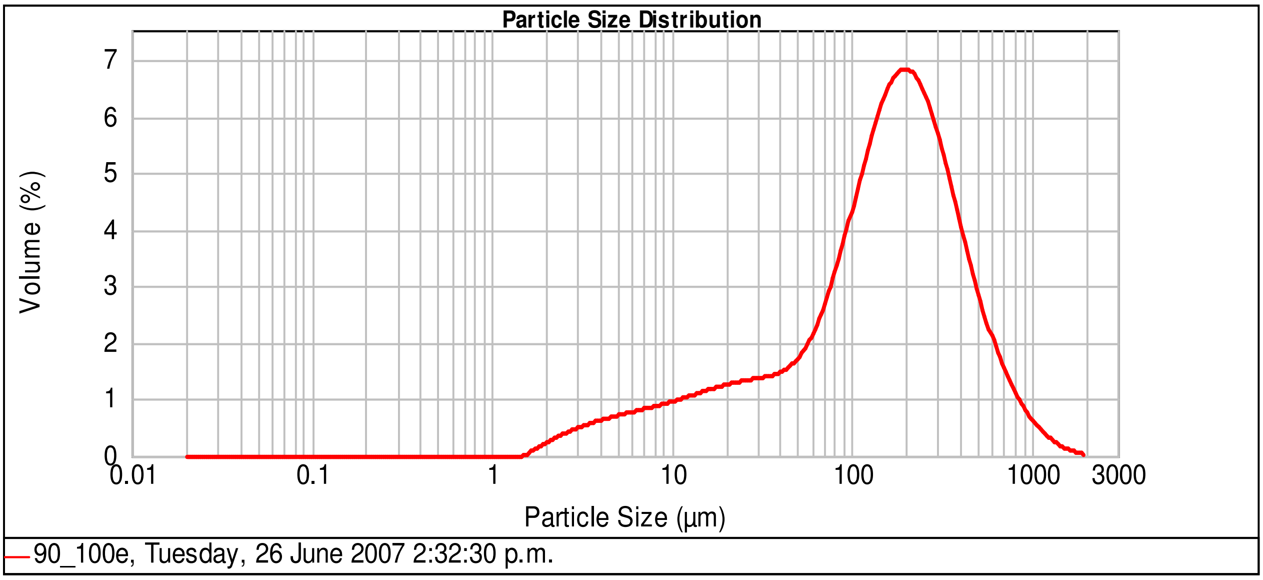
Uniformity:
0.89

Vol. Weighted Mean D[4,3]:
212.677 um

Result units:
Volume

d(0.1): 15.434 um **d(0.5):** 159.467 um **d(0.9):** 461.814 um

---



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.20
2.000	1.94
3.900	

Size (µm)	Volume In %
3.900	3.39
7.800	4.54
15.600	5.77
31.000	1.62
37.000	1.68
44.000	2.03
53.000	

Size (µm)	Volume In %
53.000	2.27
63.000	2.65
74.000	3.64
88.000	4.75
105.000	5.79
125.000	6.84
149.000	

Size (µm)	Volume In %
149.000	7.41
177.000	7.64
210.000	7.62
250.000	7.30
300.000	5.38
350.000	5.25
420.000	

Size (µm)	Volume In %
420.000	3.89
500.000	2.76
590.000	2.20
710.000	1.35
840.000	0.93
1000.000	1.11
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
80_90e

Sample Source & type:
A9

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 2:19:31 p.m.

Analysed:
Tuesday, 26 June 2007 2:19:32 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.321 %

Sensitivity:
Enhanced

Obscuration:
12.82 %

Result Emulation:
Off

Concentration:
0.0698 %Vol

Specific Surface Area:
0.135 m²/g

Span :
2.661

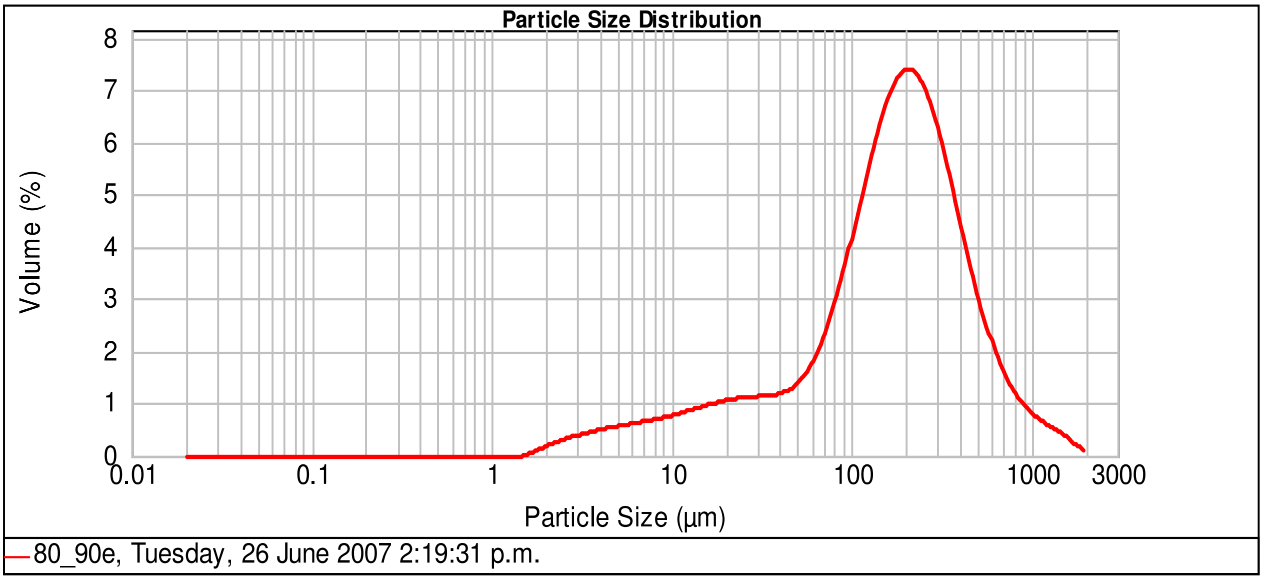
Surface Weighted Mean D[3,2]:
44.520 um

Uniformity:
0.862

Vol. Weighted Mean D[4,3]:
237.479 um

Result units:
Volume

d(0.1): 20.700 um **d(0.5):** 177.331 um **d(0.9):** 492.546 um



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.060	0.00	3.900	2.70	53.000	1.88	149.000	7.83	420.000	4.16	2000.000	0.00
0.120	0.00	7.800	3.70	63.000	2.29	177.000	8.24	500.000	2.88	4000.000	
0.241	0.00	15.600	4.85	74.000	3.31	210.000	8.33	590.000	2.25		
0.490	0.00	31.000	1.34	88.000	4.53	250.000	8.04	710.000	1.42		
0.980	0.15	37.000	1.36	105.000	5.76	300.000	5.92	840.000	1.07		
2.000	1.55	44.000	1.64	125.000	7.04	350.000	5.72	1000.000	2.07		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
70_80e

Sample Source & type:
A8

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 2:07:25 p.m.

Analysed:
Tuesday, 26 June 2007 2:07:26 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.260 %

Sensitivity:
Enhanced

Obscuration:
19.24 %

Result Emulation:
Off

Concentration:
0.0891 %Vol

Specific Surface Area:
0.162 m²/g

Span :
2.401

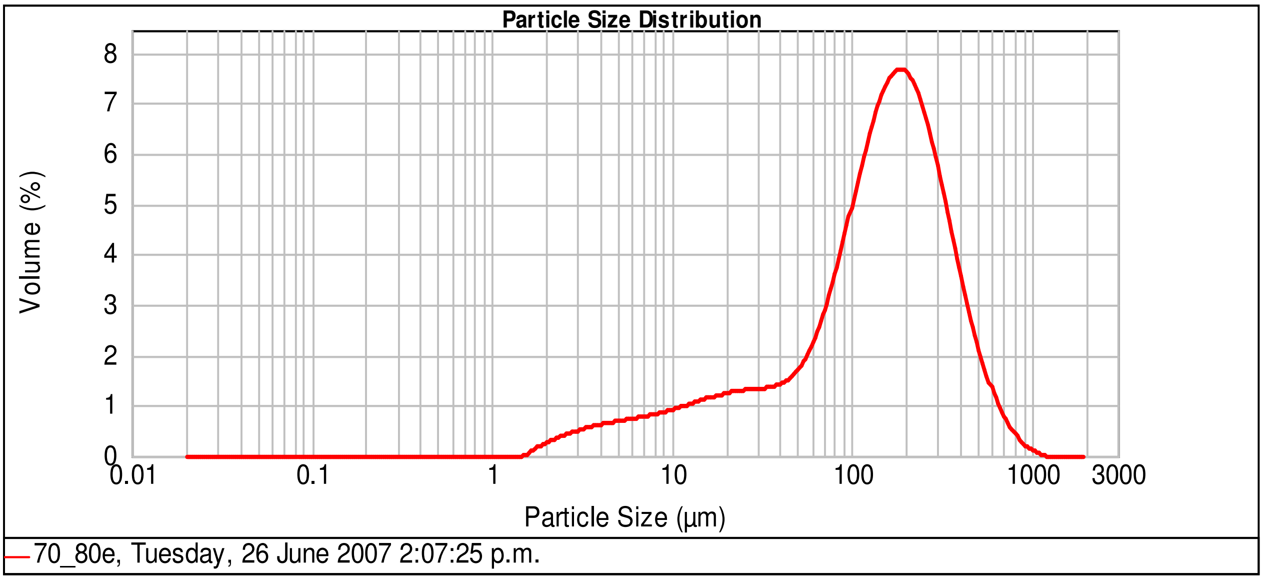
Surface Weighted Mean D[3,2]:
36.946 um

Uniformity:
0.741

Vol. Weighted Mean D[4,3]:
179.807 um

Result units:
Volume

d(0.1): 15.906 um **d(0.5):** 149.396 um **d(0.9):** 374.623 um



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.23
2.000	1.99
3.900	

Size (µm)	Volume In %
3.900	3.26
7.800	4.38
15.600	5.67
31.000	1.57
37.000	1.62
44.000	1.99
53.000	

Size (µm)	Volume In %
53.000	2.32
63.000	2.83
74.000	4.04
88.000	5.41
105.000	6.68
125.000	7.89
149.000	

Size (µm)	Volume In %
149.000	8.46
177.000	8.56
210.000	8.28
250.000	7.59
300.000	5.28
350.000	4.77
420.000	

Size (µm)	Volume In %
420.000	3.15
500.000	1.93
590.000	1.25
710.000	0.57
840.000	0.24
1000.000	0.05
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
60_70e

SOP Name:
Marine Sediment

Measured:
Tuesday, 26 June 2007 1:54:33 p.m.

Sample Source & type:
A7

Measured by:
gmdr1

Analysed:
Tuesday, 26 June 2007 1:54:34 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
10.62 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.222 %

Result Emulation:
Off

Concentration:
0.0327 %Vol

Span :
2.905

Uniformity:
0.919

Result units:
Volume

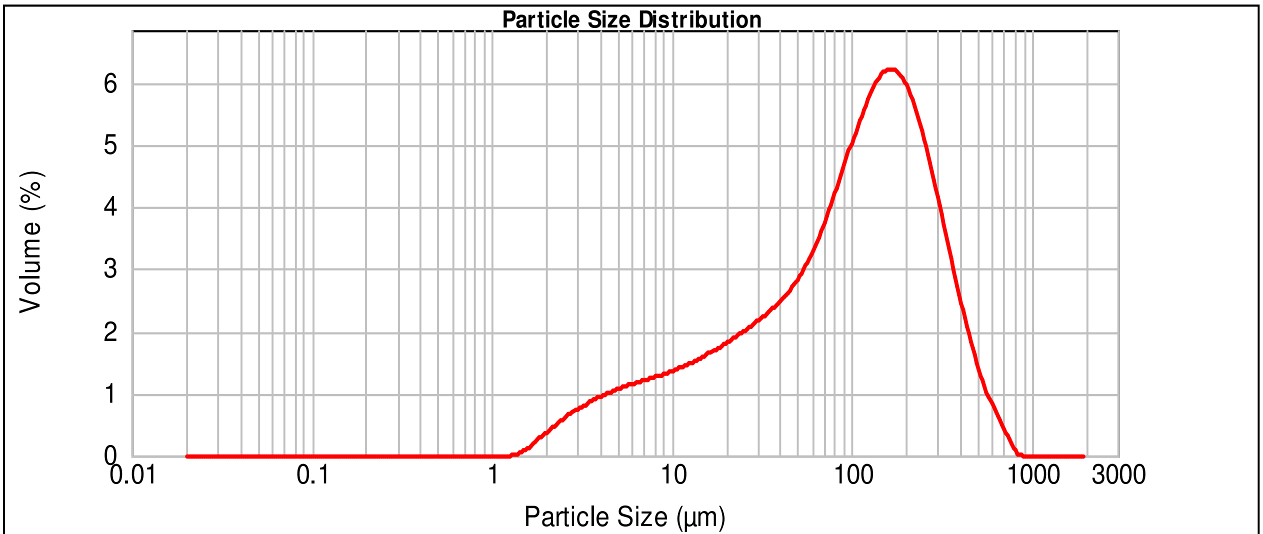
Specific Surface Area:
0.231 m²/g

Surface Weighted Mean D[3,2]:
26.018 um

Vol. Weighted Mean D[4,3]:
138.983 um

d(0.1): 9.497 um **d(0.5):** 105.709 um **d(0.9):** 316.566 um

---



60_70e, Tuesday, 26 June 2007 1:54:33 p.m.

Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.060	0.00	3.900	5.01	53.000	3.55	149.000	6.99	420.000	2.15	2000.000	0.00
0.120	0.00	7.800	6.39	63.000	3.79	177.000	6.76	500.000	1.26	4000.000	
0.241	0.00	15.600	8.50	74.000	4.74	210.000	6.29	590.000	0.73		
0.490	0.00	31.000	2.65	88.000	5.62	250.000	5.58	710.000	0.18		
0.980	0.41	37.000	2.82	105.000	6.29	300.000	3.77	840.000	0.00		
2.000	2.92	44.000	3.36	125.000	6.90	350.000	3.33	1000.000	0.00		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
50_60e

SOP Name:
Marine Sediment

Measured:
Tuesday, 26 June 2007 1:23:12 p.m.

Sample Source & type:
A6

Measured by:
gmdr1

Analysed:
Tuesday, 26 June 2007 1:23:13 p.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
16.54 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.263 %

Result Emulation:
Off

Concentration:
0.0688 %Vol

Span :
2.533

Uniformity:
0.785

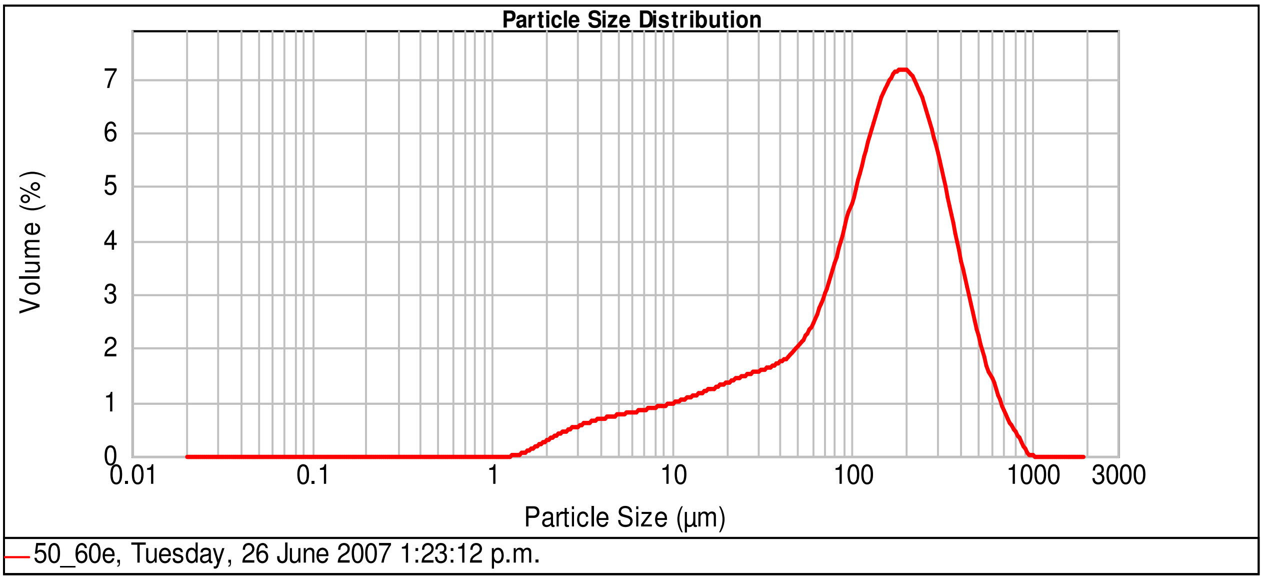
Result units:
Volume

Specific Surface Area:
0.177 m²/g

Surface Weighted Mean D[3,2]:
33.874 um

Vol. Weighted Mean D[4,3]:
175.943 um

d(0.1): 14.228 um **d(0.5): 143.754 um** **d(0.9): 378.377 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.33
2.000	2.18
3.900	

Size (μm)	Volume In %
3.900	3.56
7.800	4.64
15.600	6.30
31.000	1.89
37.000	1.98
44.000	2.38
53.000	

Size (μm)	Volume In %
53.000	2.61
63.000	2.97
74.000	4.02
88.000	5.17
105.000	6.24
125.000	7.31
149.000	

Size (μm)	Volume In %
149.000	7.85
177.000	8.00
210.000	7.84
250.000	7.32
300.000	5.20
350.000	4.81
420.000	

Size (μm)	Volume In %
420.000	3.28
500.000	2.06
590.000	1.34
710.000	0.60
840.000	0.15
1000.000	0.00
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
40_50e

Sample Source & type:
A5

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 1:05:27 p.m.

Analysed:
Tuesday, 26 June 2007 1:05:28 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.246 %

Sensitivity:
Enhanced

Obscuration:
12.13 %

Result Emulation:
Off

Concentration:
0.0508 %Vol

Specific Surface Area:
0.173 m²/g

Span :
2.834

Surface Weighted Mean D[3,2]:
34.640 um

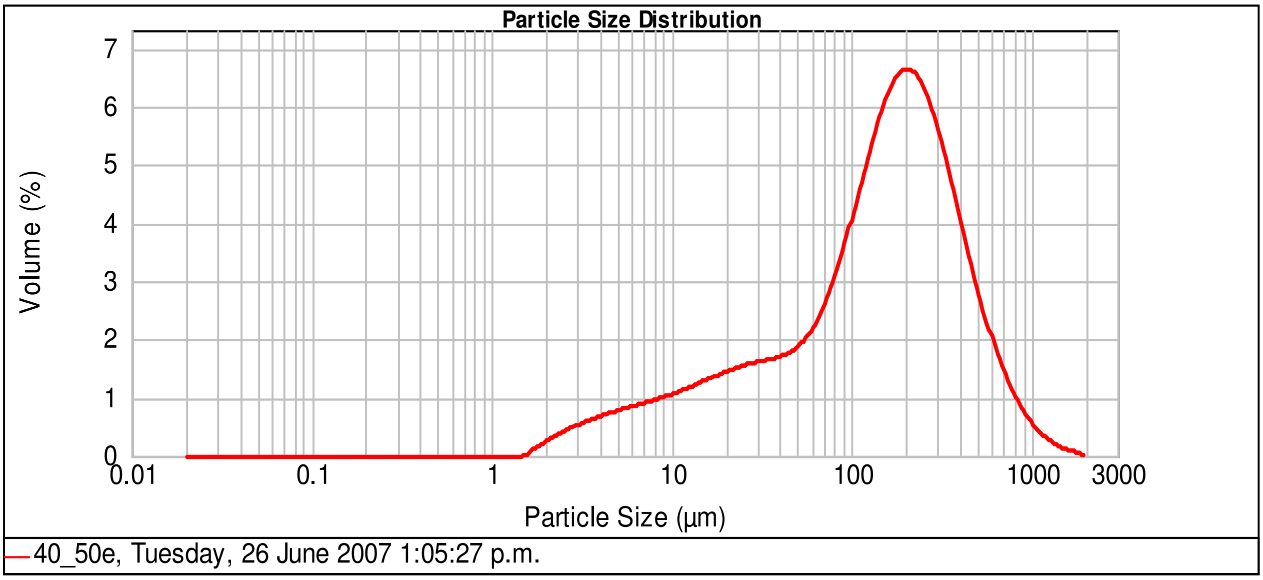
Uniformity:
0.912

Vol. Weighted Mean D[4,3]:
204.784 um

Result units:
Volume

d(0.1): 13.718 um **d(0.5):** 153.902 um **d(0.9):** 449.802 um

---



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.22
2.000	2.09
3.900	

Size (μm)	Volume In %
3.900	3.71
7.800	5.05
15.600	6.68
31.000	1.91
37.000	1.94
44.000	2.23
53.000	

Size (μm)	Volume In %
53.000	2.35
63.000	2.61
74.000	3.48
88.000	4.48
105.000	5.46
125.000	6.50
149.000	

Size (μm)	Volume In %
149.000	7.11
177.000	7.41
210.000	7.45
250.000	7.19
300.000	5.31
350.000	5.19
420.000	

Size (μm)	Volume In %
420.000	3.82
500.000	2.68
590.000	2.09
710.000	1.25
840.000	0.83
1000.000	0.96
2000.000	

Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

Result Analysis Report

Sample Name:
30_40e

Sample Source & type:
A4

Sample bulk lot ref:

SOP Name:
Marine Sediment

Measured by:
gmdr1

Result Source:
Measurement

Measured:
Tuesday, 26 June 2007 12:50:59 p.m.

Analysed:
Tuesday, 26 June 2007 12:51:00 p.m.

Particle Name:
Marine Sediment

Particle RI:
1.500

Dispersant Name:
Water

Accessory Name:
None

Absorption:
0

Dispersant RI:
1.330

Analysis model:
General purpose

Size range:
0.020 to 2000.000 um

Weighted Residual:
0.373 %

Sensitivity:
Enhanced

Obscuration:
13.59 %

Result Emulation:
Off

Concentration:
0.0642 %Vol

Specific Surface Area:
0.155 m²/g

Span :
2.364

Surface Weighted Mean D[3,2]:
38.784 um

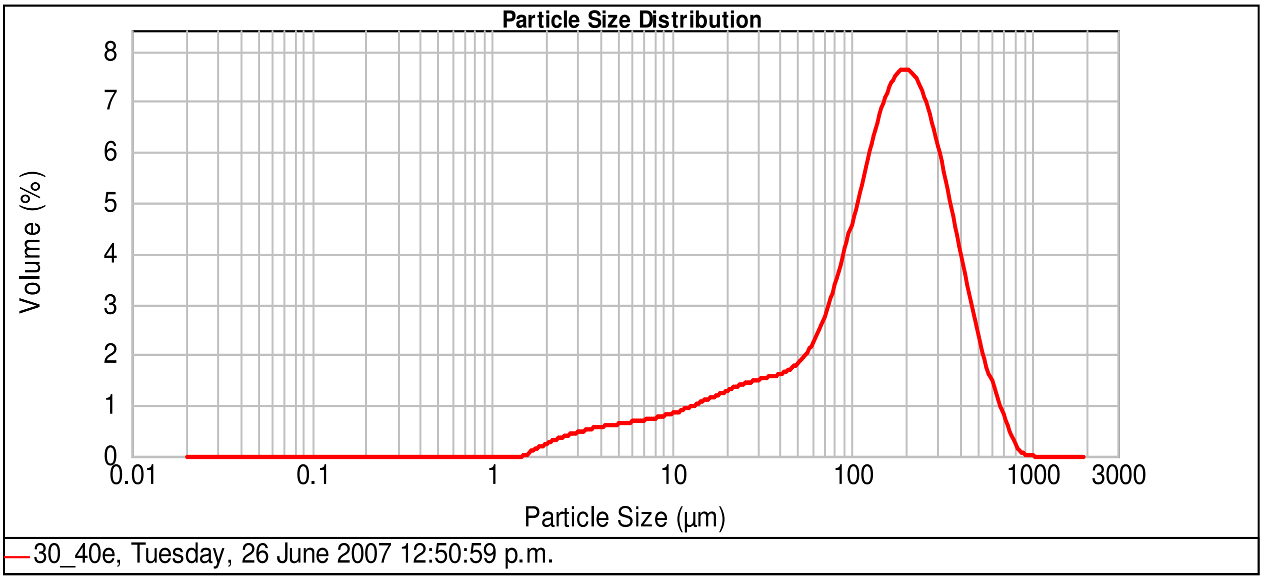
Uniformity:
0.725

Vol. Weighted Mean D[4,3]:
182.424 um

Result units:
Volume

d(0.1): 17.671 um **d(0.5):** 154.203 um **d(0.9):** 382.184 um

---



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.060	0.00	3.900	2.96	53.000	2.36	149.000	8.22	420.000	3.55	2000.000	0.00
0.120	0.00	7.800	4.05	63.000	2.72	177.000	8.52	500.000	2.17	4000.000	
0.241	0.00	15.600	5.99	74.000	3.77	210.000	8.45	590.000	1.32		
0.490	0.00	31.000	1.79	88.000	5.01	250.000	7.97	710.000	0.41		
0.980	0.22	37.000	1.84	105.000	6.23	300.000	5.69	840.000	0.04		
2.000	1.84	44.000	2.16	125.000	7.49	350.000	5.26	1000.000	0.00		
3.900		53.000		149.000		420.000		2000.000			

Operator notes:

MASTERSIZER 2000

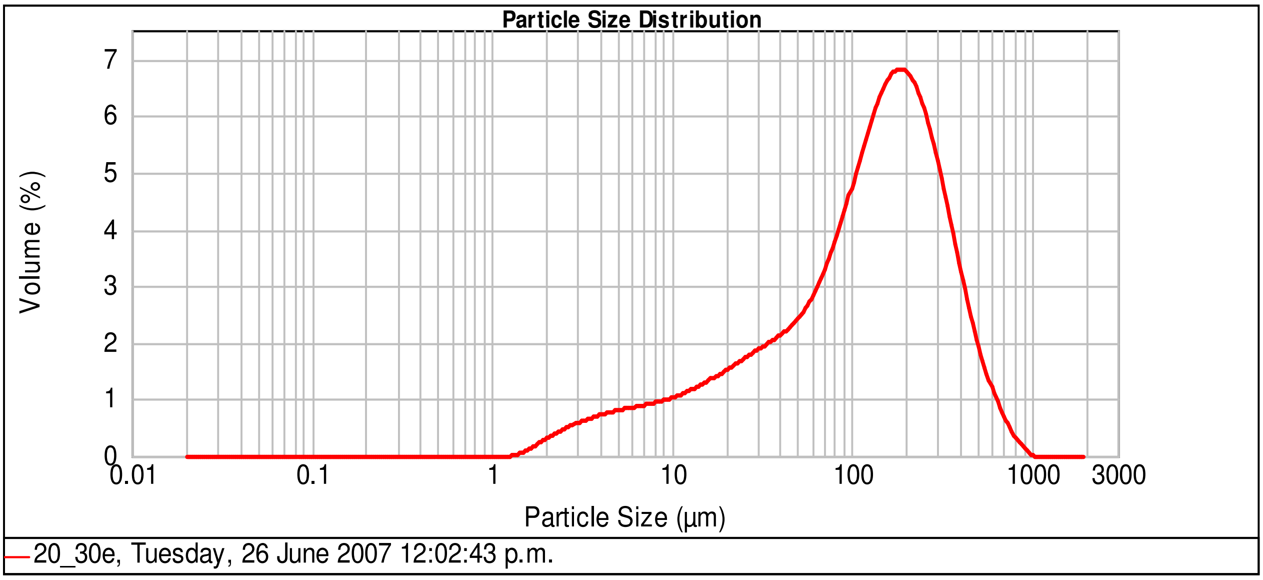
Result Analysis Report

Sample Name: 20_30e	**SOP Name:** Marine Sediment	**Measured:** Tuesday, 26 June 2007 12:02:43 p.m.
Sample Source & type: A3	**Measured by:** gmdr1	**Analysed:** Tuesday, 26 June 2007 12:02:44 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 12.40 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.221 %	**Result Emulation:** Off

Concentration: 0.0475 %Vol	**Span :** 2.632	**Uniformity:** 0.828	**Result units:** Volume
Specific Surface Area: 0.188 m²/g	**Surface Weighted Mean D[3,2]:** 31.901 um	**Vol. Weighted Mean D[4,3]:** 164.188 um	

d(0.1): 13.275 um **d(0.5): 131.404 um** **d(0.9): 359.096 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.35
2.000	2.29
3.900	

Size (µm)	Volume In %
3.900	3.75
7.800	4.92
15.600	7.19
31.000	2.28
37.000	2.42
44.000	2.87
53.000	

Size (µm)	Volume In %
53.000	3.03
63.000	3.30
74.000	4.25
88.000	5.25
105.000	6.17
125.000	7.10
149.000	

Size (µm)	Volume In %
149.000	7.53
177.000	7.61
210.000	7.39
250.000	6.83
300.000	4.78
350.000	4.35
420.000	

Size (µm)	Volume In %
420.000	2.89
500.000	1.76
590.000	1.11
710.000	0.45
840.000	0.13
1000.000	0.00
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MASTERSIZER 2000

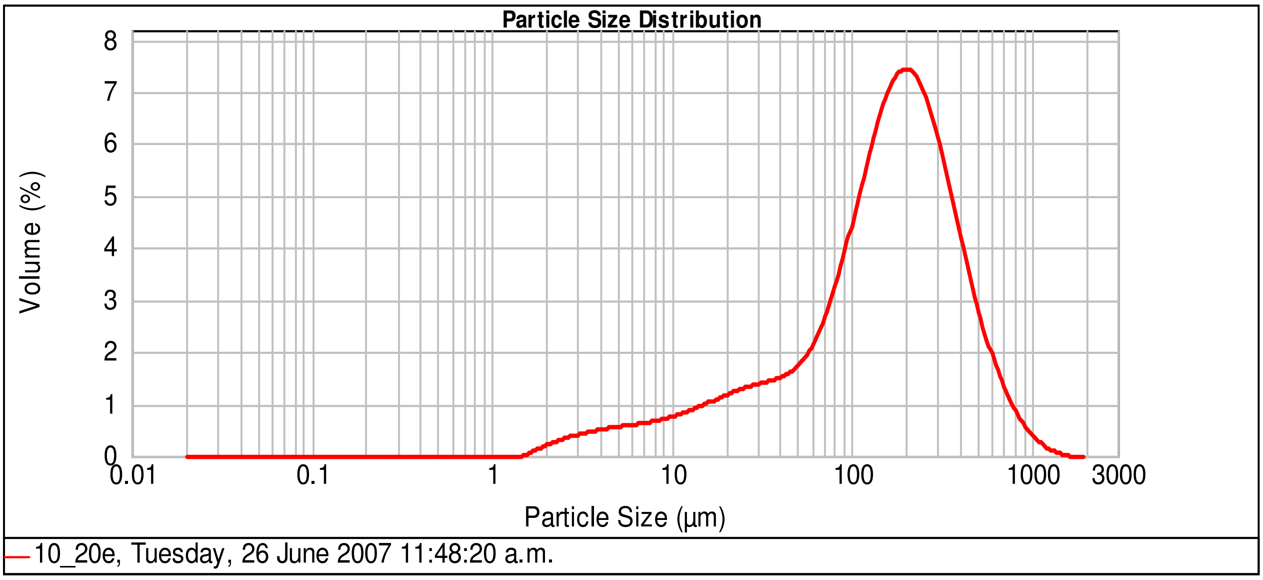
Result Analysis Report

Sample Name: 10_20e	**SOP Name:** Marine Sediment	**Measured:** Tuesday, 26 June 2007 11:48:20 a.m.
Sample Source & type: A2	**Measured by:** gmdr1	**Analysed:** Tuesday, 26 June 2007 11:48:21 a.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** None	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 11.85 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.262 %	**Result Emulation:** Off

Concentration: 0.0614 %Vol	**Span :** 2.508	**Uniformity:** 0.78	**Result units:** Volume
Specific Surface Area: 0.141 m²/g	**Surface Weighted Mean D[3,2]:** 42.693 um	**Vol. Weighted Mean D[4,3]:** 205.268 um	

d(0.1): 20.375 um **d(0.5): 164.037 um** **d(0.9): 431.816 um**



Size (µm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.18
2.000	1.61
3.900	

Size (µm)	Volume In %
3.900	2.64
7.800	3.65
15.600	5.48
31.000	1.65
37.000	1.71
44.000	2.03
53.000	

Size (µm)	Volume In %
53.000	2.24
63.000	2.61
74.000	3.64
88.000	4.85
105.000	6.04
125.000	7.27
149.000	

Size (µm)	Volume In %
149.000	7.98
177.000	8.30
210.000	8.28
250.000	7.90
300.000	5.74
350.000	5.48
420.000	

Size (µm)	Volume In %
420.000	3.92
500.000	2.65
590.000	1.96
710.000	1.09
840.000	0.64
1000.000	0.46
2000.000	

Size (µm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
0_10e

SOP Name:
Marine Sediment

Measured:
Tuesday, 26 June 2007 11:36:20 a.m.

Sample Source & type:
A1

Measured by:
gmdr1

Analysed:
Tuesday, 26 June 2007 11:36:21 a.m.

Sample bulk lot ref:

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
None

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
10.77 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.861 %

Result Emulation:
Off

Concentration:
0.0320 %Vol

Span :
2.780

Uniformity:
0.89

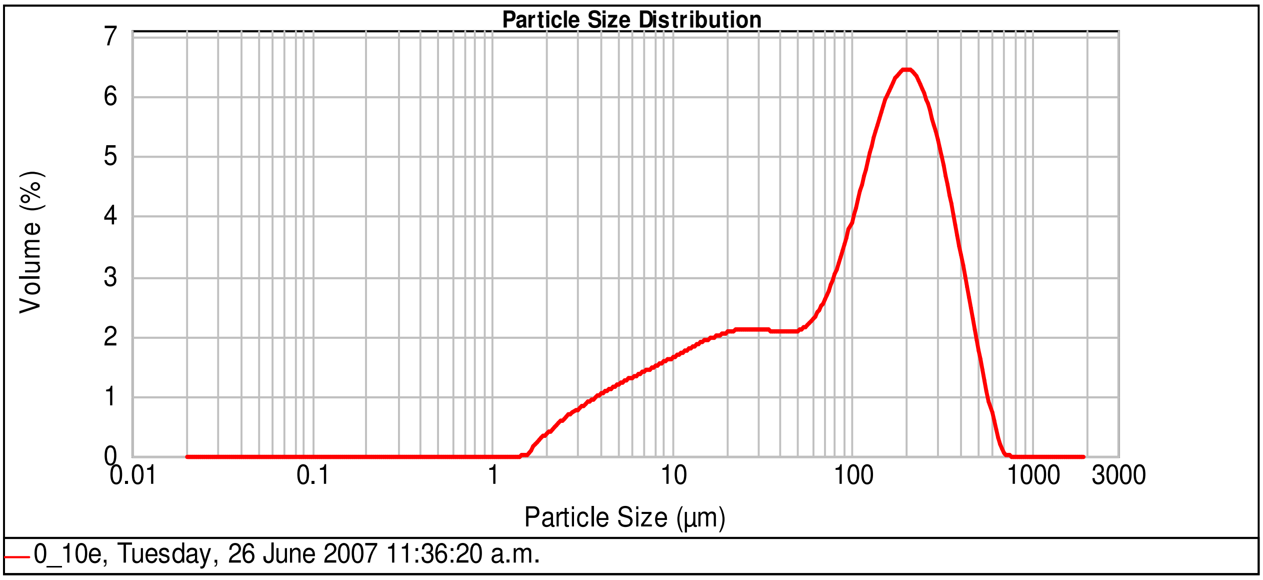
Result units:
Volume

Specific Surface Area:
0.24 m²/g

Surface Weighted Mean D[3,2]:
24.949 um

Vol. Weighted Mean D[4,3]:
148.005 um

d(0.1): 8.590 um **d(0.5): 119.465 um** **d(0.9): 340.646 um**



Size (μm)	Volume In %
0.060	0.00
0.120	0.00
0.241	0.00
0.490	0.00
0.980	0.32
2.000	3.06
3.900	

Size (μm)	Volume In %
3.900	5.67
7.800	7.70
15.600	9.30
31.000	2.43
37.000	2.34
44.000	2.53
53.000	

Size (μm)	Volume In %
53.000	2.49
63.000	2.63
74.000	3.40
88.000	4.32
105.000	5.26
125.000	6.29
149.000	

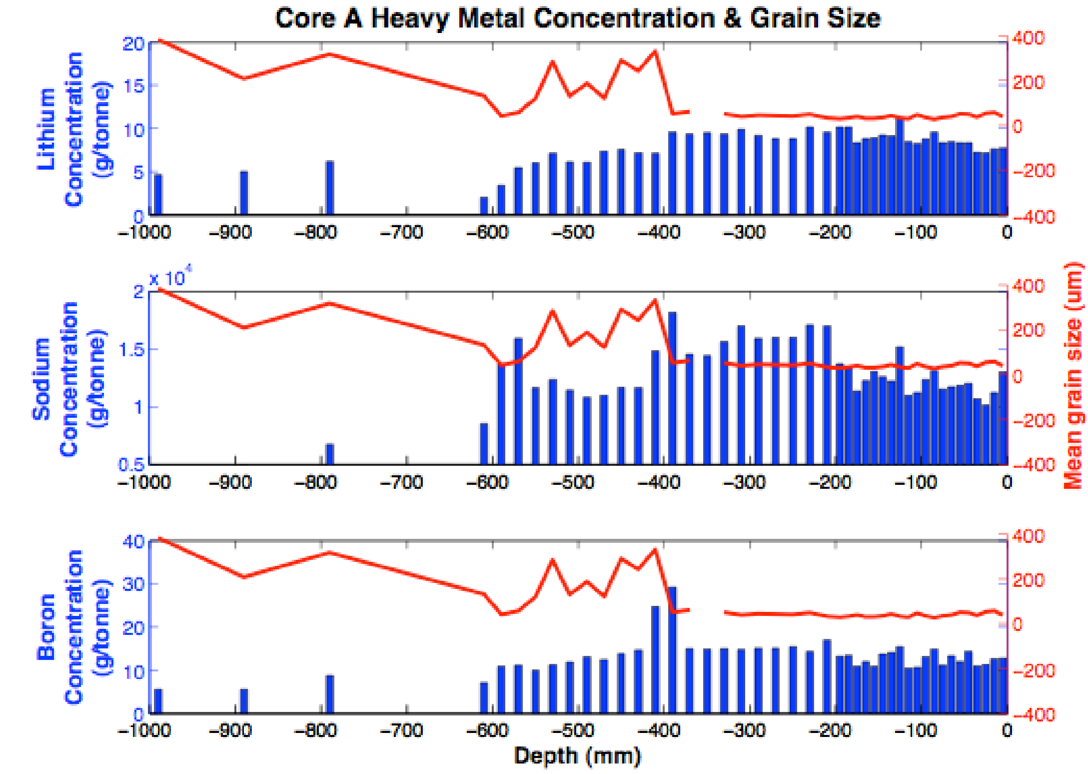
Size (μm)	Volume In %
149.000	6.91
177.000	7.20
210.000	7.20
250.000	6.83
300.000	4.89
350.000	4.49
420.000	

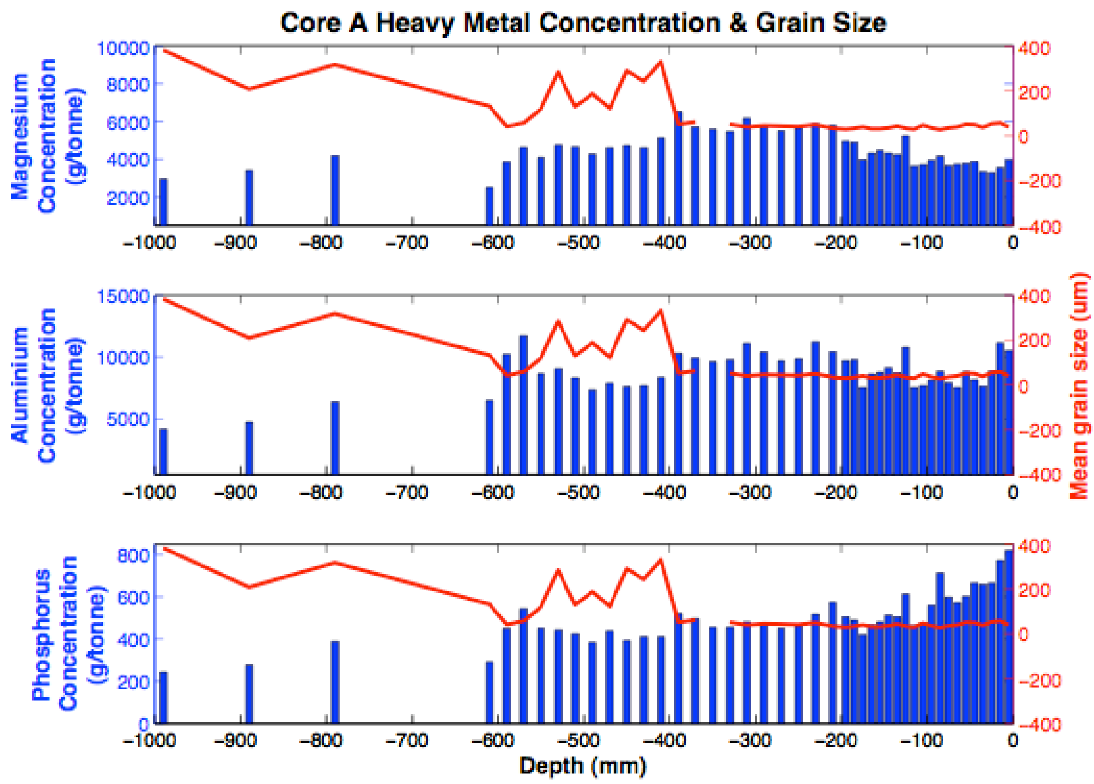
Size (μm)	Volume In %
420.000	2.88
500.000	1.48
590.000	0.36
710.000	0.00
840.000	0.00
1000.000	0.00
2000.000	

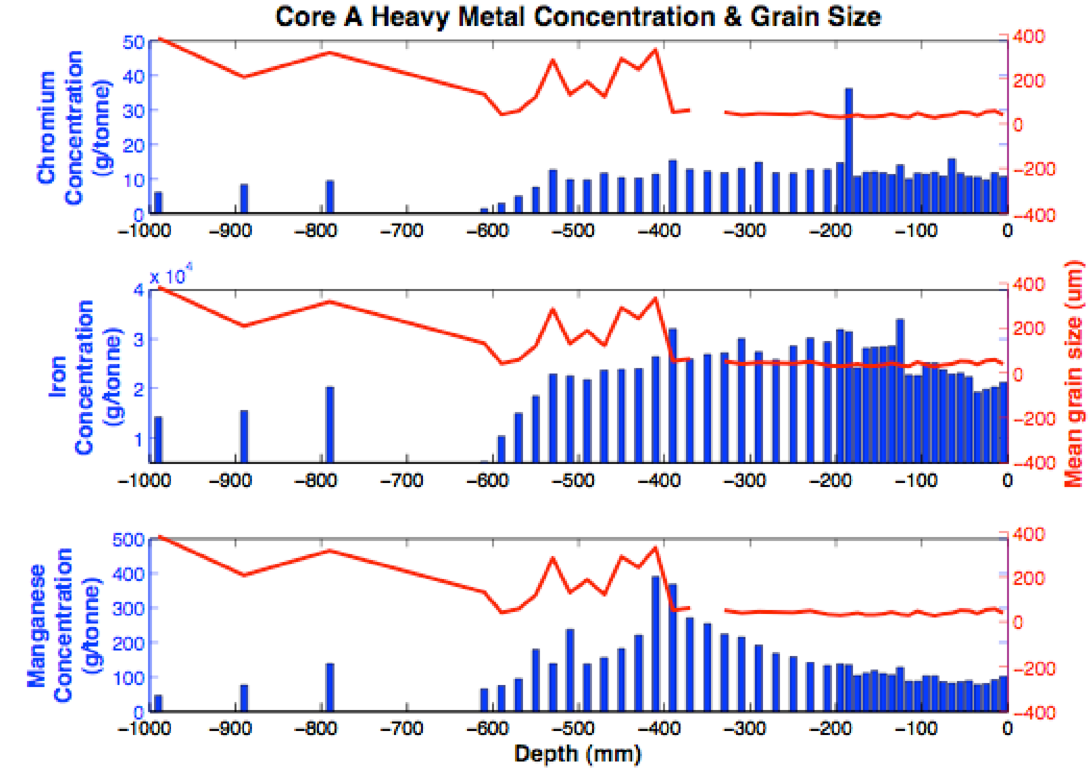
Size (μm)	Volume In %
2000.000	0.00
4000.000	

Operator notes:

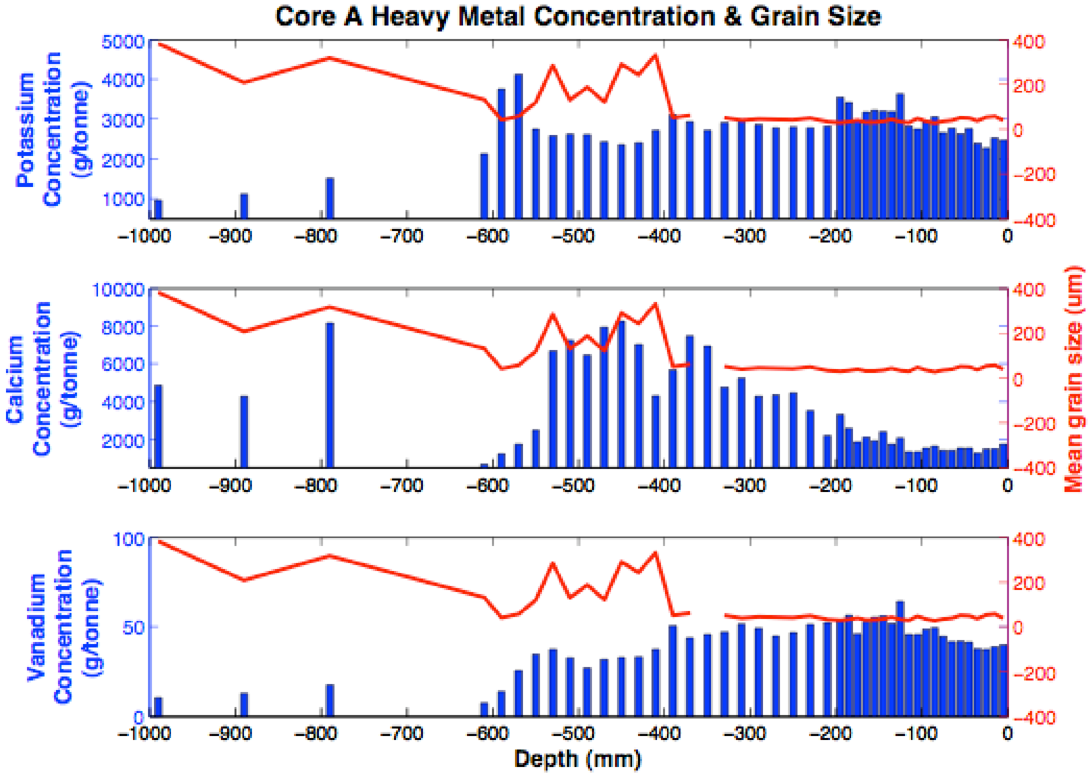
APPENDIX II
Heavy Metal
Concentration Graphs
(Refer to CD ROM- Back Cover)


Core A Heavy Metal Concentration & Grain Size
Lithium Concentration (g/tonne)
Sodium Concentration (g/tonne)
Boron Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

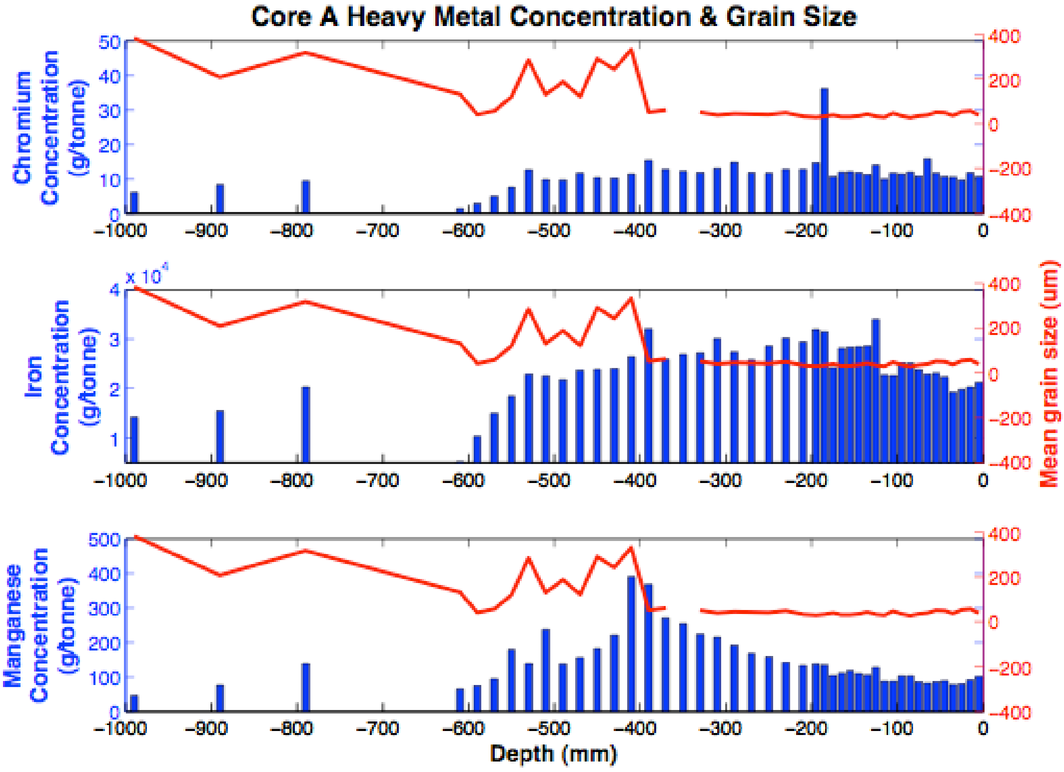

Core A Heavy Metal Concentration & Grain Size
Magnesium Concentration (g/tonne)
Aluminium Concentration (g/tonne)
Phosphorus Concentration (g/tonne)
Mean grain size (um)
Depth (mm)



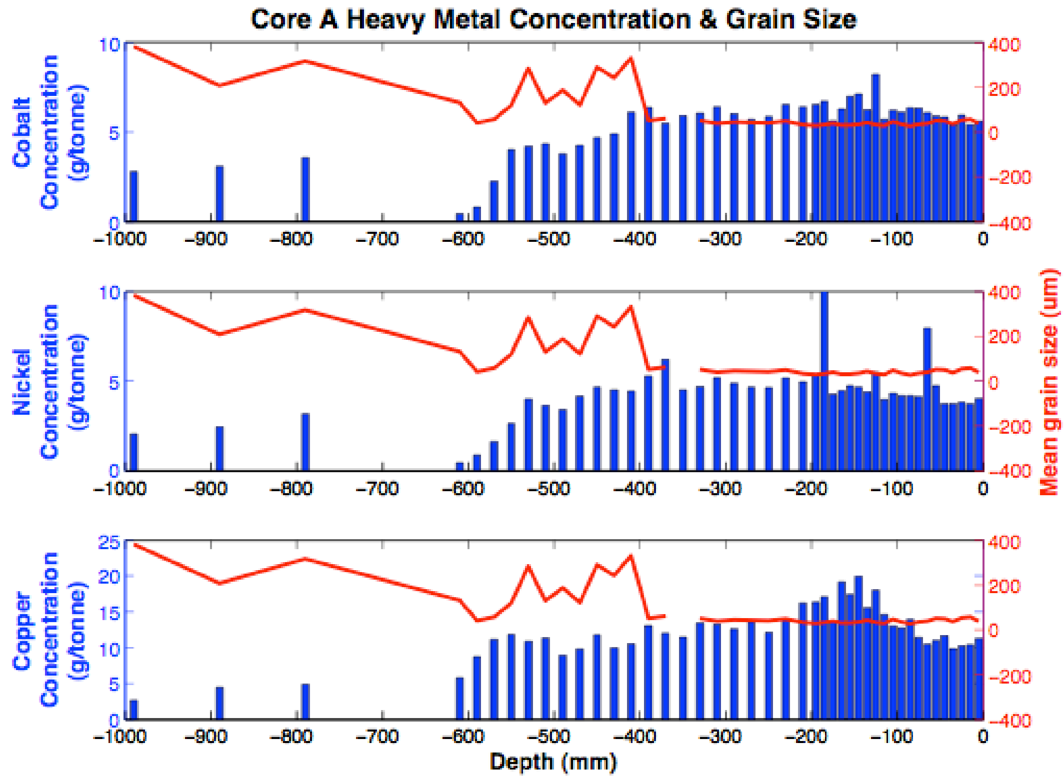
Core A Heavy Metal Concentration & Grain Size
Chromium Concentration (g/tonne)
Iron Concentration (g/tonne)
Manganese Concentration (g/tonne)
Mean grain size (um)
Depth (mm)



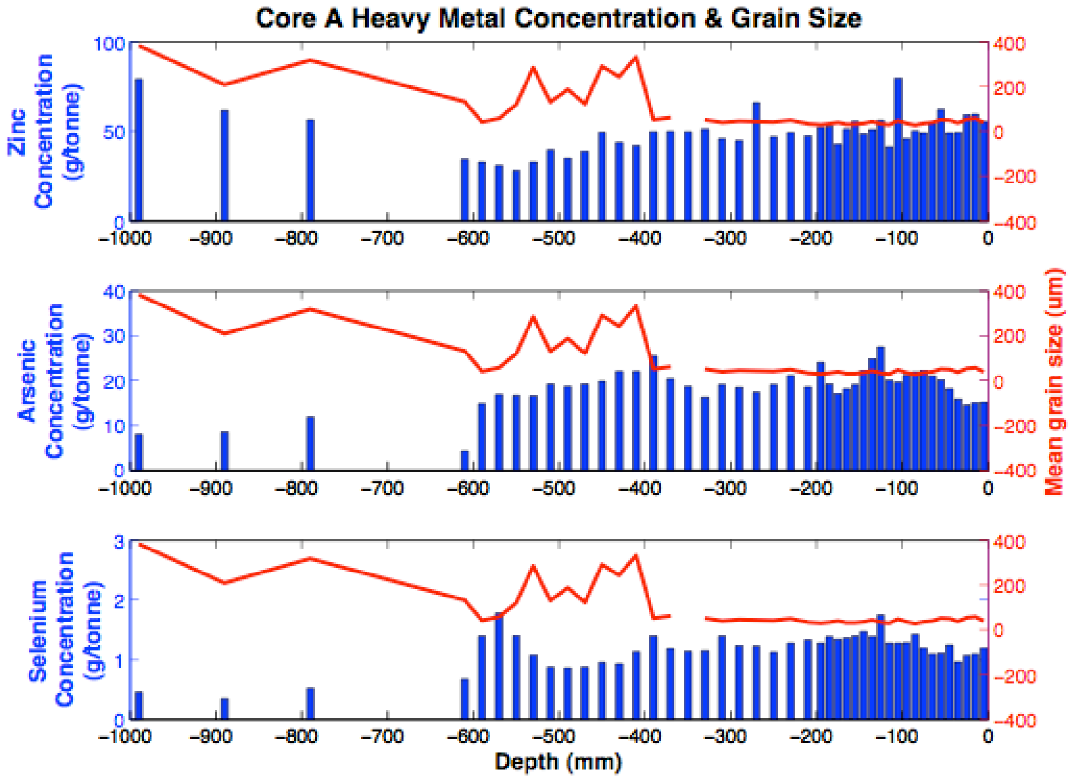
Core A Heavy Metal Concentration & Grain Size
Potassium Concentration (g/tonne)
Calcium Concentration (g/tonne)
Vanadium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

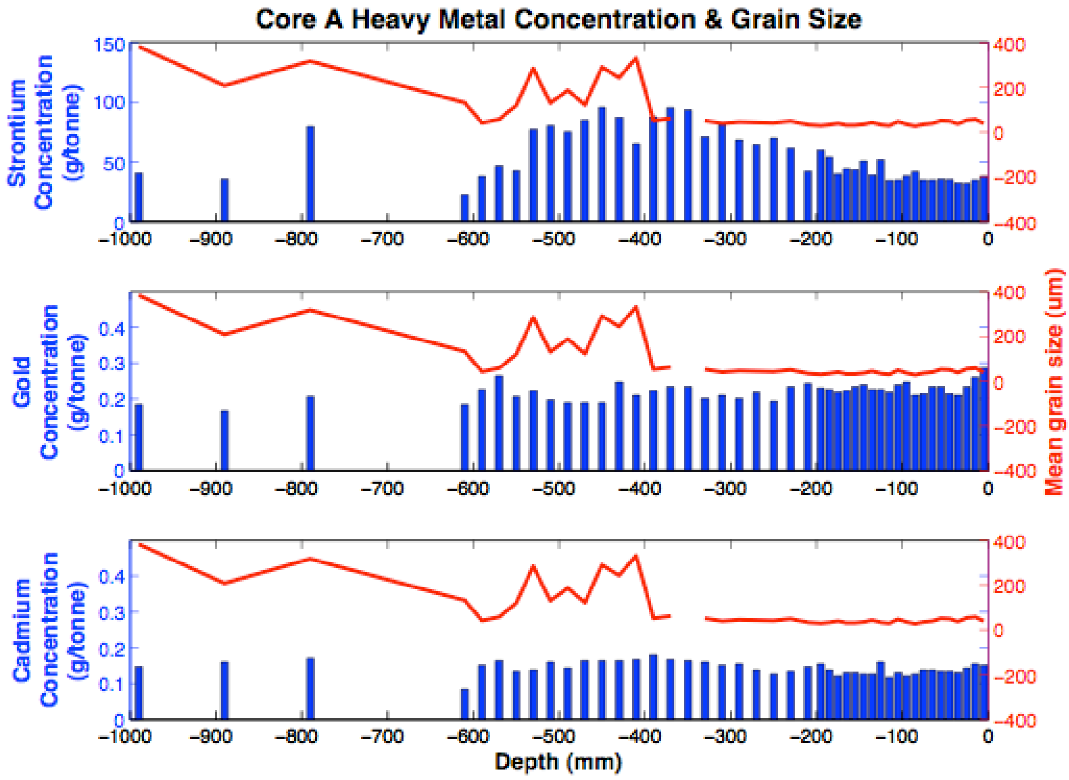


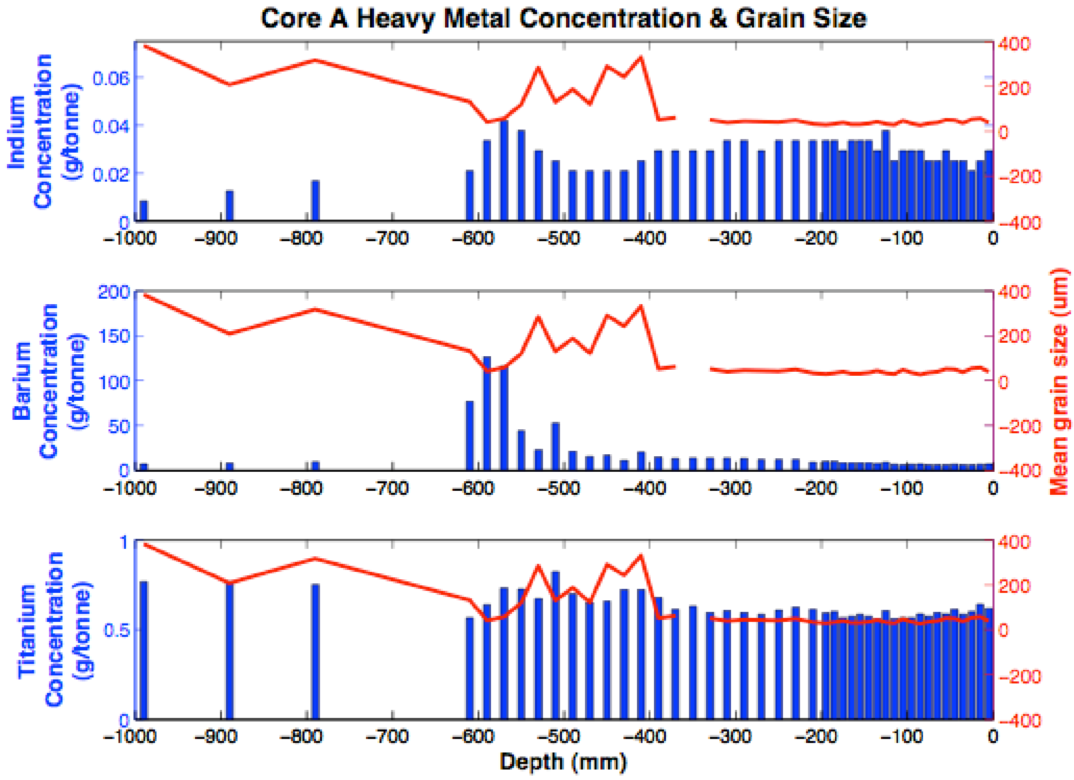
Core A Heavy Metal Concentration & Grain Size
Chromium Concentration (g/tonne)
Iron Concentration (g/tonne)
x 10^4
Manganese Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

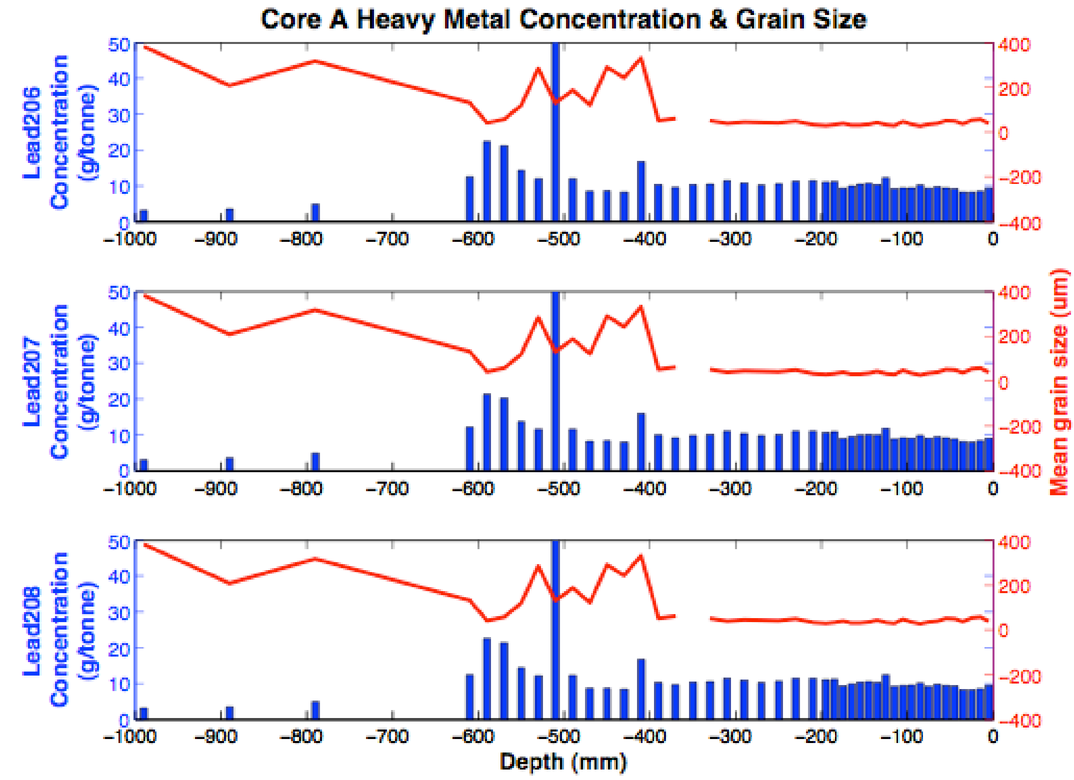


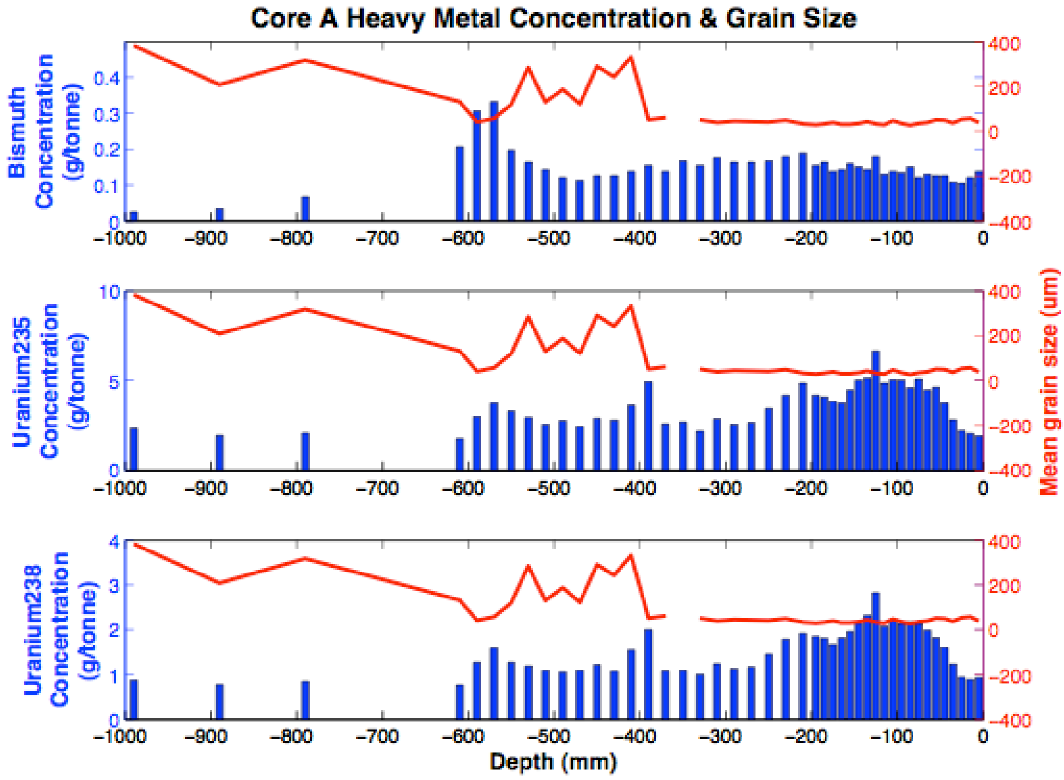
Core A Heavy Metal Concentration & Grain Size
Cobalt Concentration (g/tonne)
Nickel Concentration (g/tonne)
Copper Concentration (g/tonne)
Mean grain size (um)
Depth (mm)


Core A Heavy Metal Concentration & Grain Size
Zinc Concentration (g/tonne)
Arsenic Concentration (g/tonne)
Selenium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

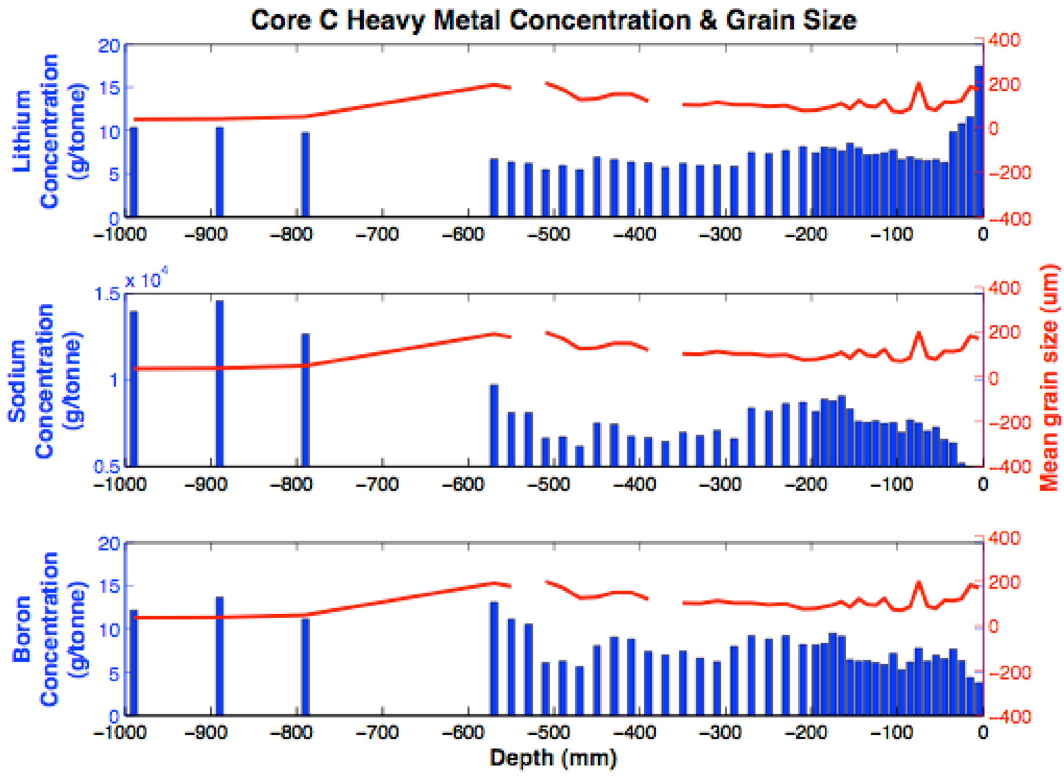

Core A Heavy Metal Concentration & Grain Size
Strontium Concentration (g/tonne)
Gold Concentration (g/tonne)
Cadmium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)


Core A Heavy Metal Concentration & Grain Size
Indium Concentration (g/tonne)
Barium Concentration (g/tonne)
Titanium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

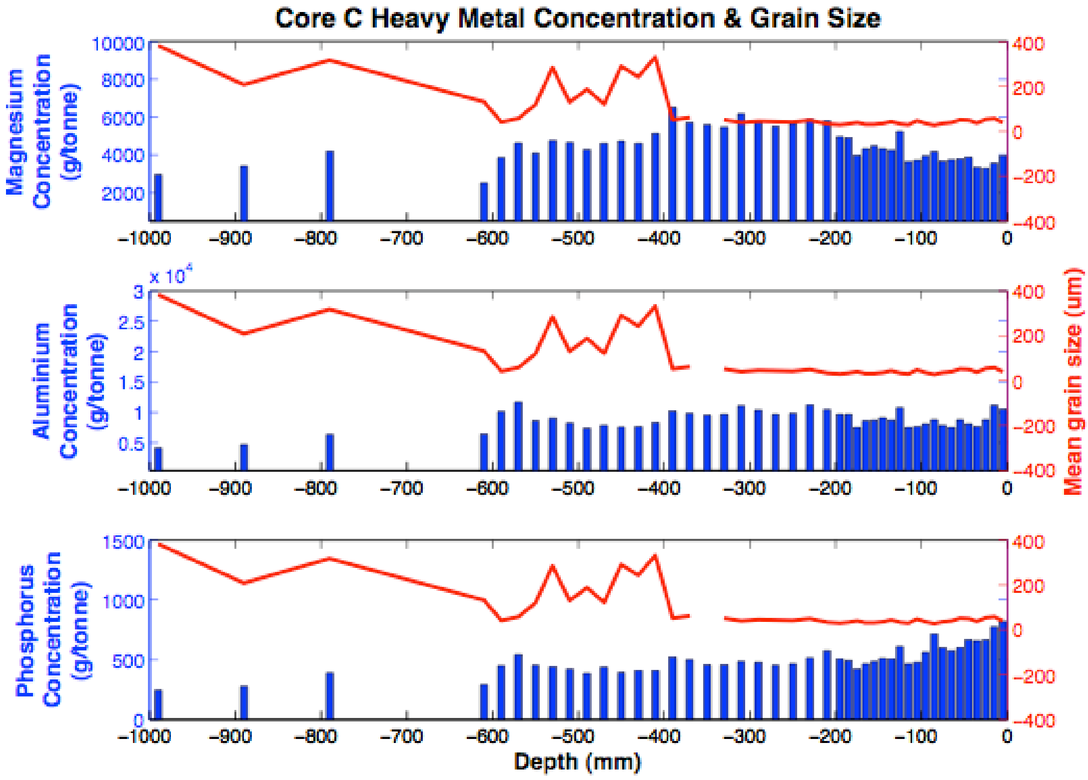

Core A Heavy Metal Concentration & Grain Size
Lead206 Concentration (g/tonne)
Lead207 Concentration (g/tonne)
Lead208 Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

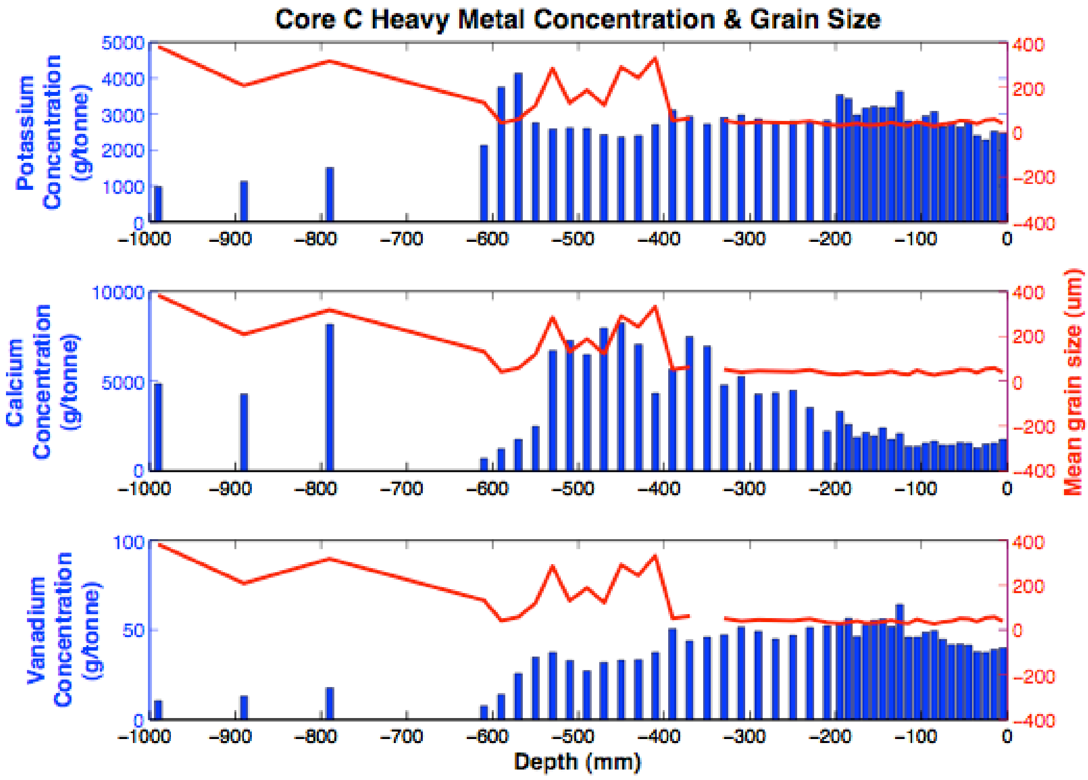


Core A Heavy Metal Concentration & Grain Size
Bismuth Concentration (g/tonne)
Uranium235 Concentration (g/tonne)
Uranium238 Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

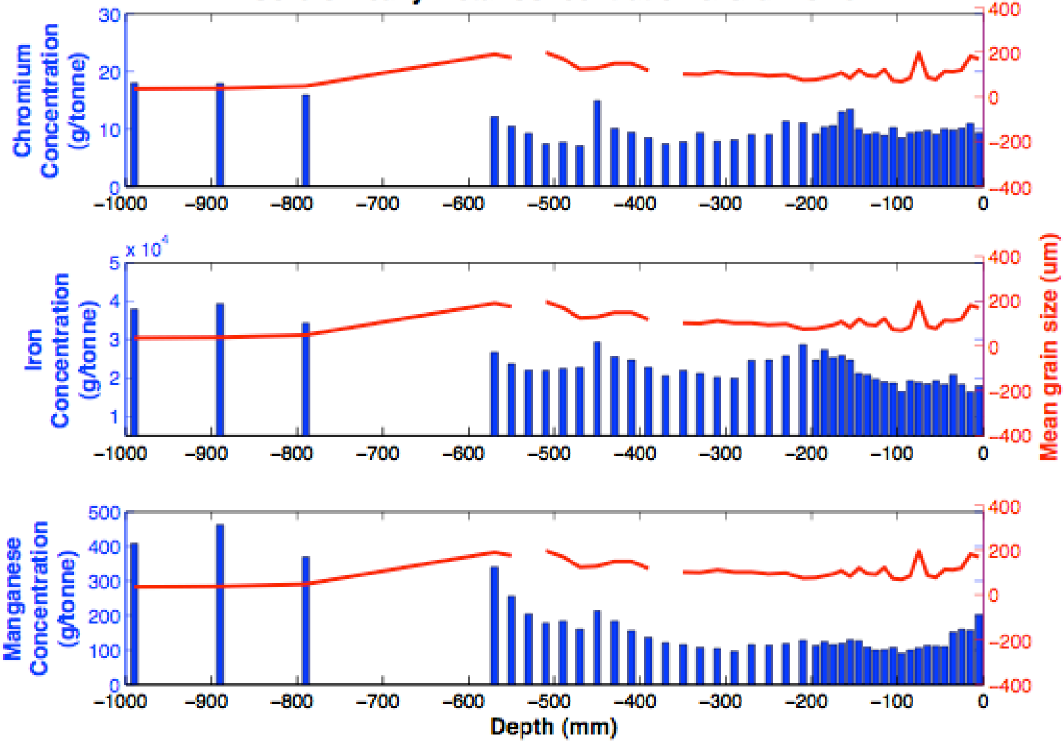


Core C Heavy Metal Concentration & Grain Size
Lithium Concentration (g/tonne)
Sodium Concentration (g/tonne)
x 10^4
Boron Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

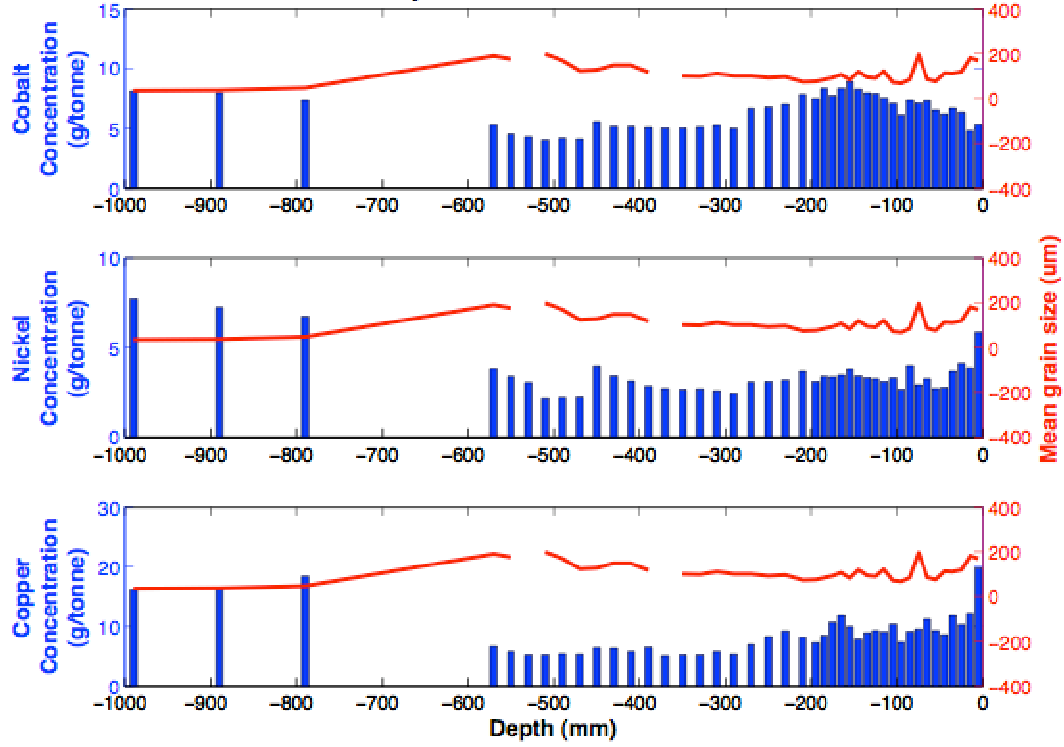

Core C Heavy Metal Concentration & Grain Size
Magnesium Concentration (g/tonne)
Aluminium Concentration (g/tonne)
Phosphorus Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

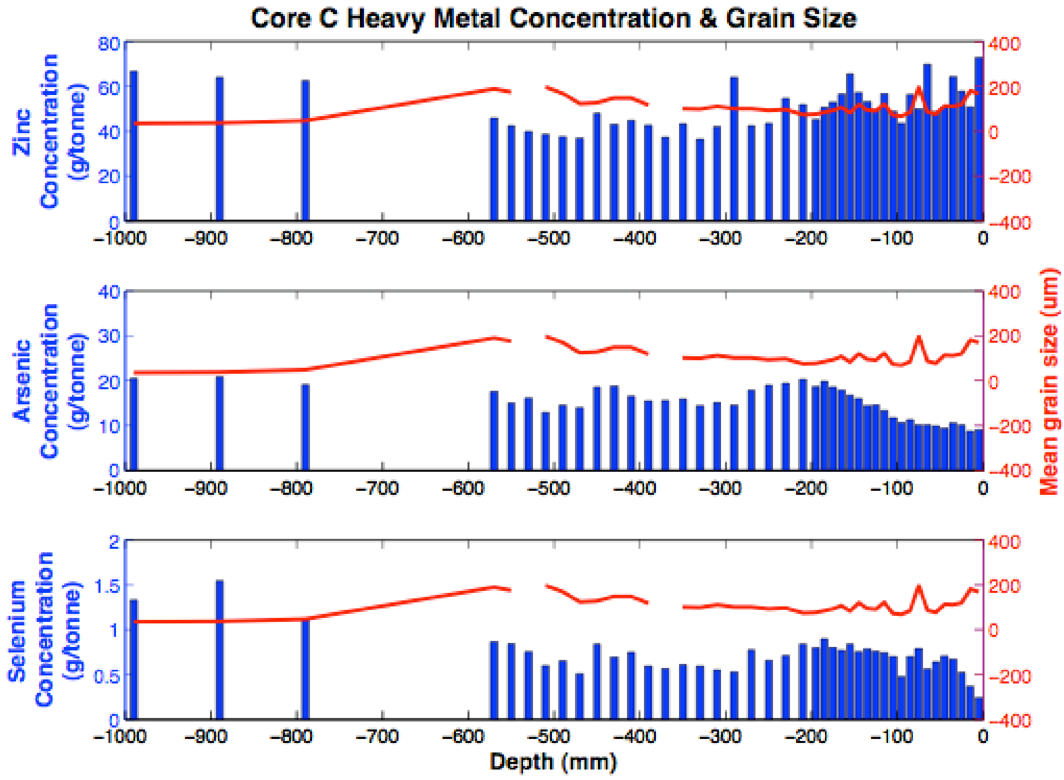

Core C Heavy Metal Concentration & Grain Size
Potassium Concentration (g/tonne)
Calcium Concentration (g/tonne)
Vanadium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

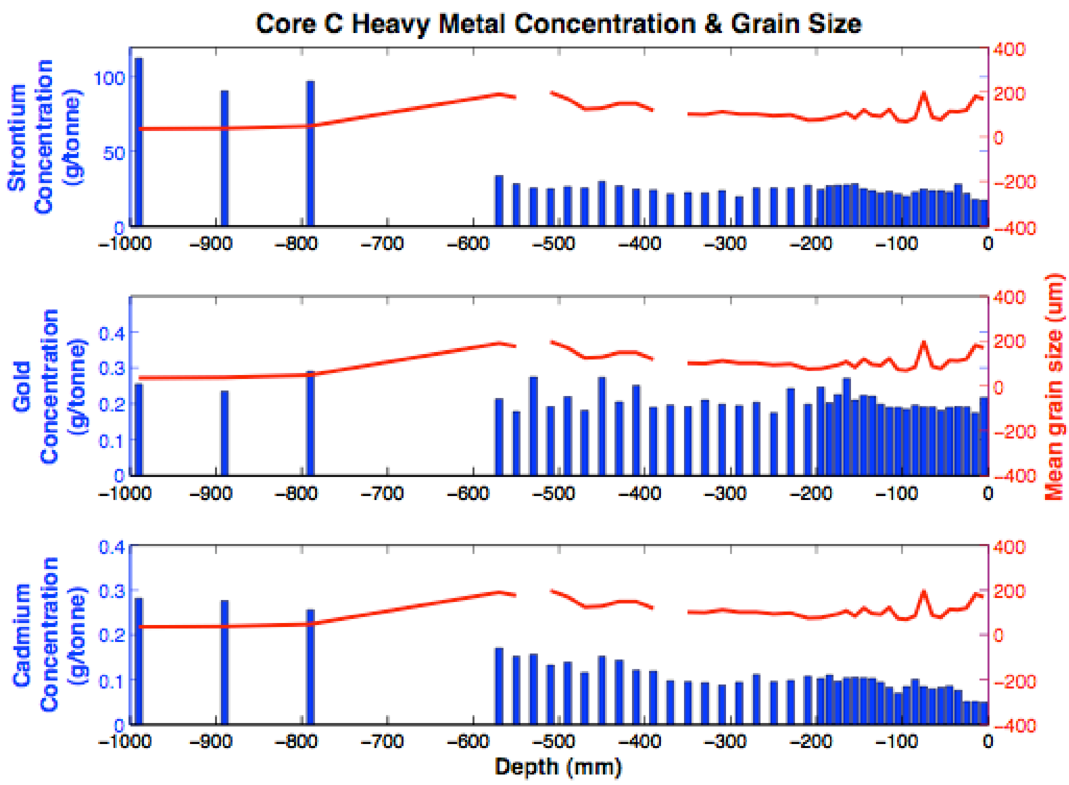
Core C Heavy Metal Concentration & Grain Size

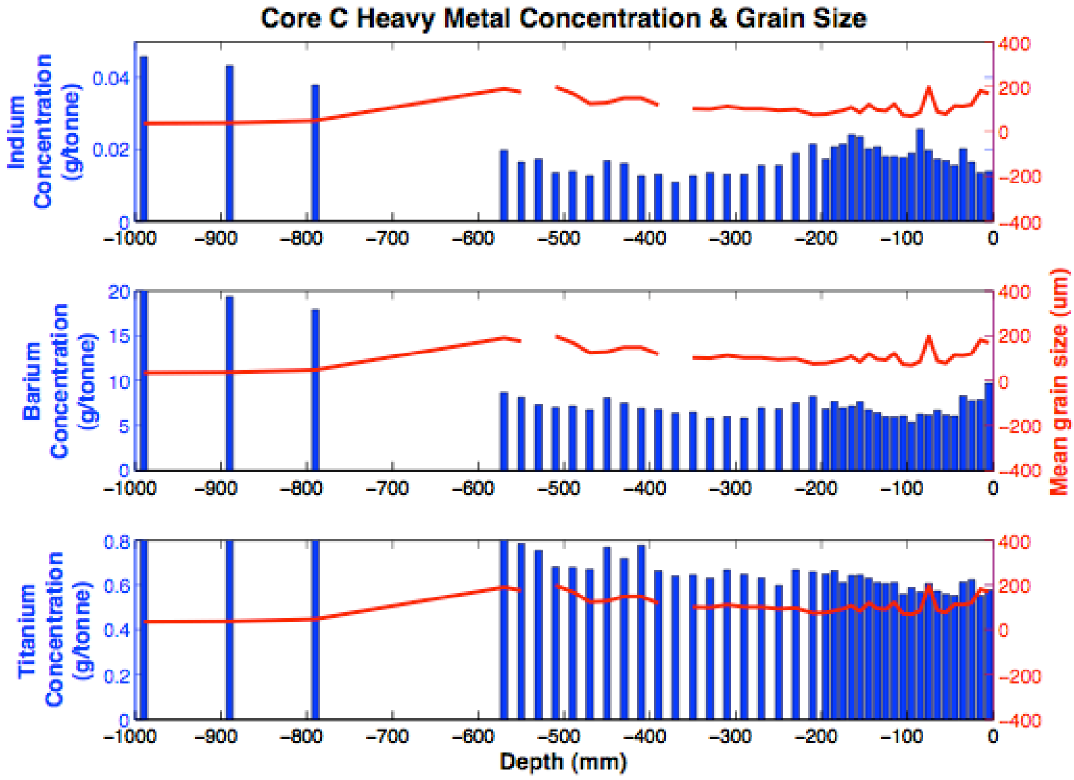


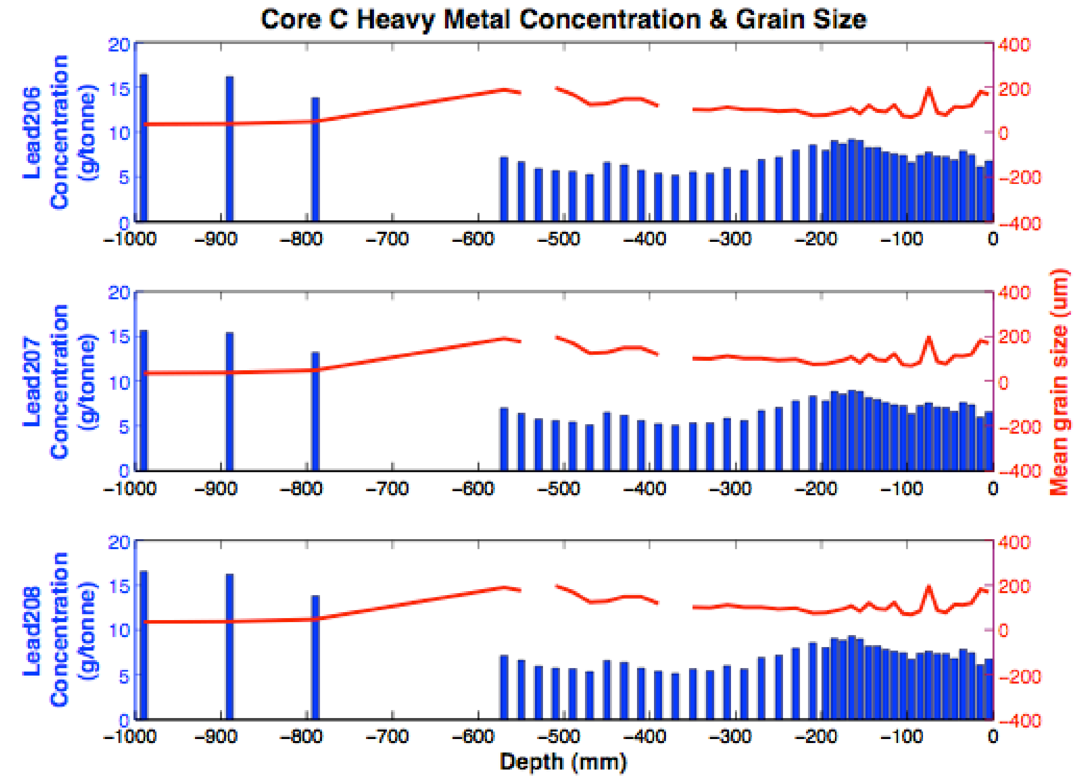
Core C Heavy Metal Concentration & Grain Size

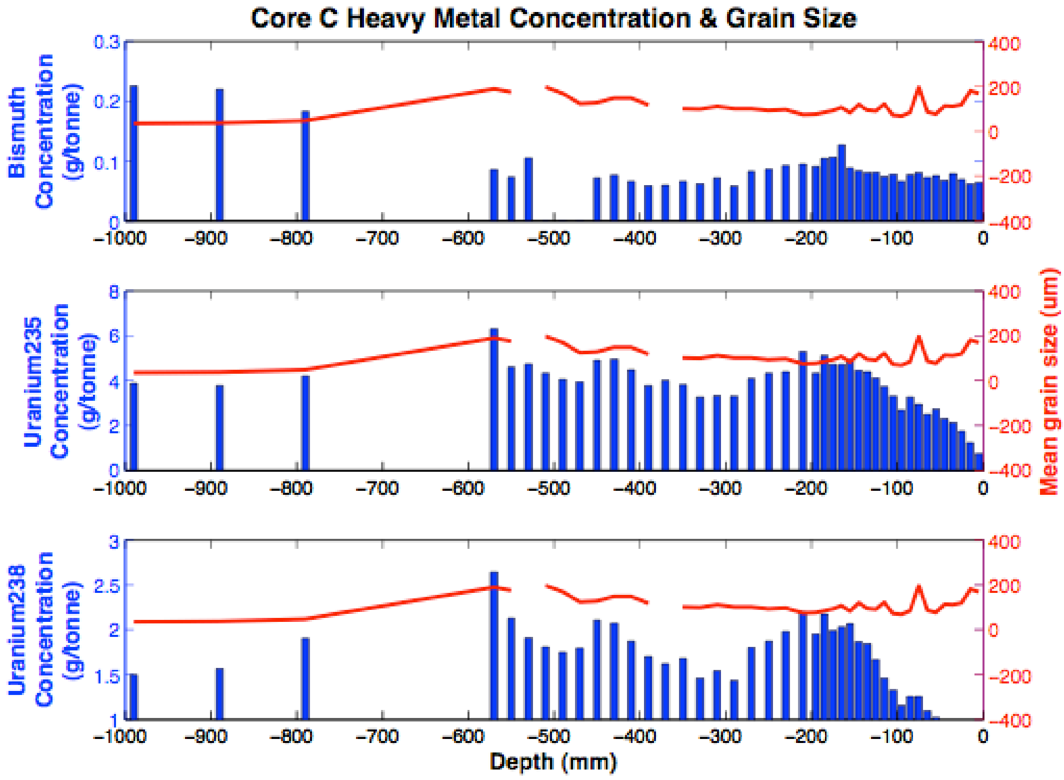


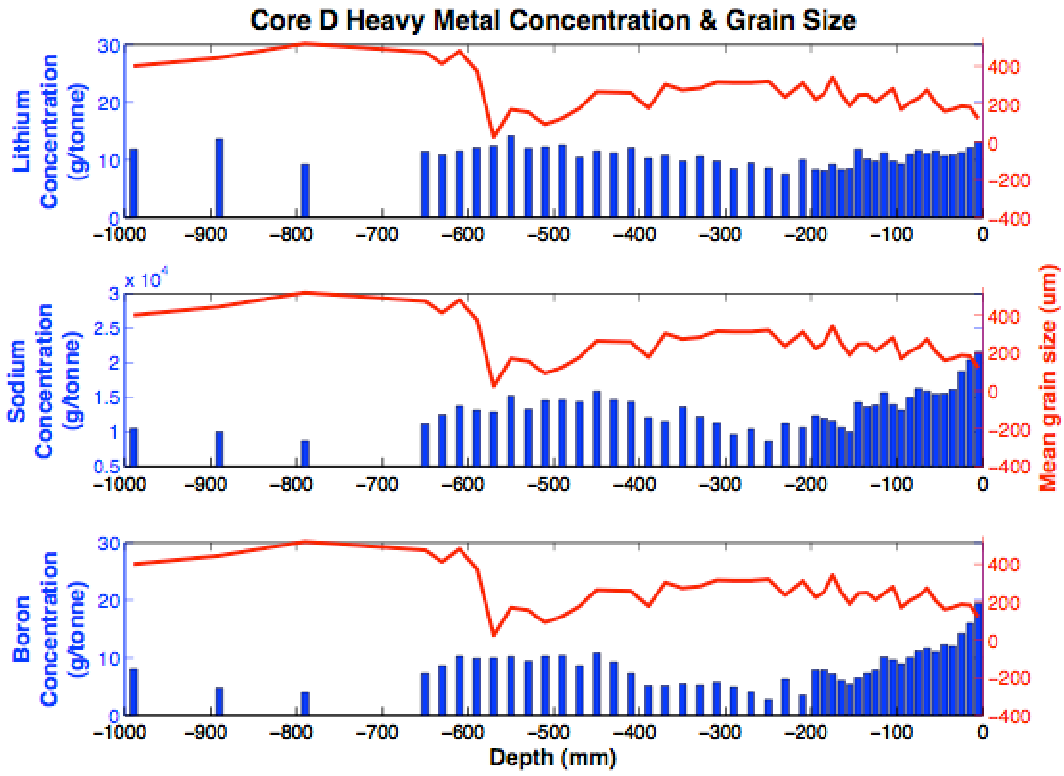

Core C Heavy Metal Concentration & Grain Size
Zinc Concentration (g/tonne)
Arsenic Concentration (g/tonne)
Selenium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

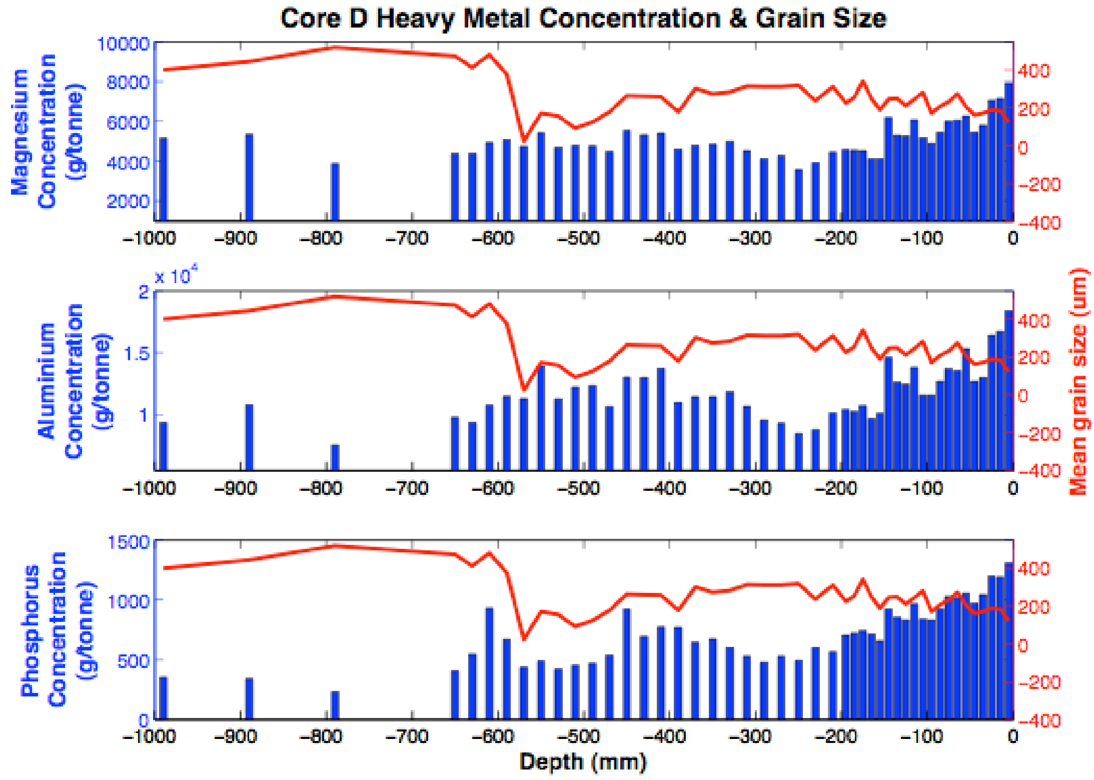

Core C Heavy Metal Concentration & Grain Size
Strontium Concentration (g/tonne)
Gold Concentration (g/tonne)
Cadmium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

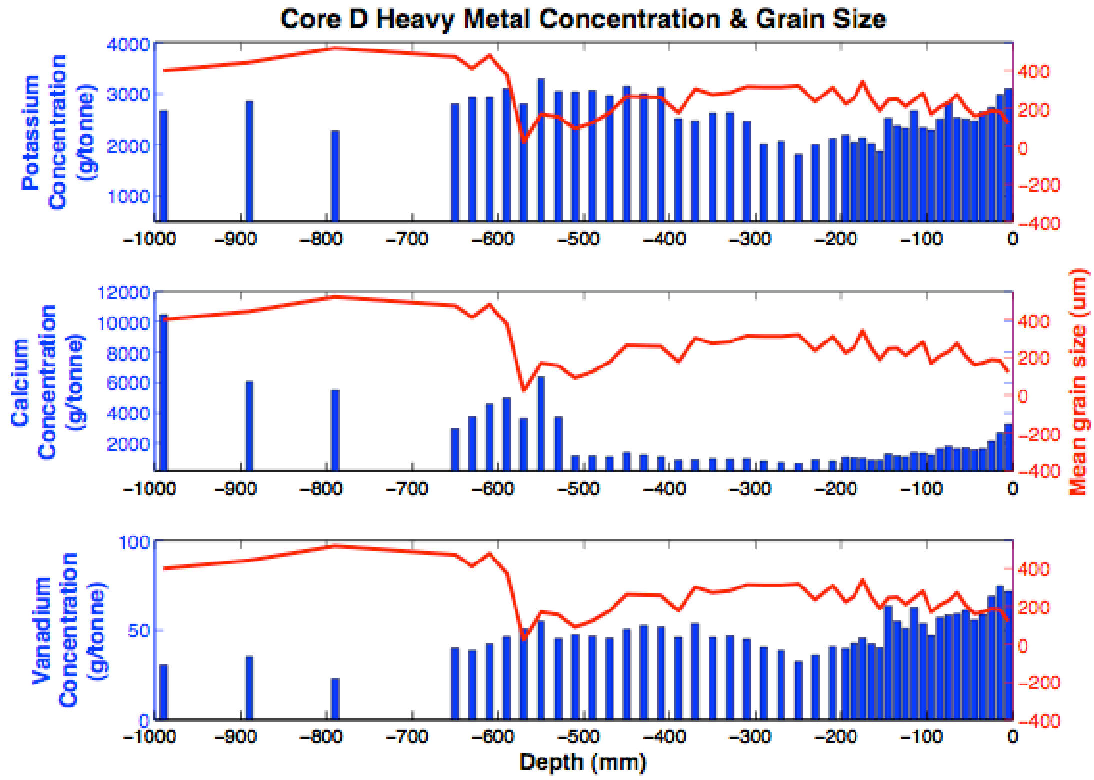

Core C Heavy Metal Concentration & Grain Size
Indium Concentration (g/tonne)
Barium Concentration (g/tonne)
Titanium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

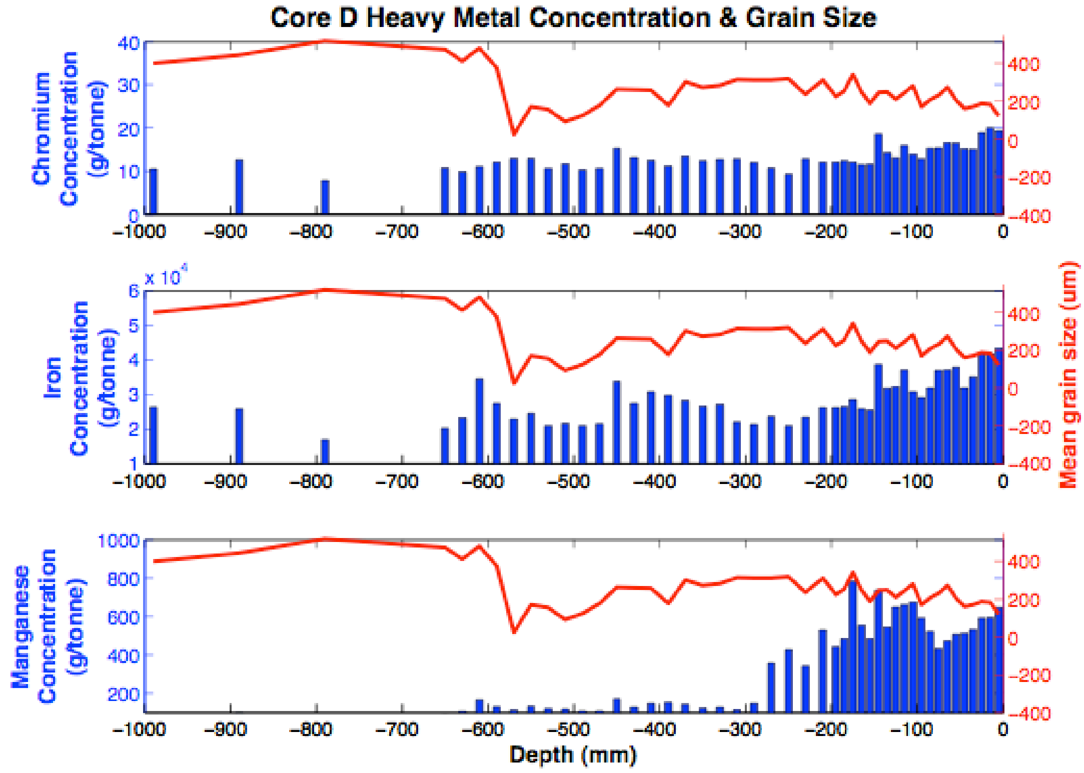

Core C Heavy Metal Concentration & Grain Size
Lead206 Concentration (g/tonne)
Lead207 Concentration (g/tonne)
Lead208 Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

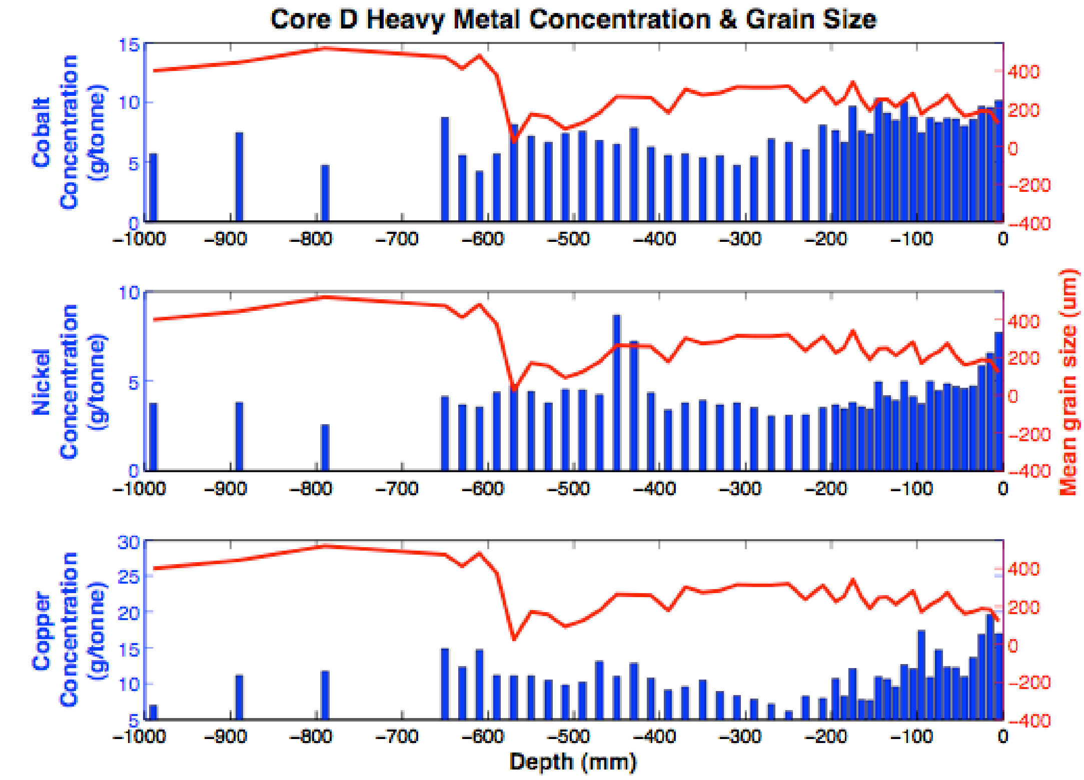

Core C Heavy Metal Concentration & Grain Size
Bismuth Concentration (g/tonne)
Uranium235 Concentration (g/tonne)
Uranium238 Concentration (g/tonne)
Mean grain size (um)
Depth (mm)


Core D Heavy Metal Concentration & Grain Size
Lithium Concentration (g/tonne)
Sodium Concentration (g/tonne)
x 10^4
Boron Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

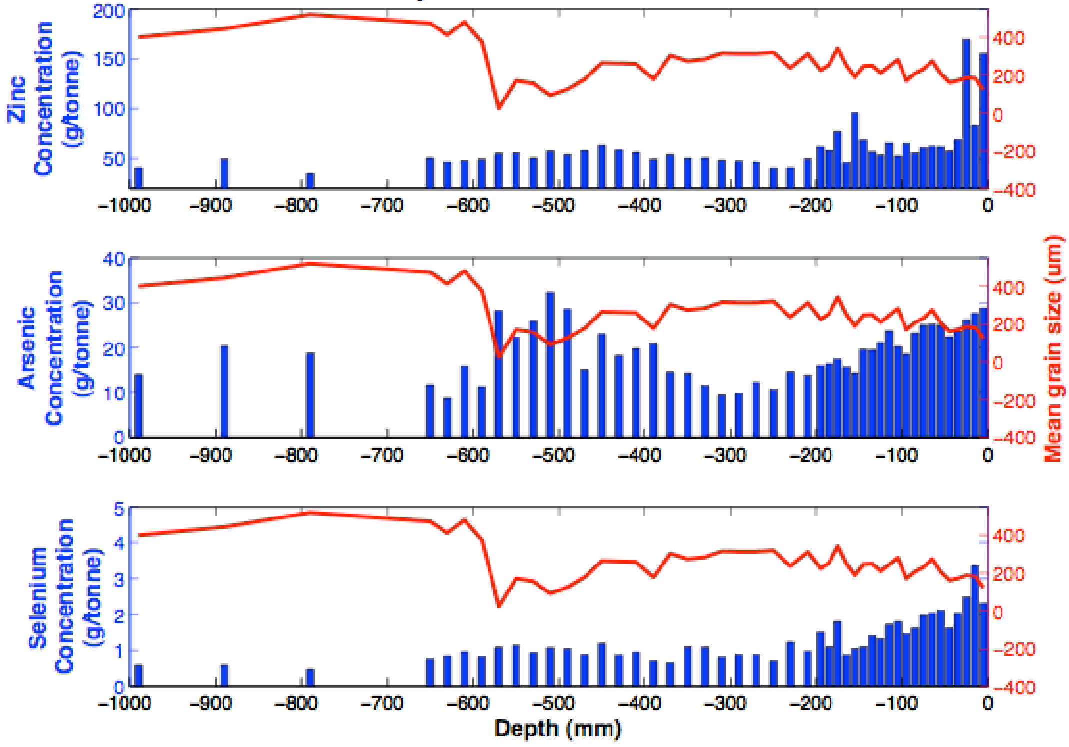

Core D Heavy Metal Concentration & Grain Size
Magnesium Concentration (g/tonne)
Aluminium Concentration (g/tonne)
Phosphorus Concentration (g/tonne)
Mean grain size (um)
Depth (mm)


Core D Heavy Metal Concentration & Grain Size
Potassium Concentration (g/tonne)
Calcium Concentration (g/tonne)
Vanadium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

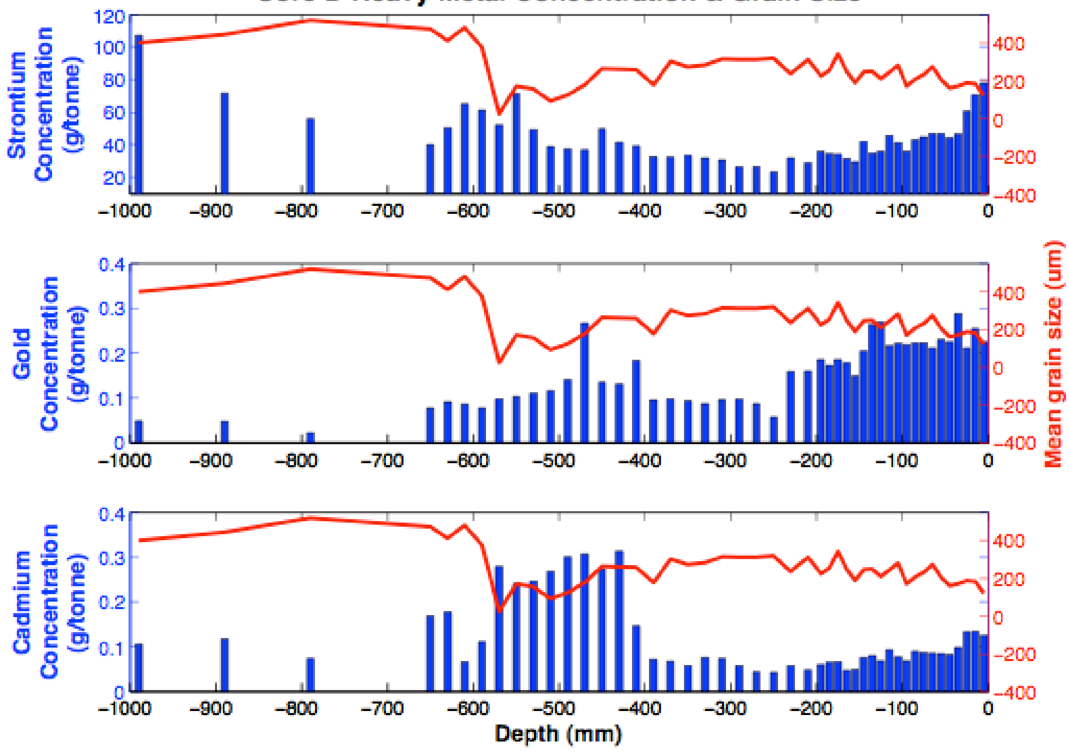

Core D Heavy Metal Concentration & Grain Size
Chromium Concentration (g/tonne)
Iron Concentration (g/tonne)
Manganese Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

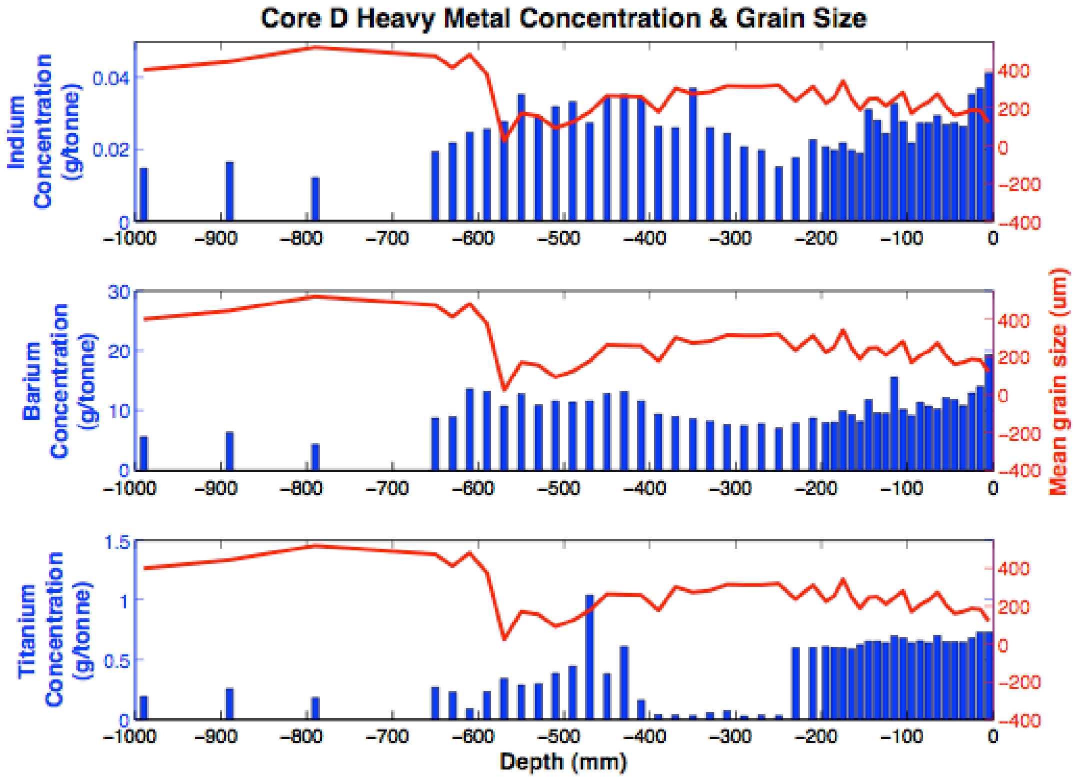

Core D Heavy Metal Concentration & Grain Size
Cobalt Concentration (g/tonne)
Nickel Concentration (g/tonne)
Copper Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

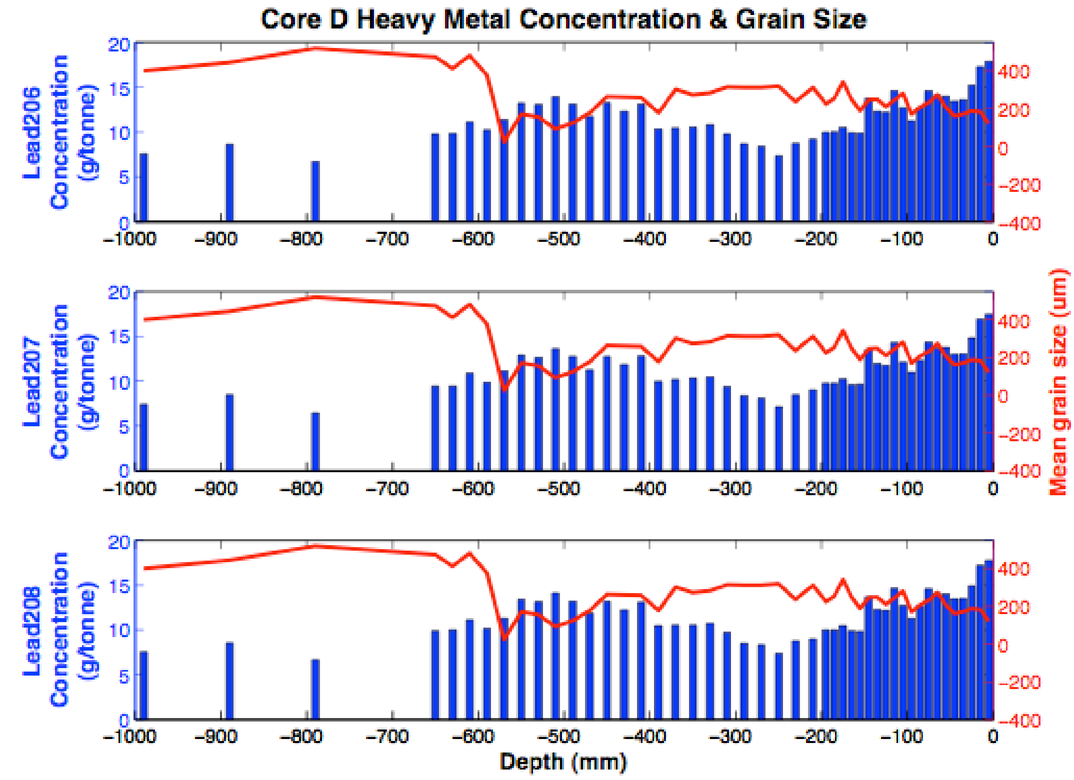
Core D Heavy Metal Concentration & Grain Size

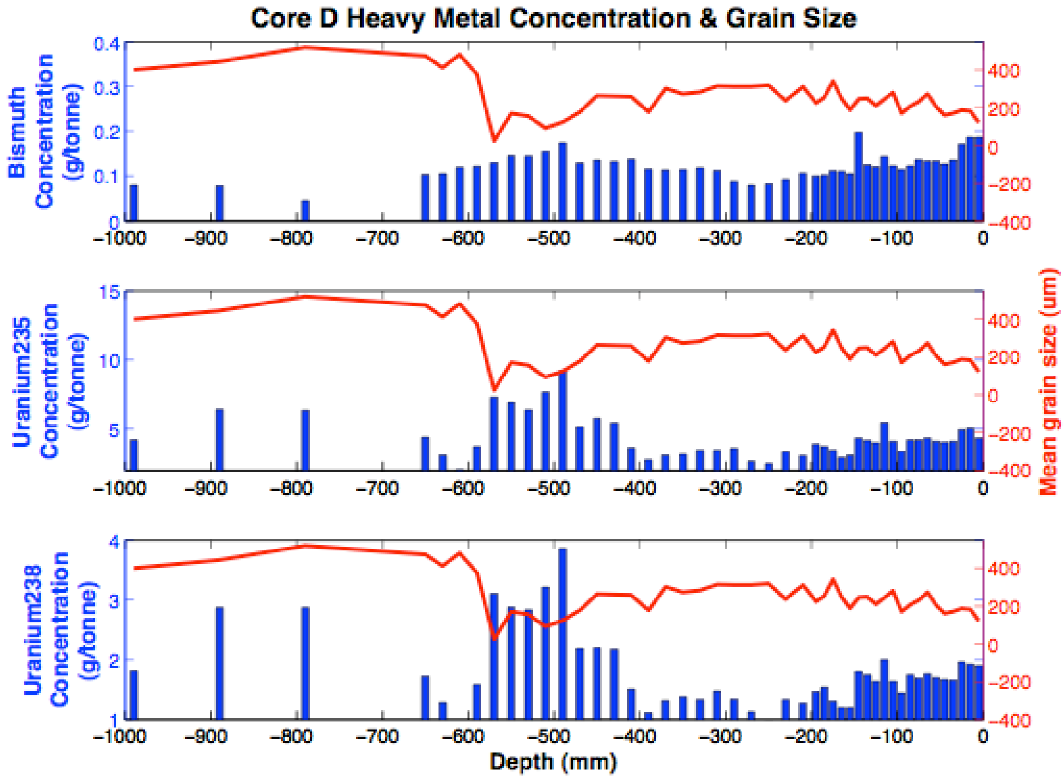


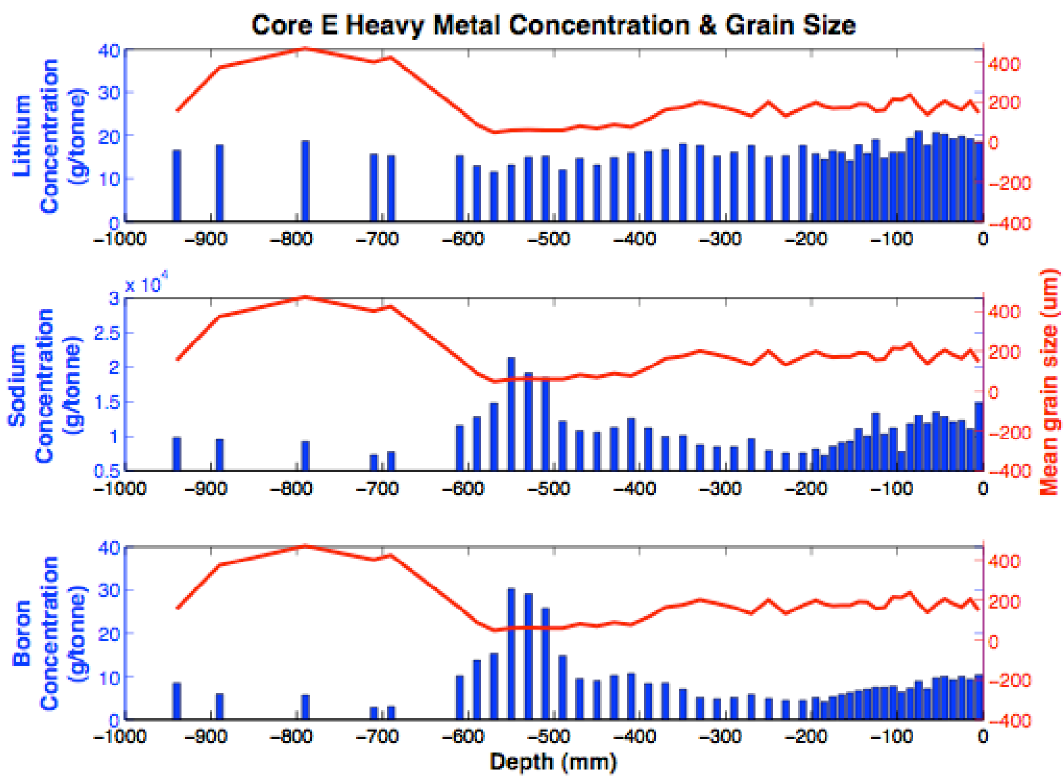
Core D Heavy Metal Concentration & Grain Size

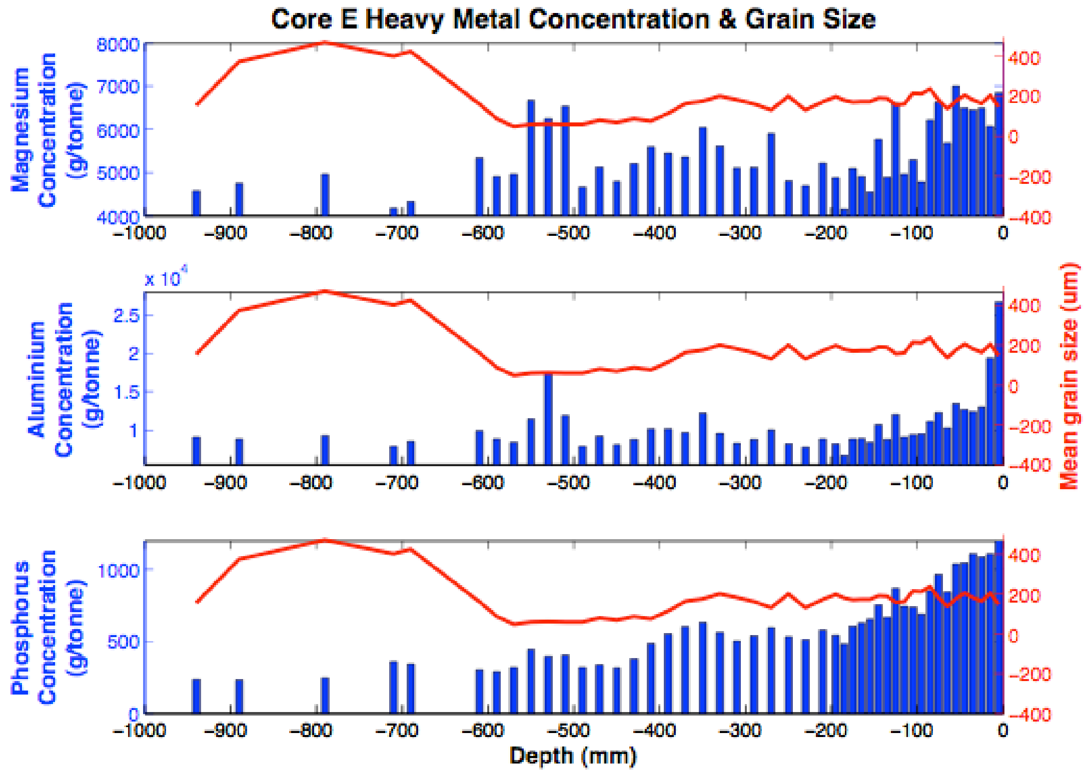


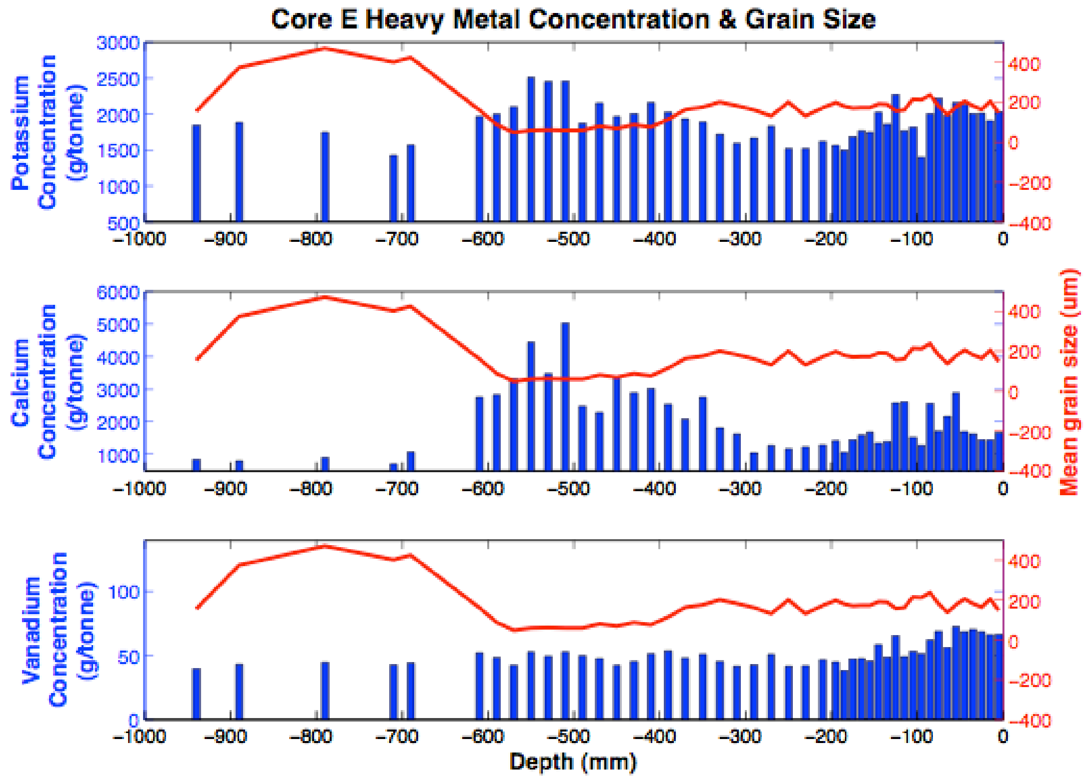

Core D Heavy Metal Concentration & Grain Size
Indium Concentration (g/tonne)
Barium Concentration (g/tonne)
Titanium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

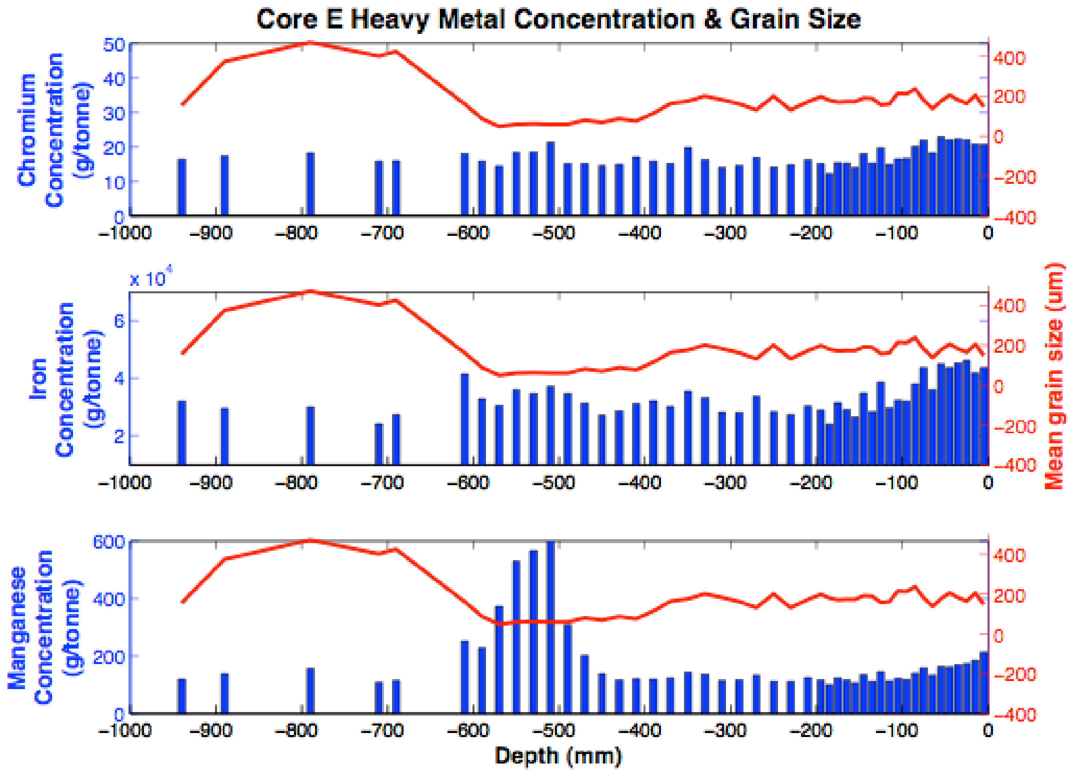

Core D Heavy Metal Concentration & Grain Size
Lead206 Concentration (g/tonne)
Lead207 Concentration (g/tonne)
Lead208 Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

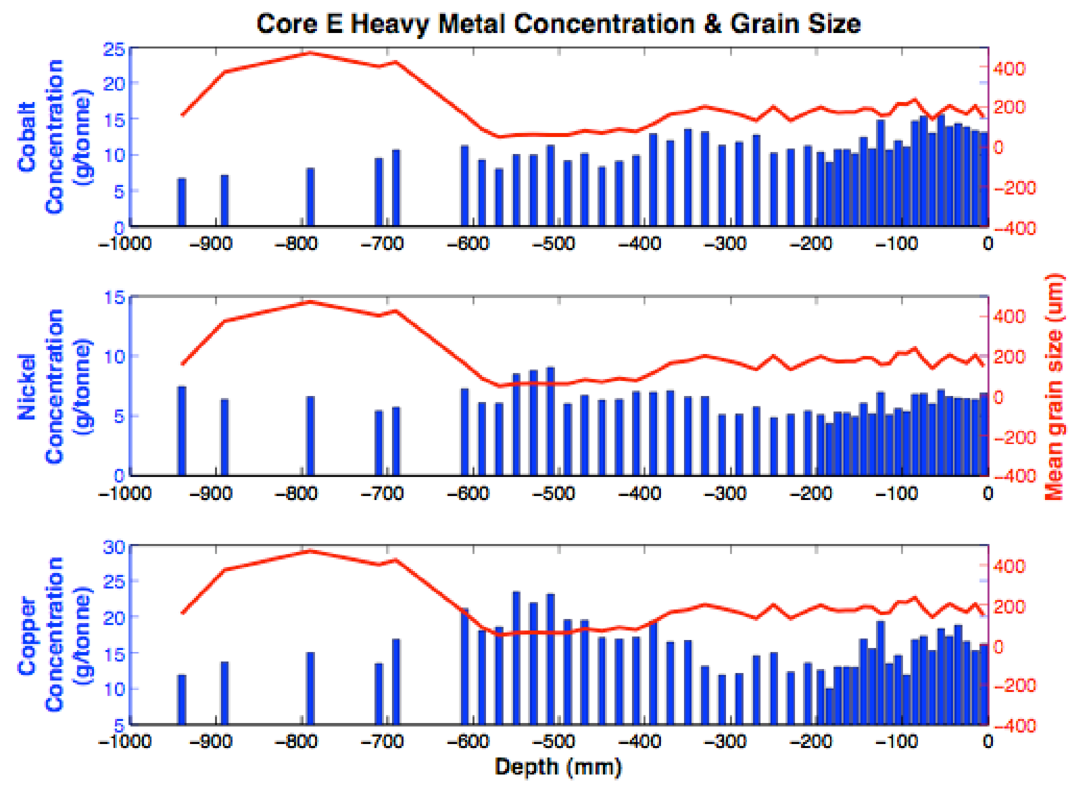

Core D Heavy Metal Concentration & Grain Size
Bismuth Concentration (g/tonne)
Uranium235 Concentration (g/tonne)
Uranium238 Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

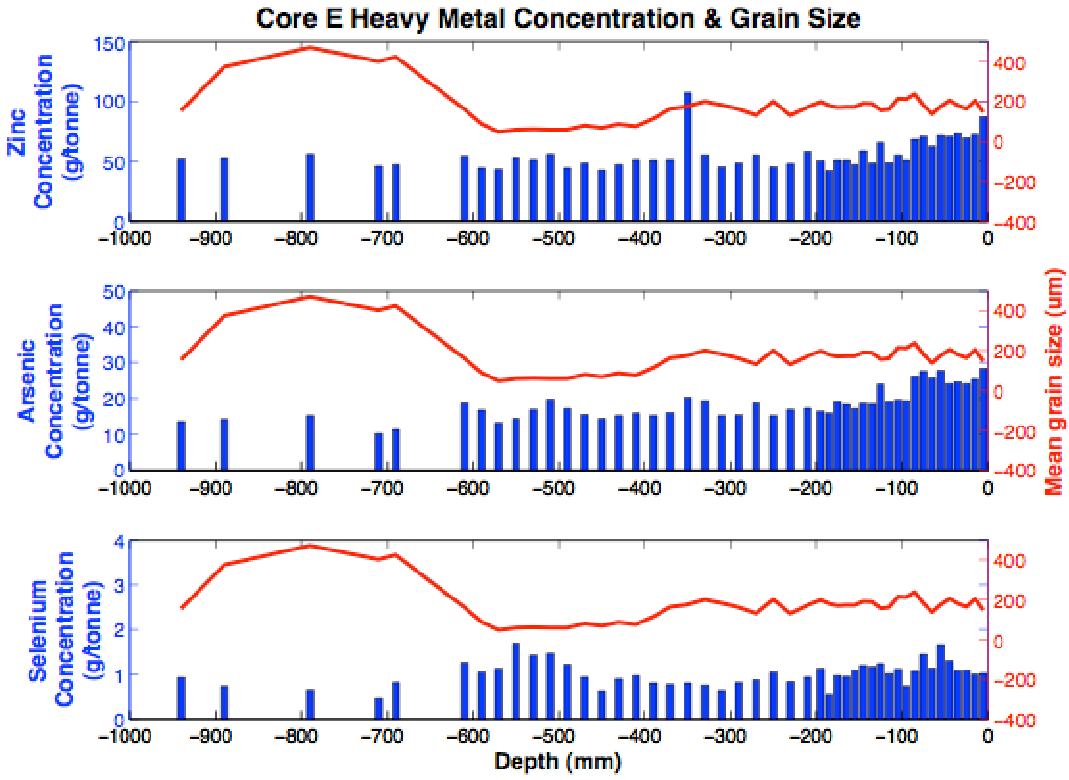

Core E Heavy Metal Concentration & Grain Size
Lithium Concentration (g/tonne)
Sodium Concentration (g/tonne)
x 10^4
Boron Concentration (g/tonne)
Mean grain size (um)
Depth (mm)


Core E Heavy Metal Concentration & Grain Size
Magnesium Concentration (g/tonne)
Aluminium Concentration (g/tonne)
Phosphorus Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

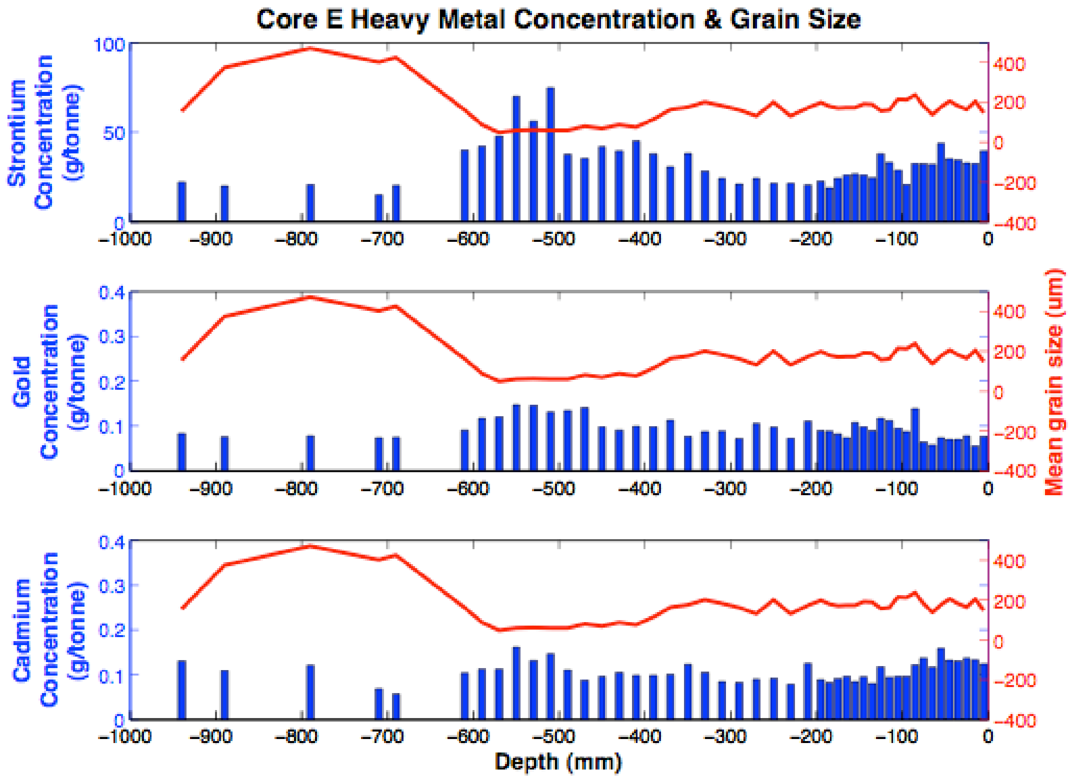

Core E Heavy Metal Concentration & Grain Size
Potassium Concentration (g/tonne)
Calcium Concentration (g/tonne)
Vanadium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)


Core E Heavy Metal Concentration & Grain Size
Chromium Concentration (g/tonne)
Iron Concentration (g/tonne)
x 10^4
Manganese Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

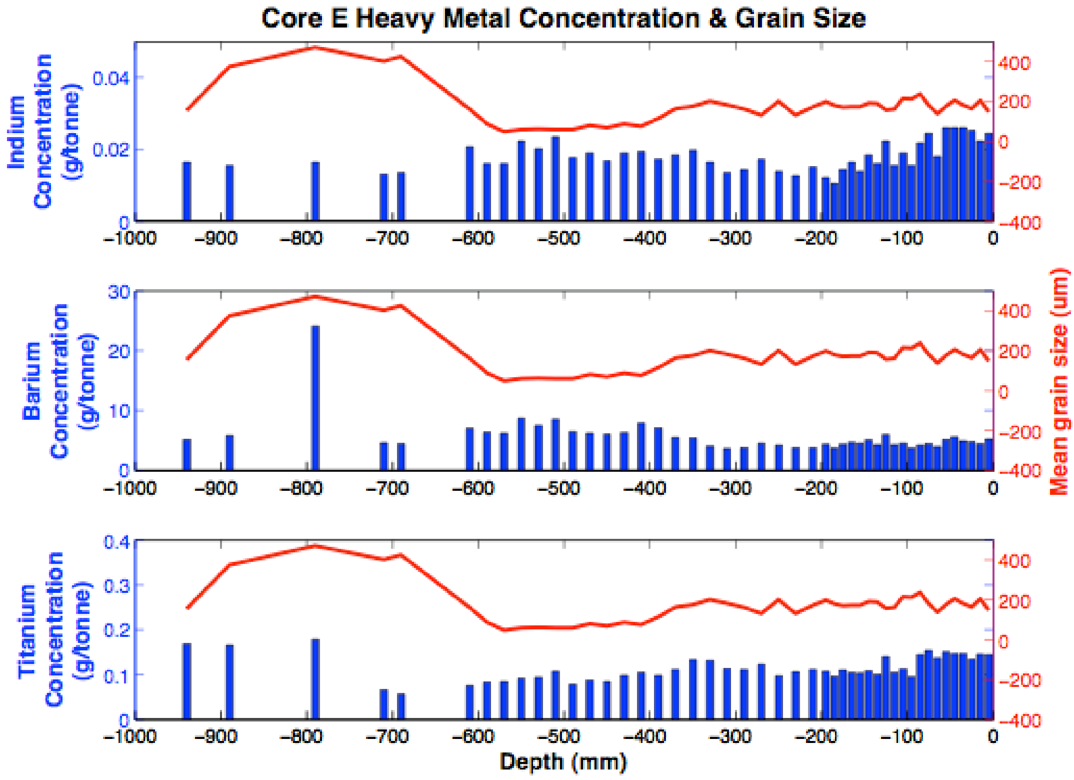

Core E Heavy Metal Concentration & Grain Size
Cobalt Concentration (g/tonne)
Nickel Concentration (g/tonne)
Copper Concentration (g/tonne)
Mean grain size (um)
Depth (mm)



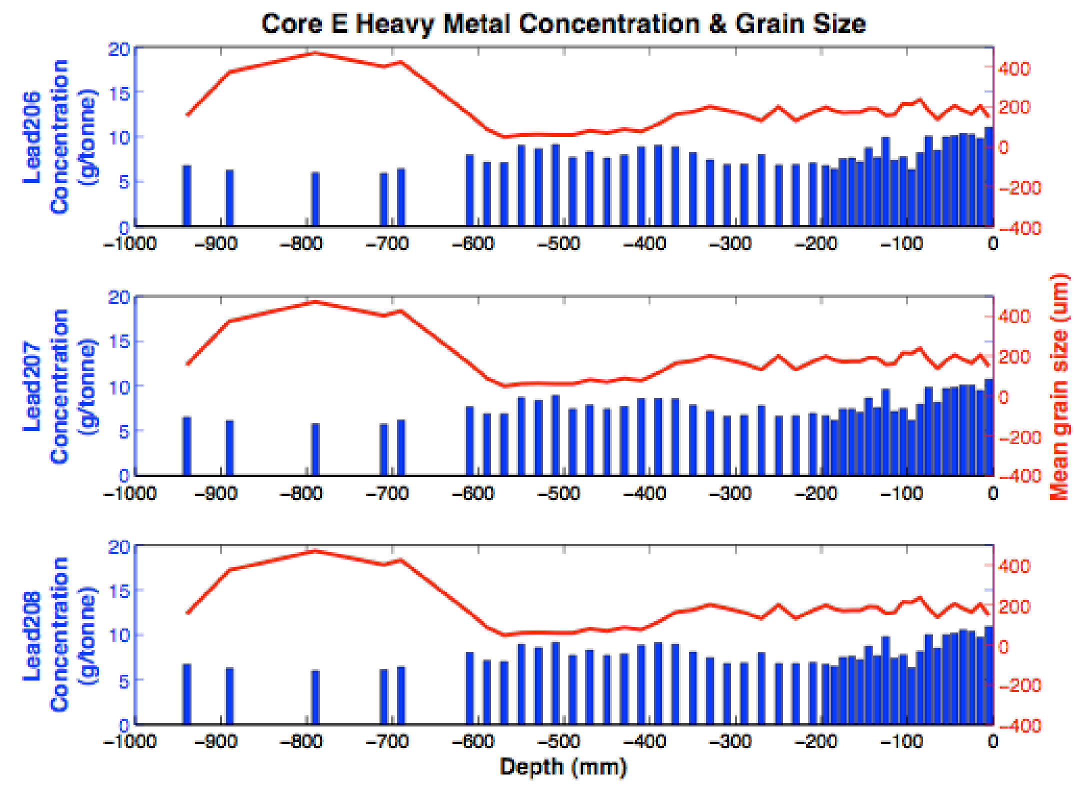
Core E Heavy Metal Concentration & Grain Size
Zinc Concentration (g/tonne)
Arsenic Concentration (g/tonne)
Selenium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)



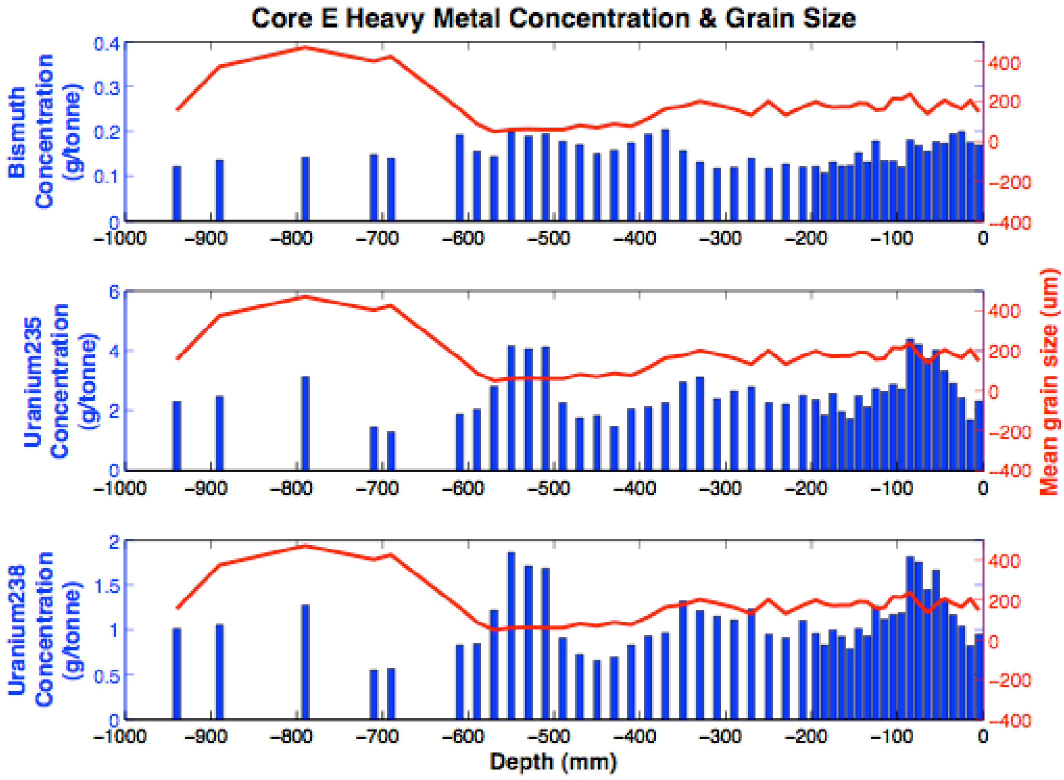
Core E Heavy Metal Concentration & Grain Size
Strontium Concentration (g/tonne)
Gold Concentration (g/tonne)
Cadmium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)



Core E Heavy Metal Concentration & Grain Size
Indium Concentration (g/tonne)
Barium Concentration (g/tonne)
Titanium Concentration (g/tonne)
Mean grain size (um)
Depth (mm)



Core E Heavy Metal Concentration & Grain Size
Lead206 Concentration (g/tonne)
Lead207 Concentration (g/tonne)
Lead208 Concentration (g/tonne)
Mean grain size (um)
Depth (mm)



Core E Heavy Metal Concentration & Grain Size
Bismuth Concentration (g/tonne)
Uranium235 Concentration (g/tonne)
Uranium238 Concentration (g/tonne)
Mean grain size (um)
Depth (mm)

APPENDIX III

Model Calibration

(Refer to CD ROM- Back Cover)

		Velocity		Elevation	
Shakespeare Cliff	Bed roughness	BSS	RMSE	BSS	RMSE
	0.1	0.9488	0.0517	0.9932	0.0068
	0.08	0.9721	0.0279	0.9993	0.0007
	0.001	0.9438	0.05462	0.647	0.353
	0.008	0.9631	0.0369	0.999	0.001
	0.0001	0.9622	0.0378	0.9988	0.0012
	0.0004	0.9601	0.0399	0.999	0.001

		Velocity		Elevation	
Wharekaho	Bed roughness	BSS	RMSE	BSS	RMSE
	0.1	0.7803	0.2197	0.7692	0.2308
	0.08	0.889	0.111	0.6785	0.3215
	0.001	0.8206	0.1794	0.9643	0.0357
	0.008	0.8139	0.1861	0.7367	0.2633
	0.0001	0.8657	0.1343	0.7772	0.2228
	0.0004	0.8665	0.1335	0.7542	0.2458

		Velocity		Elevation	
Entrance	Bed roughness	BSS	RMSE	BSS	RMSE
	0.1	0.3543	0.6457	0.2143	0.7857
	0.08	0.9243	0.0757	0.9654	0.0346
	0.001	0.7209	0.2791	0.9405	0.0595
	0.008	0.8775	0.1225	0.9561	0.0439
	0.0001	0.8012	0.1988	0.9429	0.0571
	0.0004	0.8572	0.1428	0.6388	0.3612

		Velocity		Elevation	
Rivers	Bed roughness	BSS	RMSE	BSS	RMSE
	0.1	0.8372	0.1628	0.9094	0.0906
	0.08	0.9075	0.0925	0.9456	0.0544
	0.001	0.9356	0.0644	0.9619	0.0381
	0.008	0.8979	0.1021	0.9541	0.0459
	0.0001	0.8871	0.1129	0.9547	0.0453
	0.0004	0.6029	0.3971	0.4934	0.5066

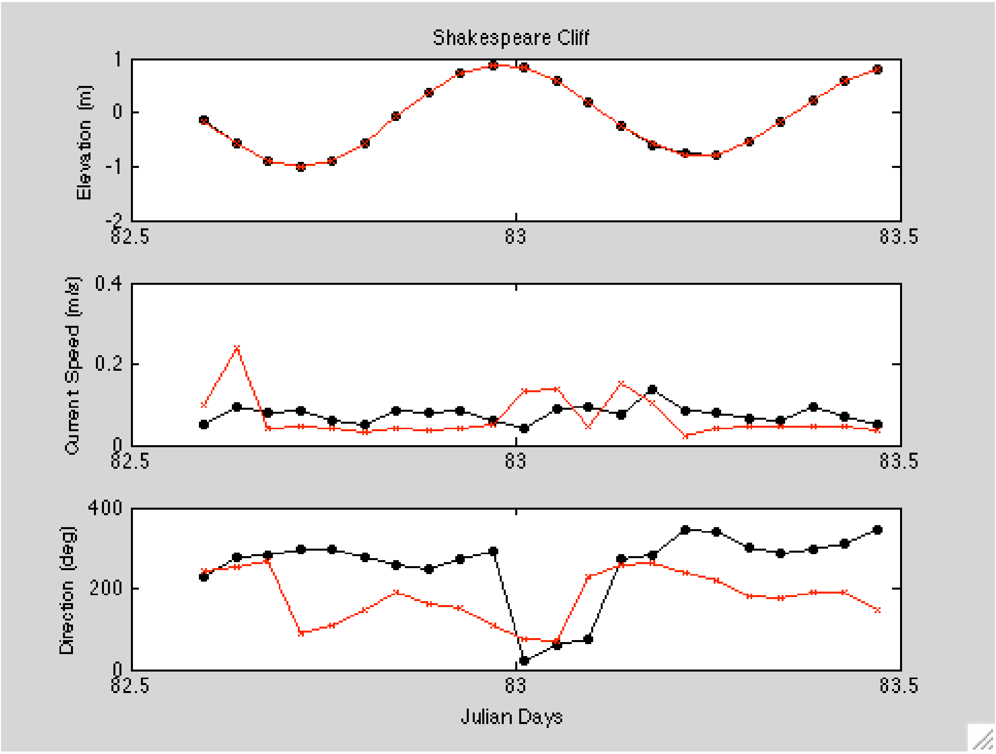
Model calibration graphs:

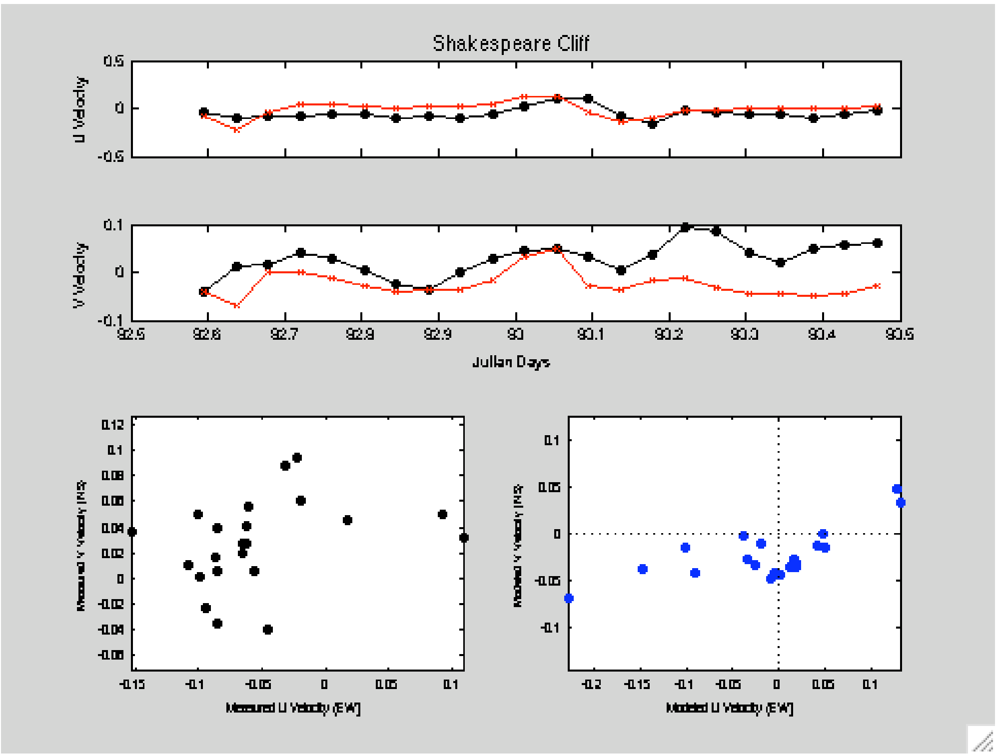
Note: bed roughness was changed for each calibration run.

Calibration Run 1

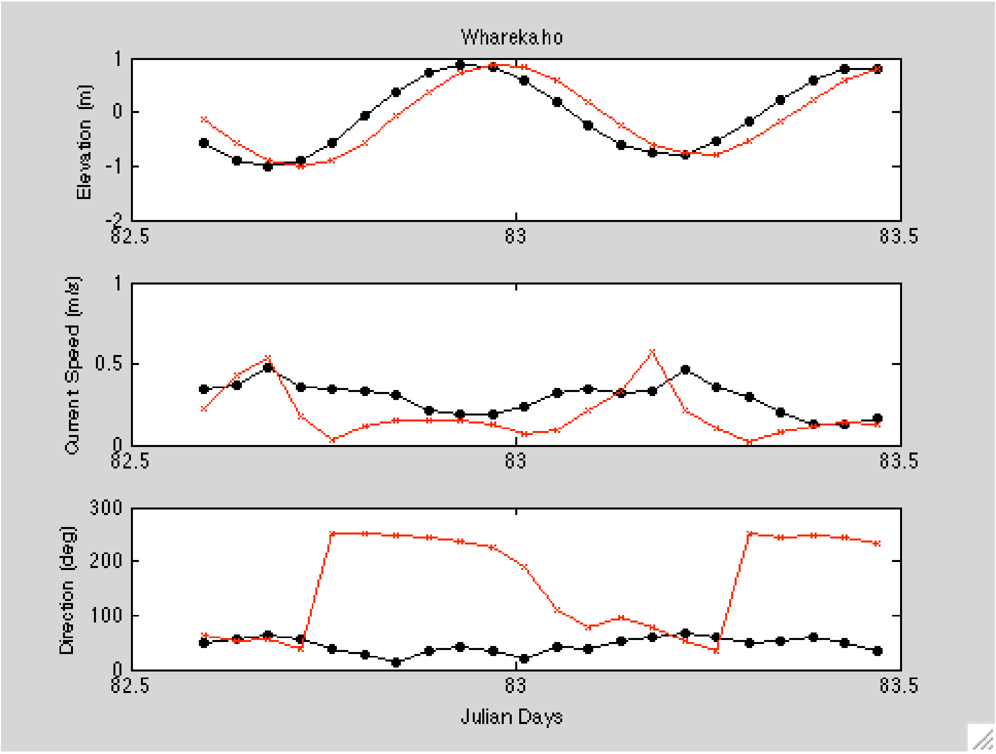
Bed Roughness 0.0001

Shakespeare Cliff

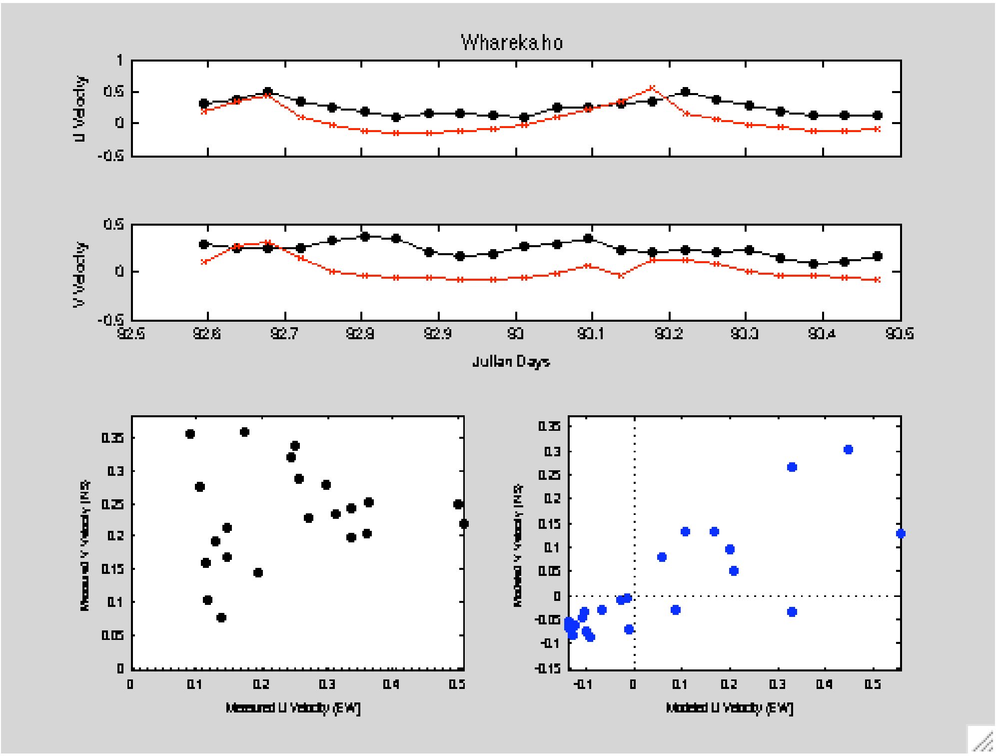




Wharekaho

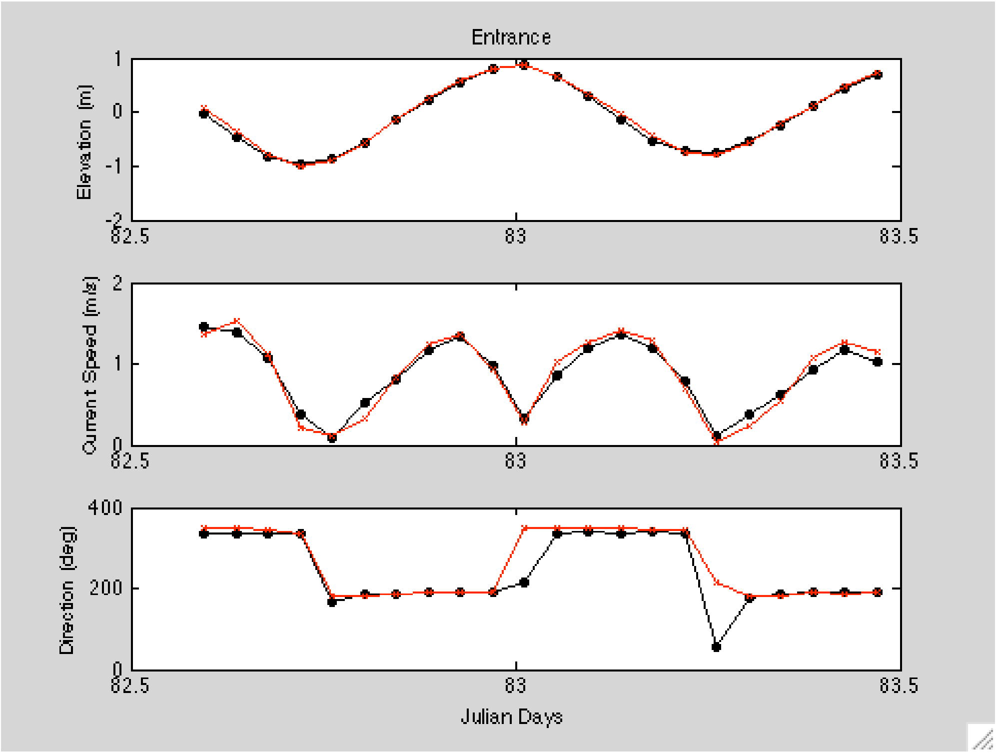


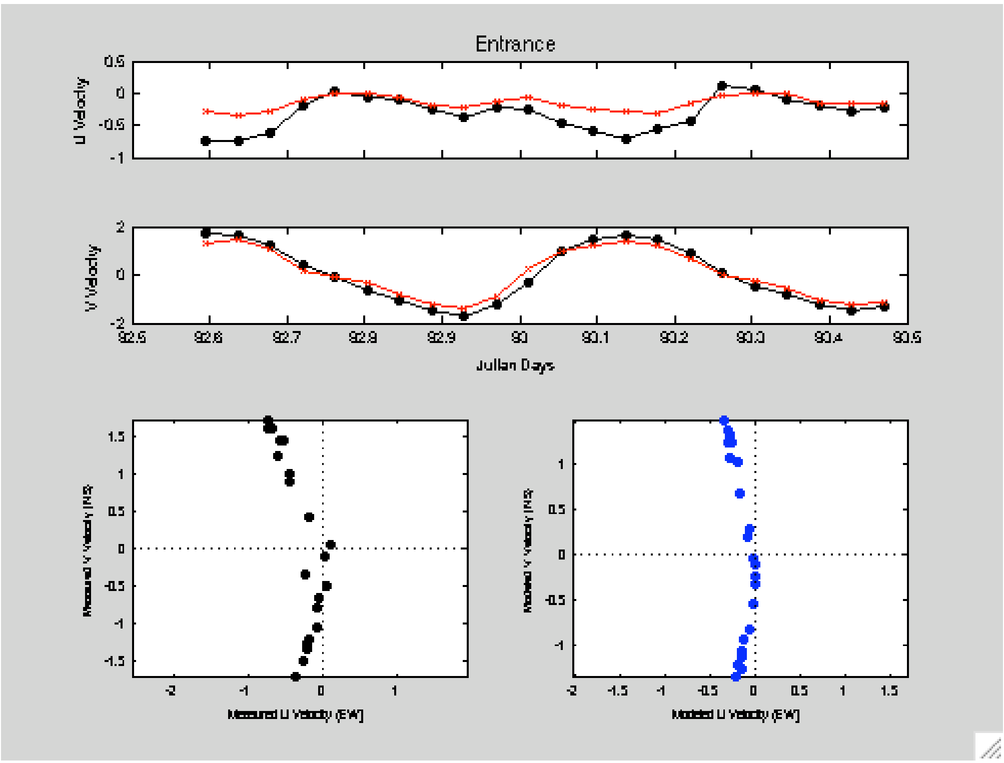
Wharekaho
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days



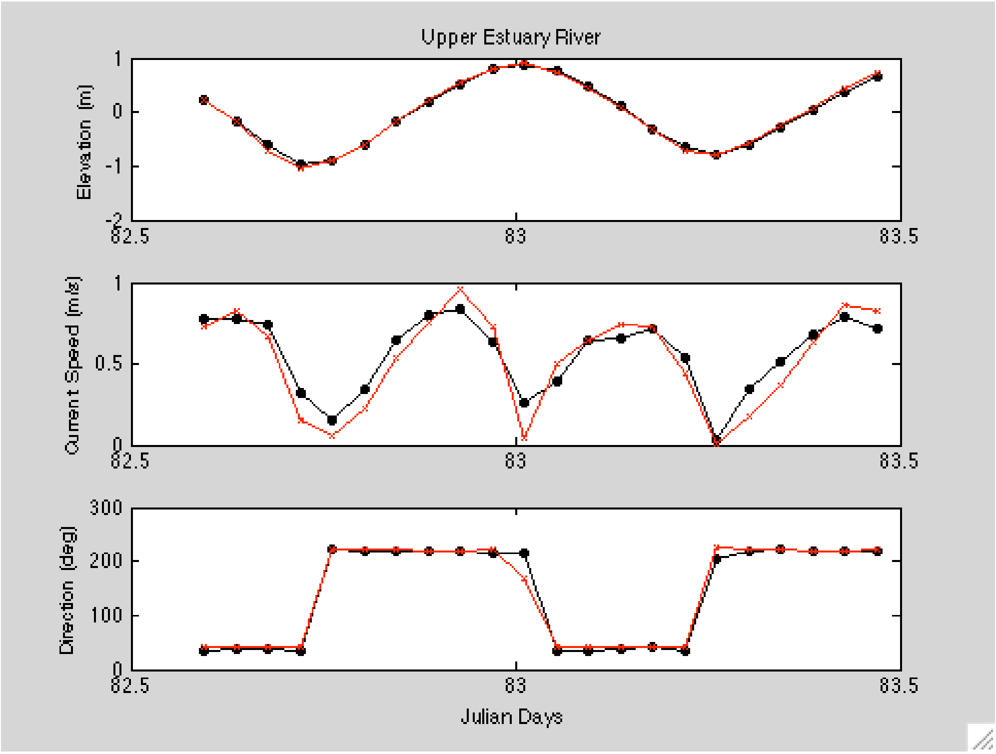
Wharekaho
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Entrance

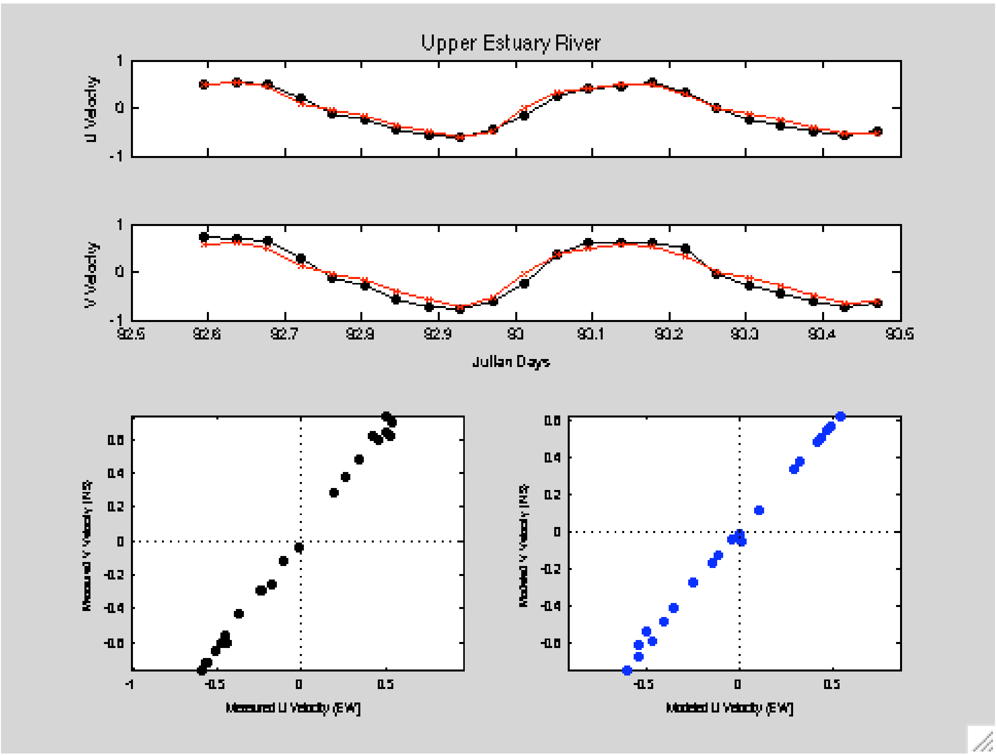

Entrance
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days


Entrance
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Rivers



Upper Estuary River
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days

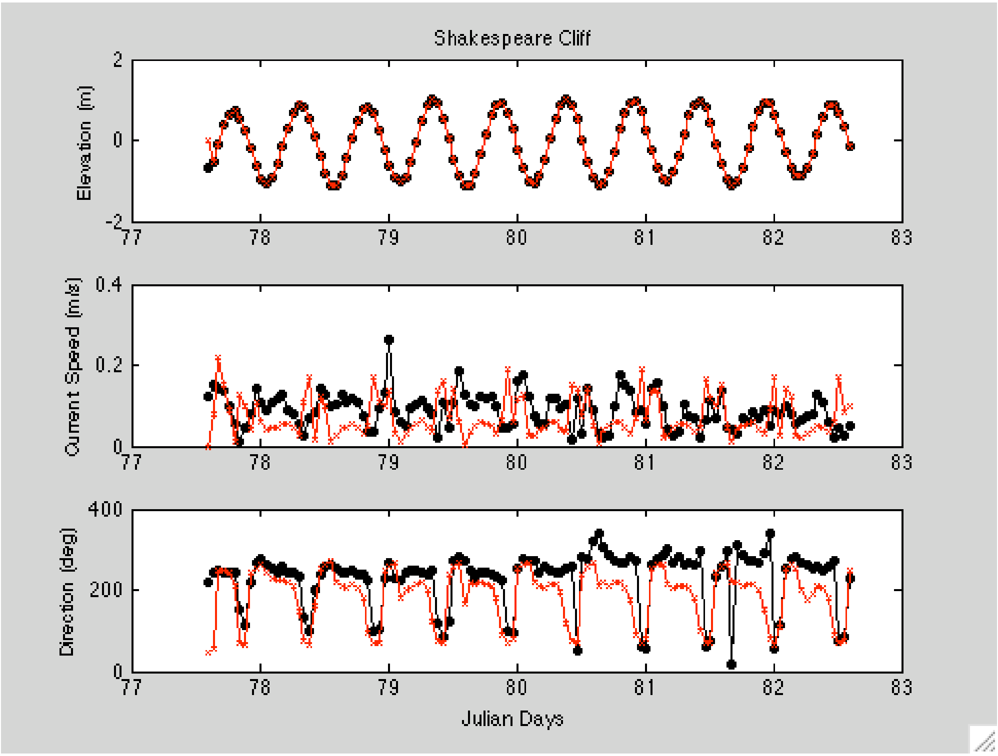


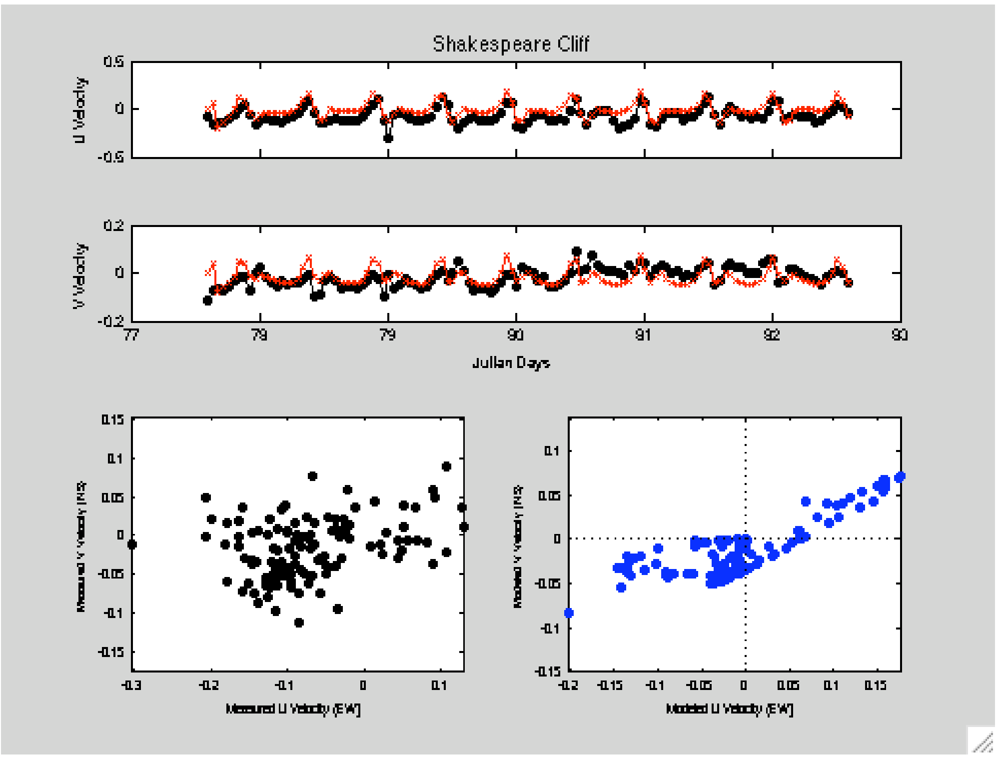
Upper Estuary River
U Velocity
V Velocity
Julian Days
Measured U Velocity (EW)
Measured V Velocity (NS)
Modeled U Velocity (EW)
Modeled V Velocity (NS)

Calibration Run 2.

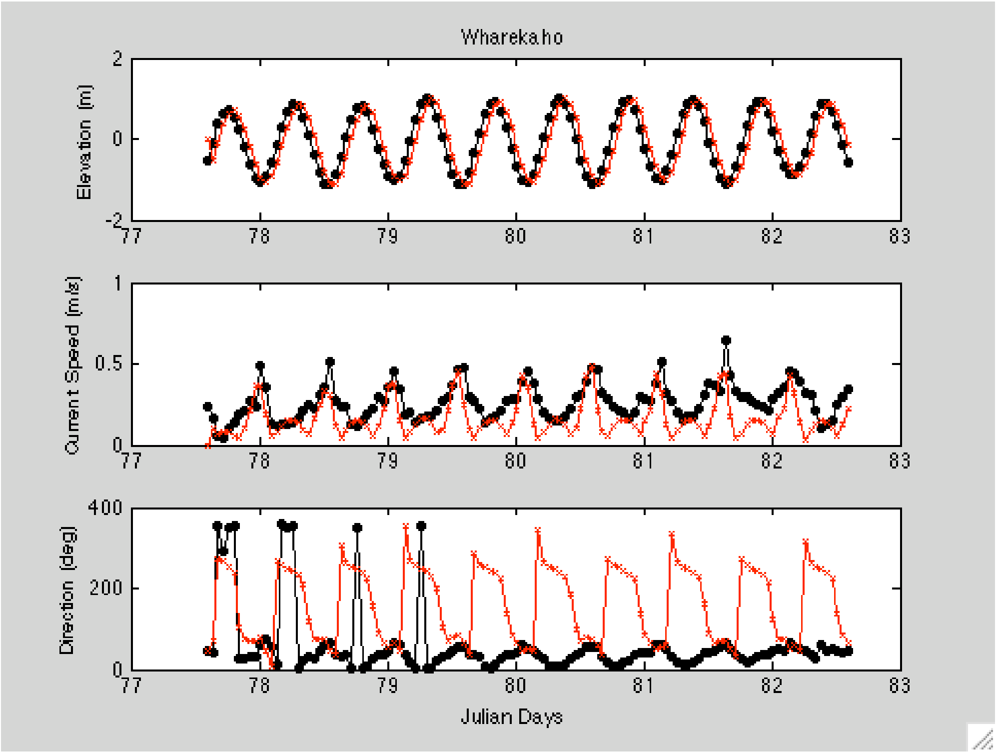
Bed Roughness 0.01

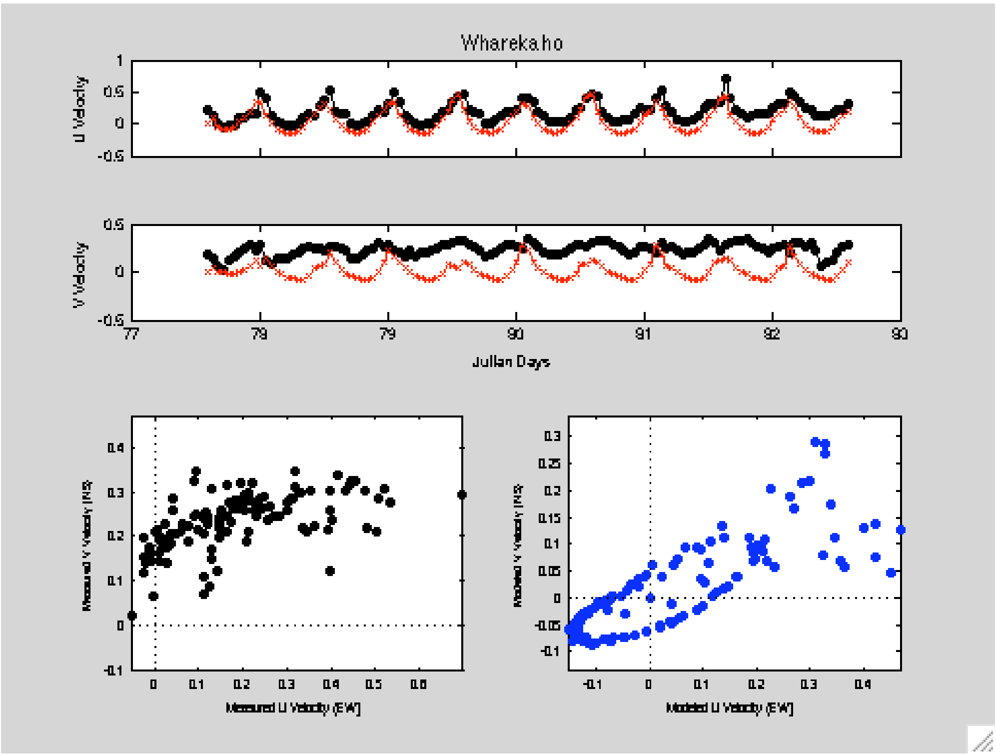
Shakespeare Cliff



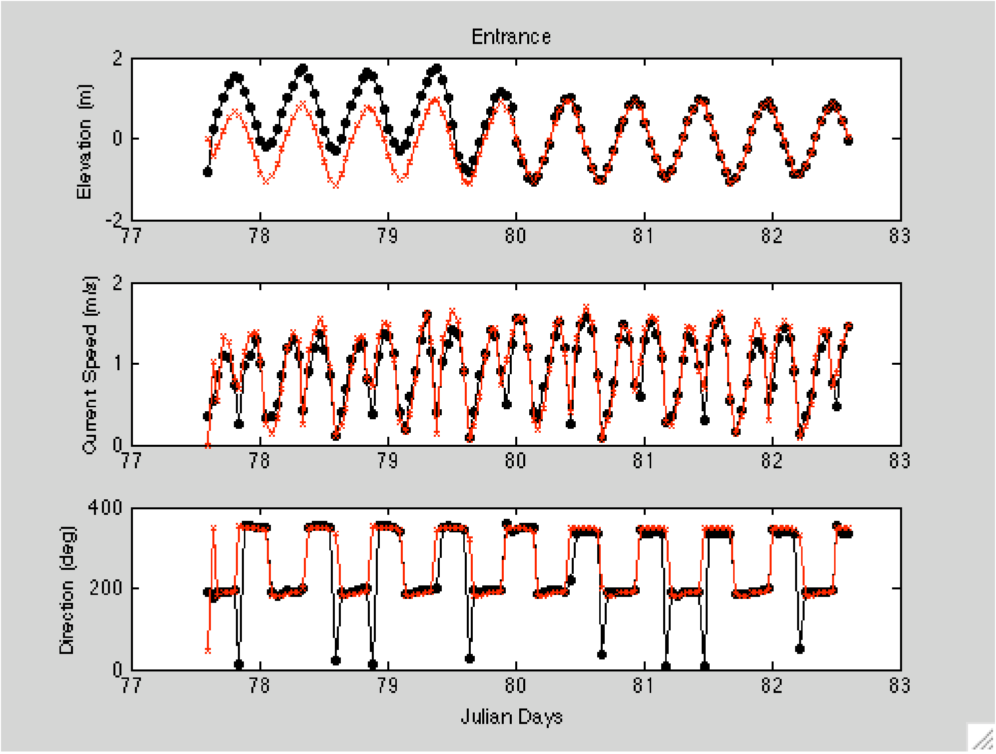


Wharekaho

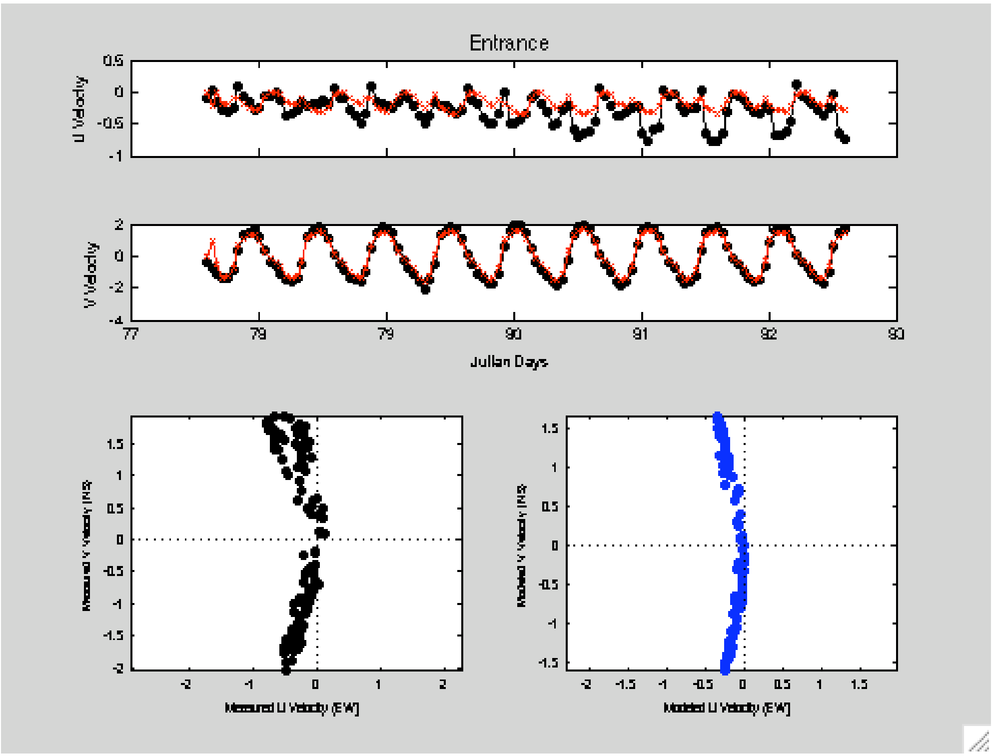

Wharekaho
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days


Wharekaho
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Entrance

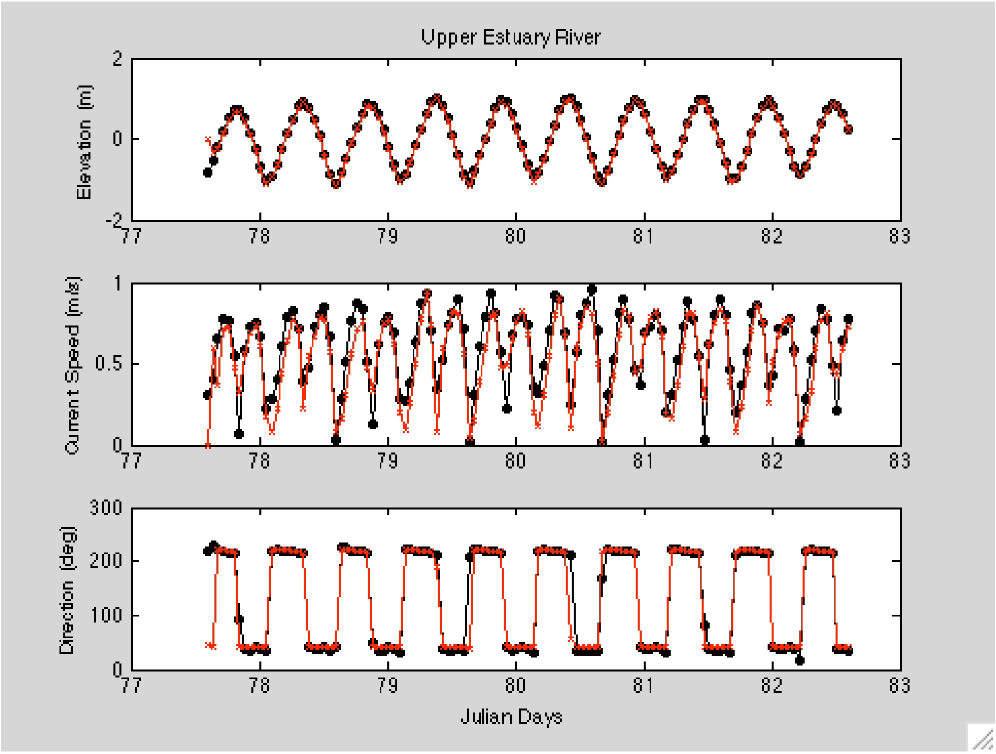


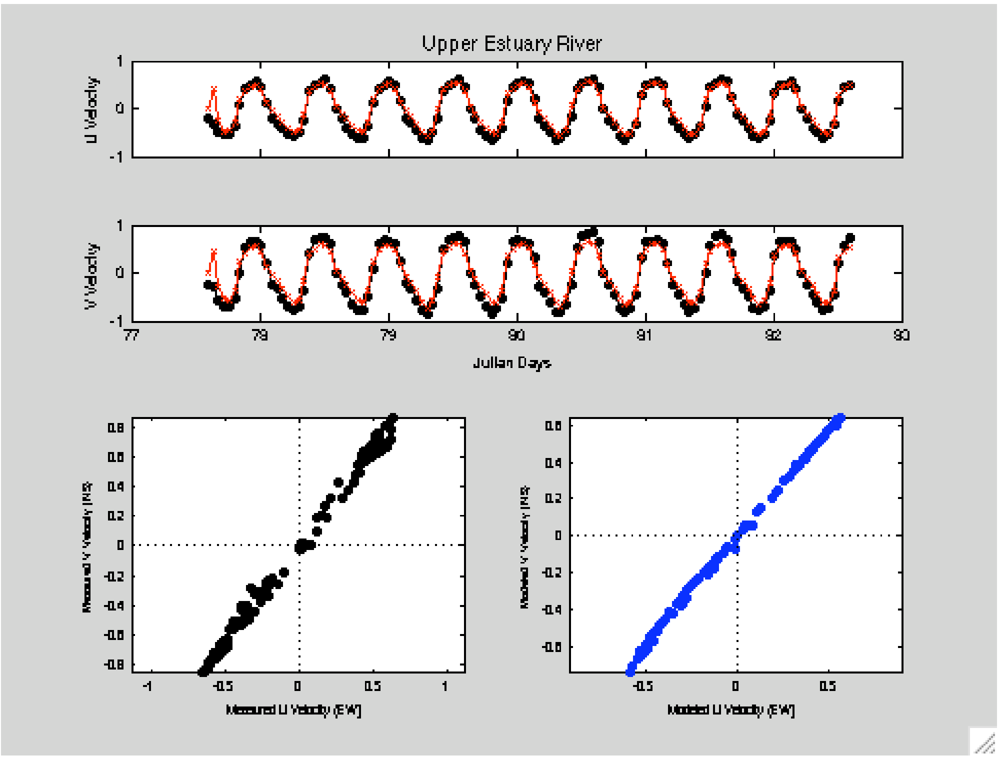
Entrance
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days



Entrance
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Rivers

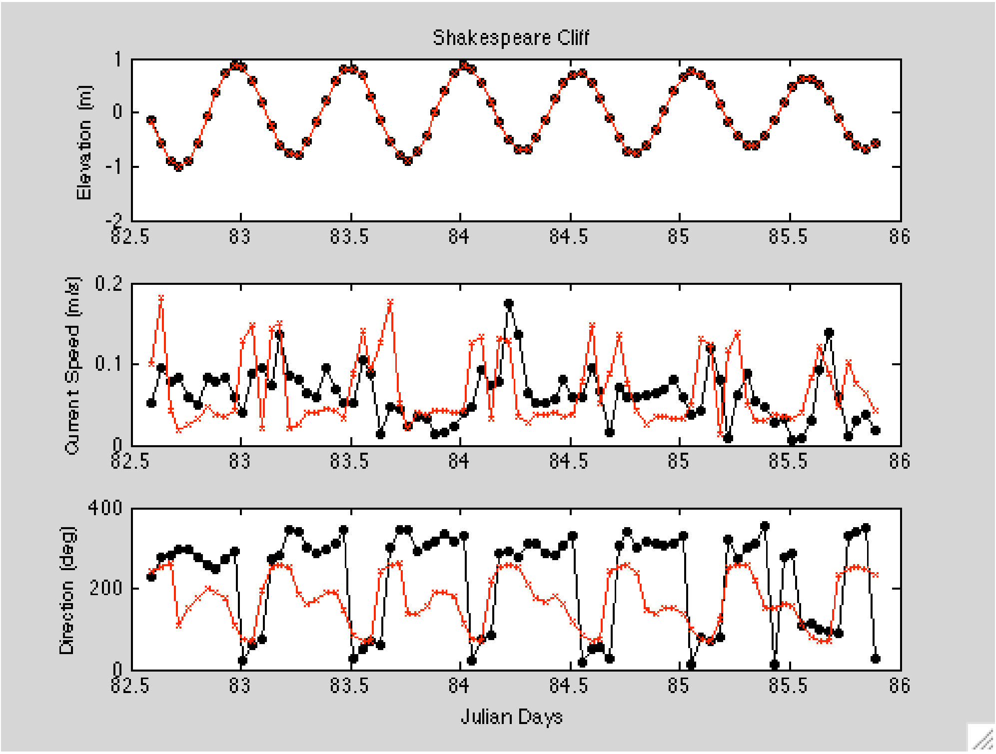

Upper Estuary River
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days

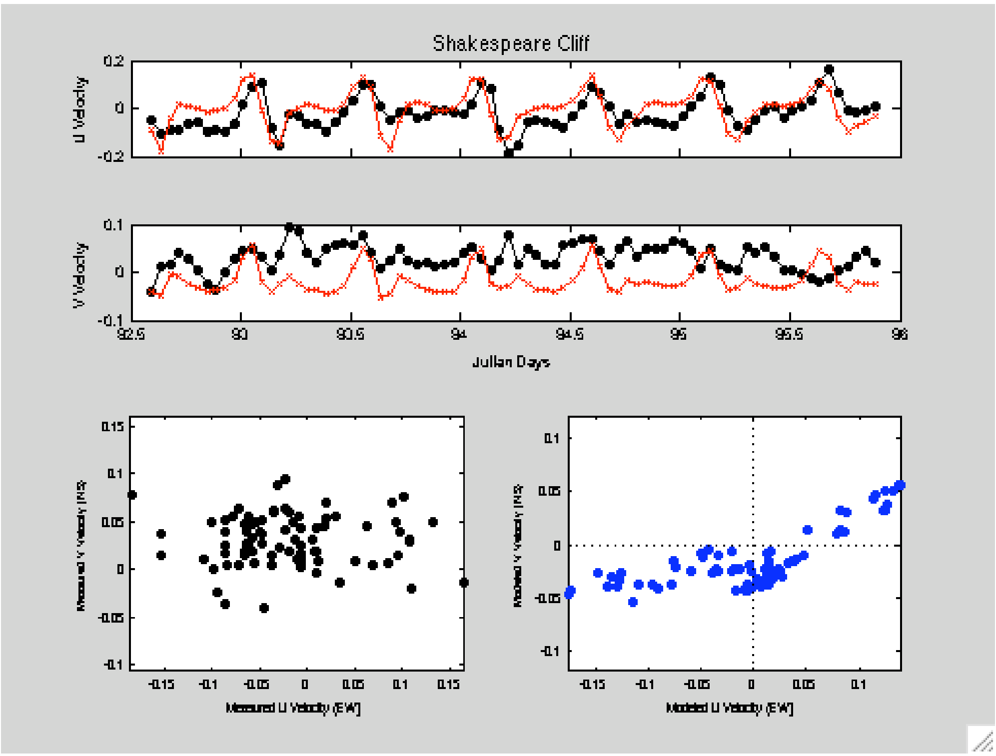

Upper Estuary River
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Calibration Run 3.

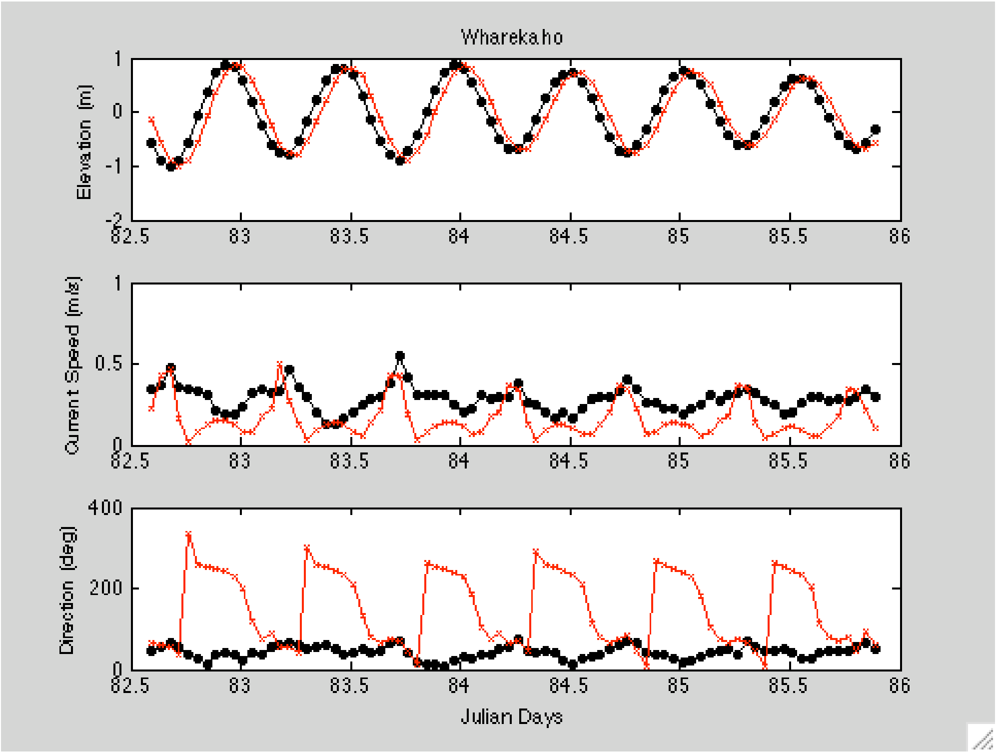
Bed Roughness 0.0004

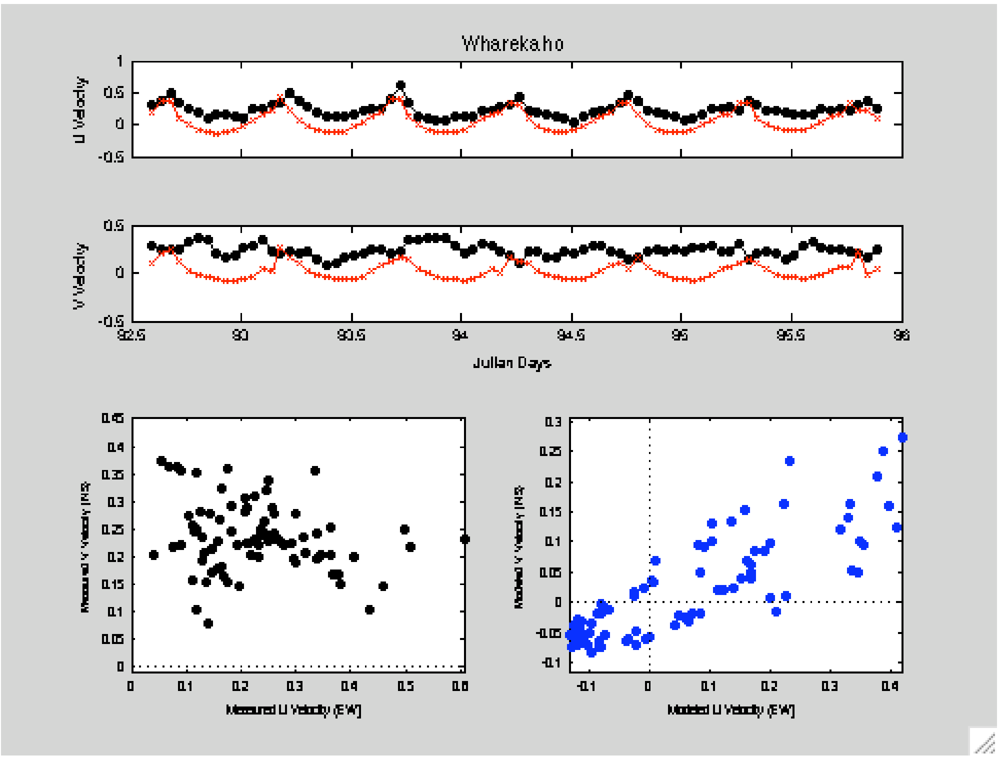
Shakespeare Cliff



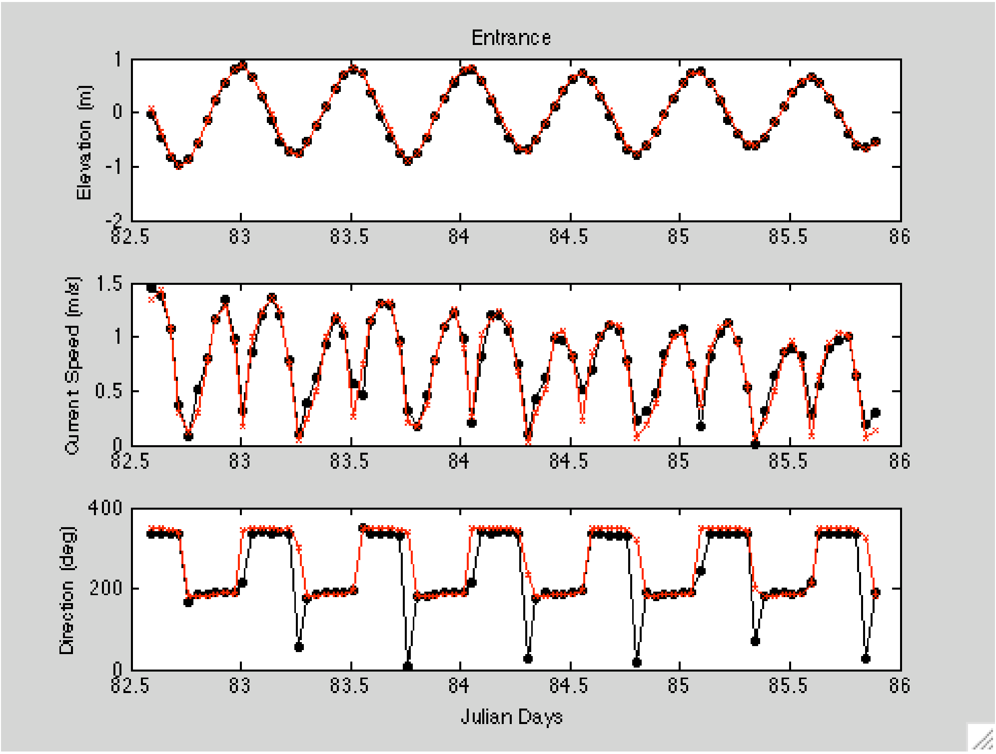


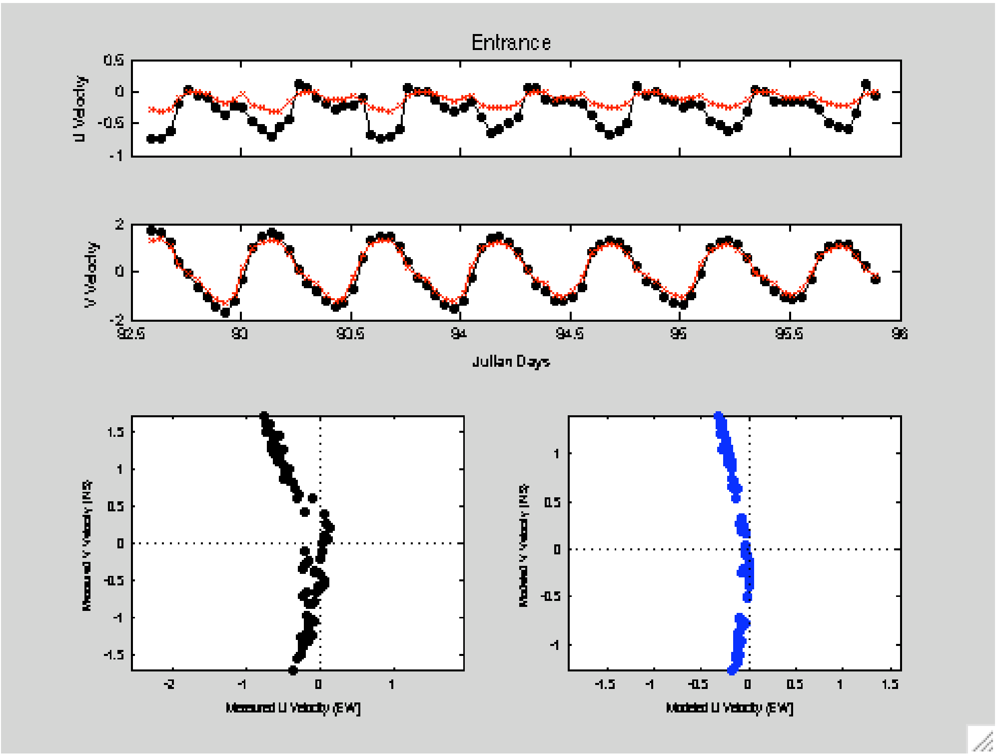
Wharekaho


Wharekaho
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days

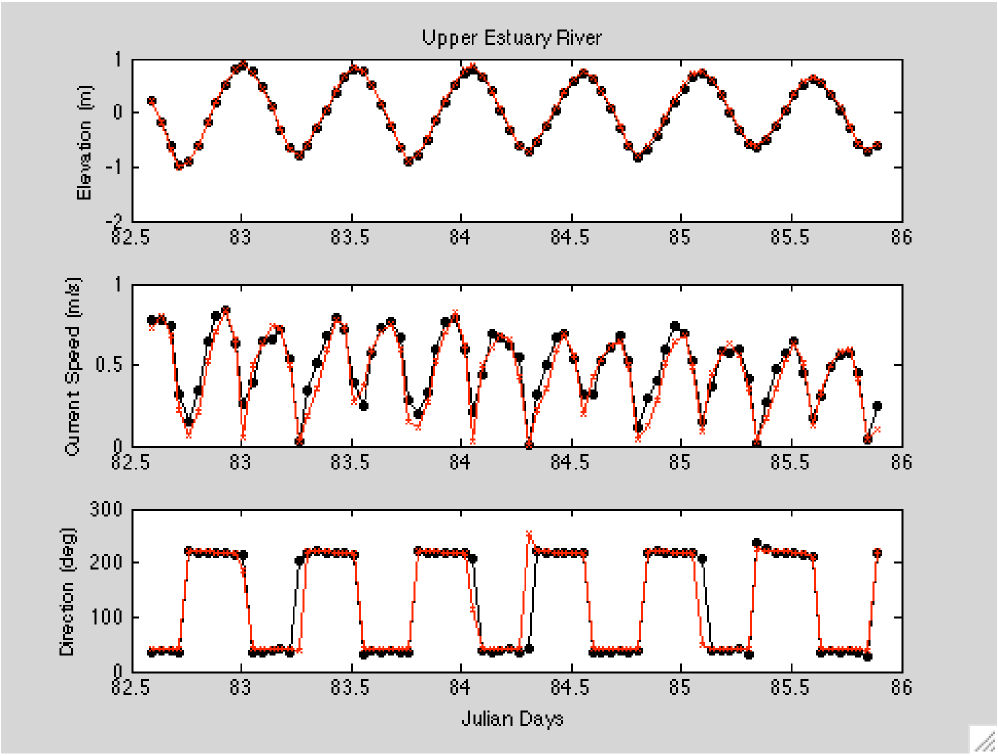

Wharekaho
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Entrance

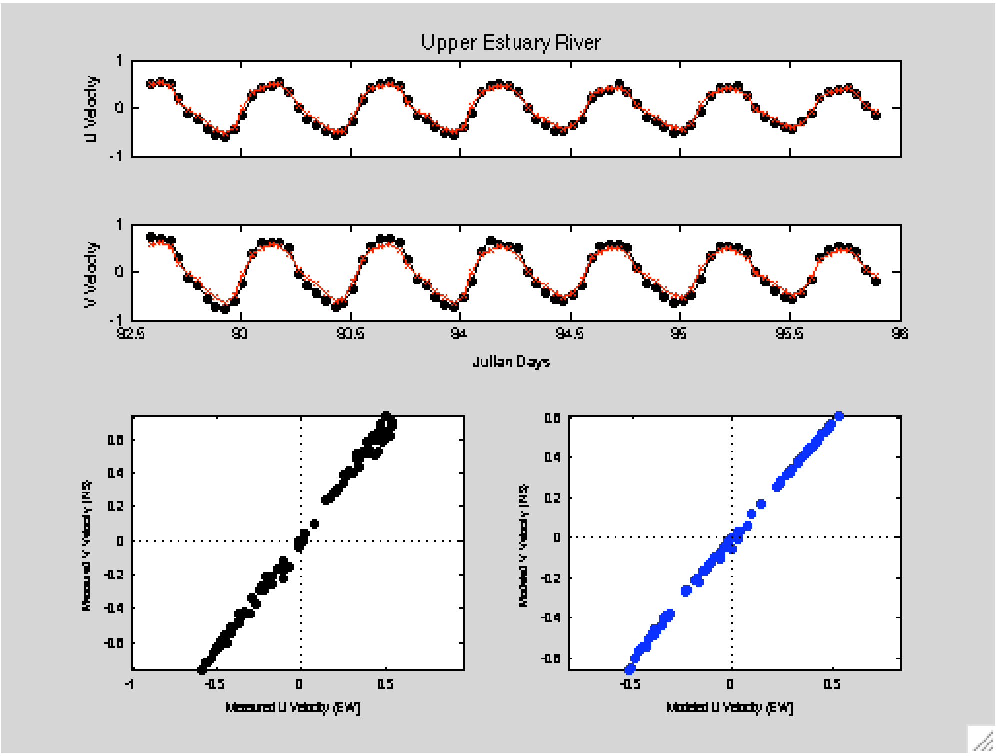

Entrance
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days


Entrance
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Rivers



Upper Estuary River
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days

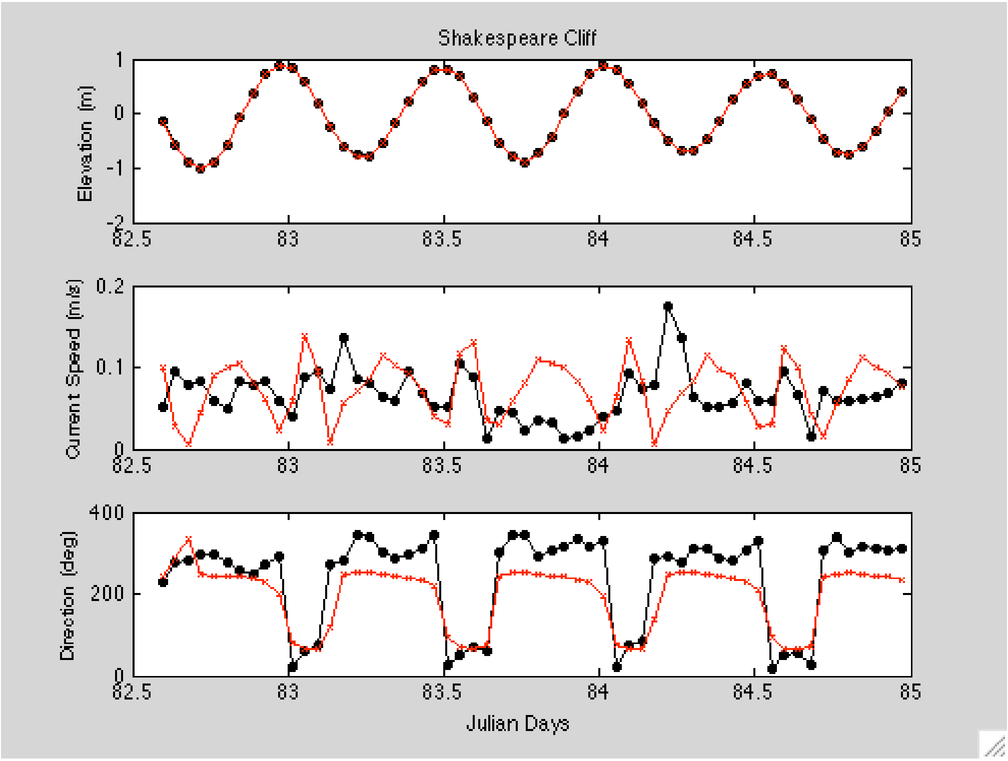


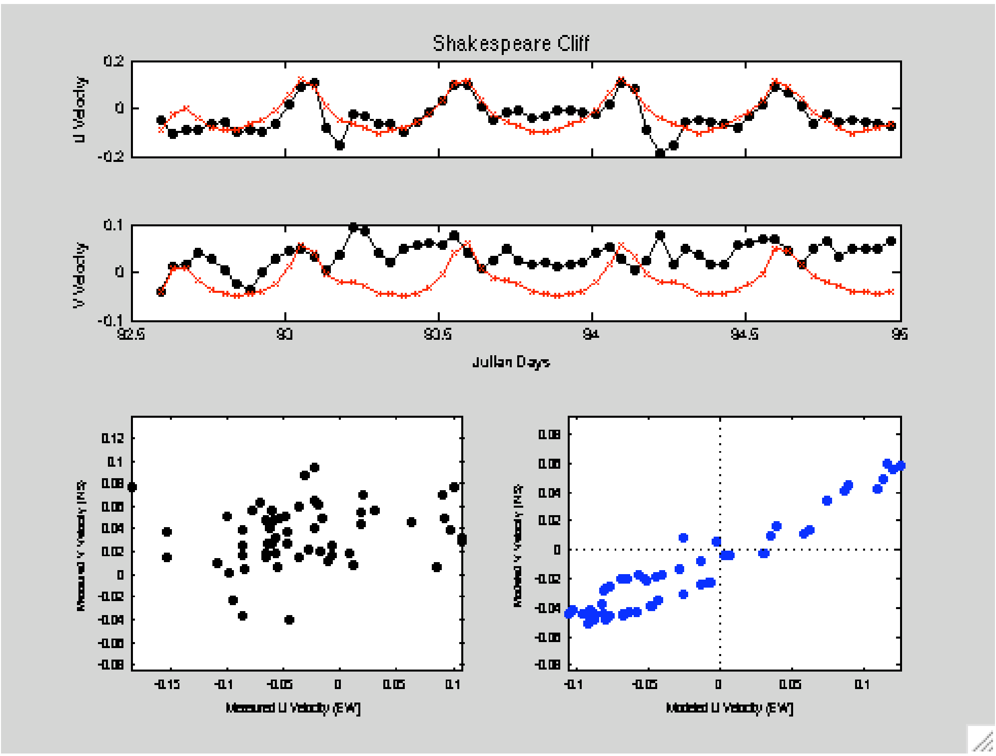
Upper Estuary River
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Calibration Run 4

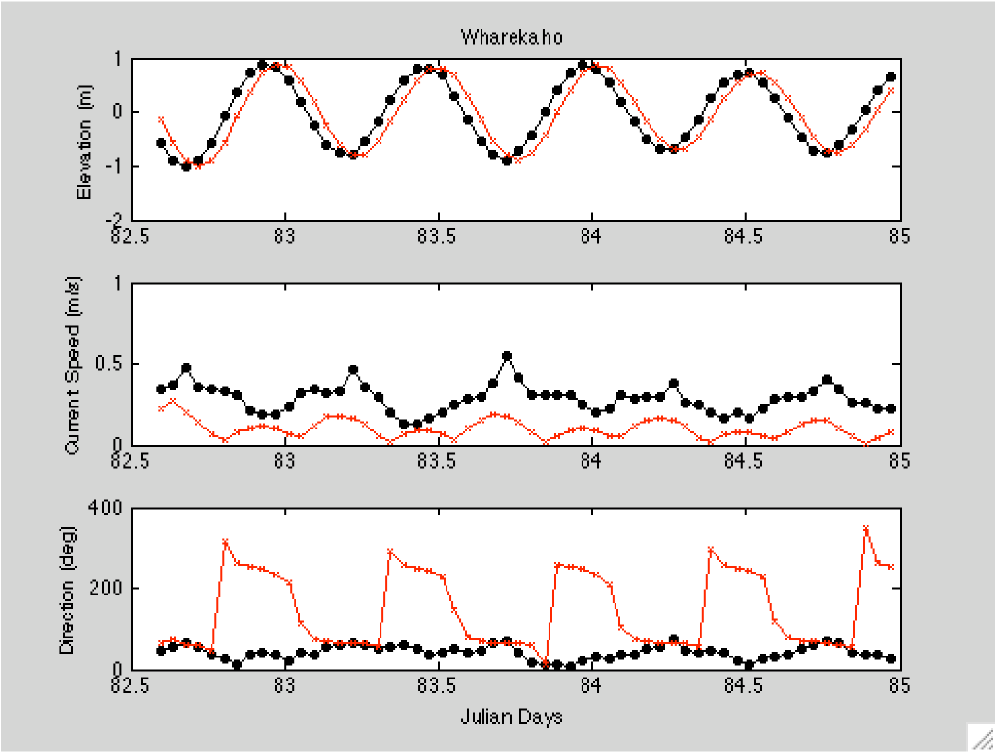
Bed Roughness 0.008

Shakespeare Cliff

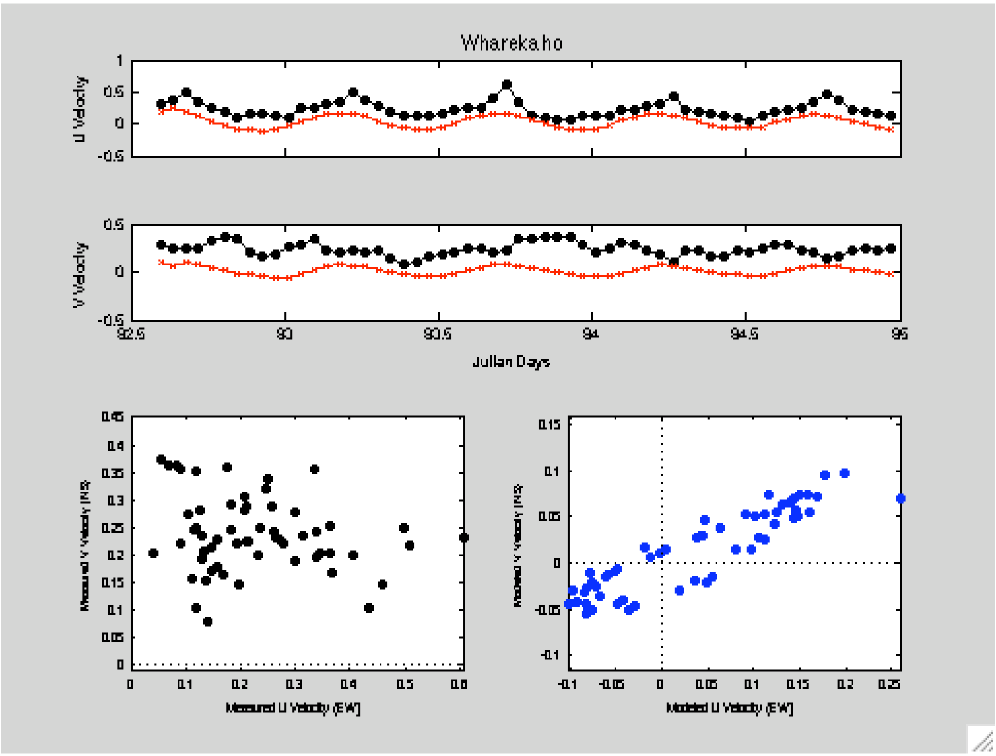




Wharekaho

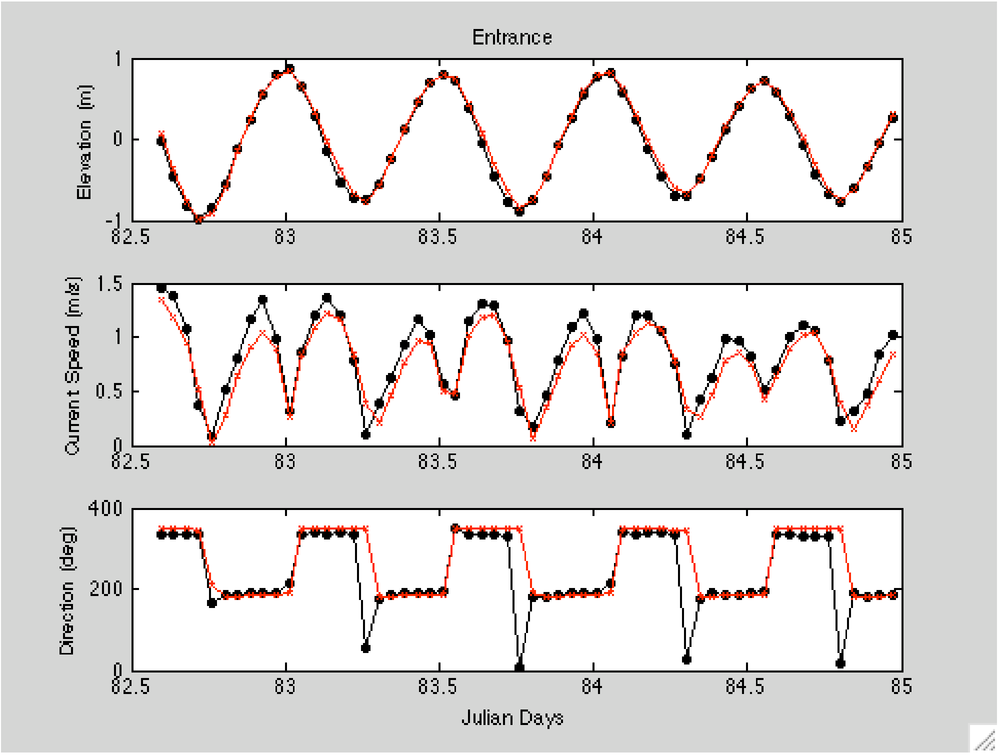


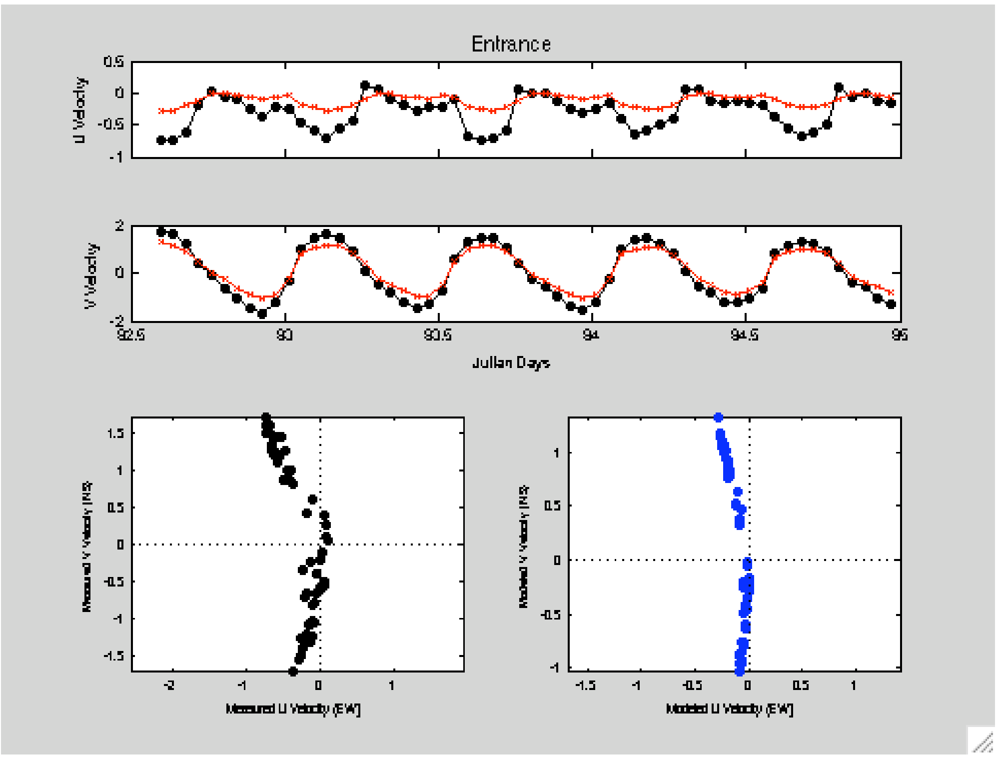
Wharekaho
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days



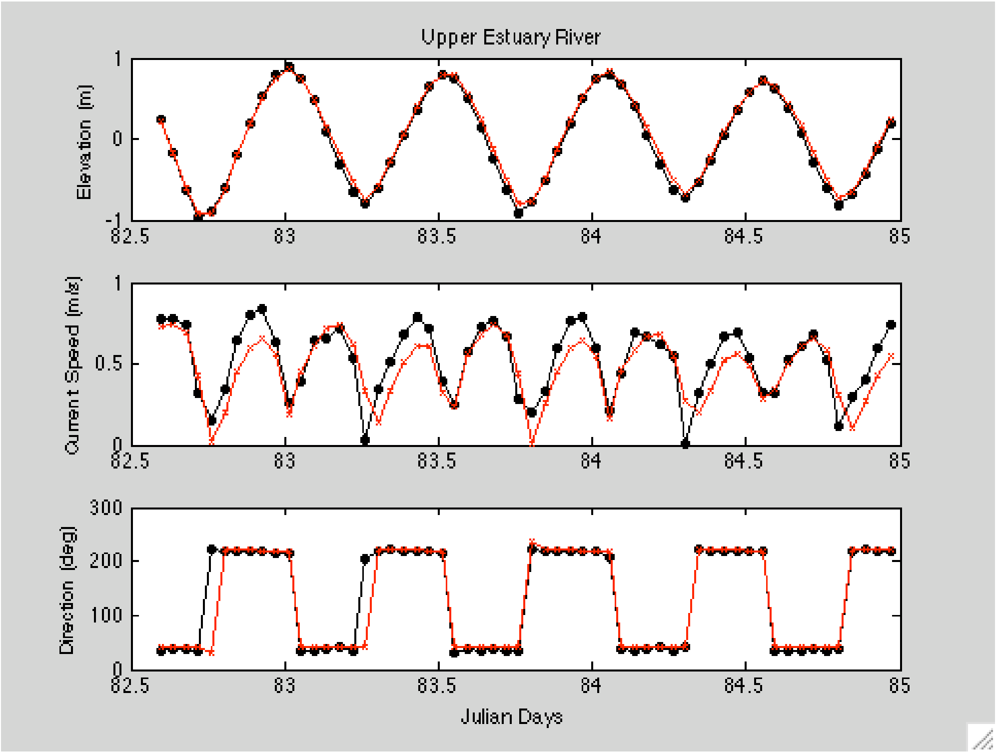
Wharekaho
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Entrance

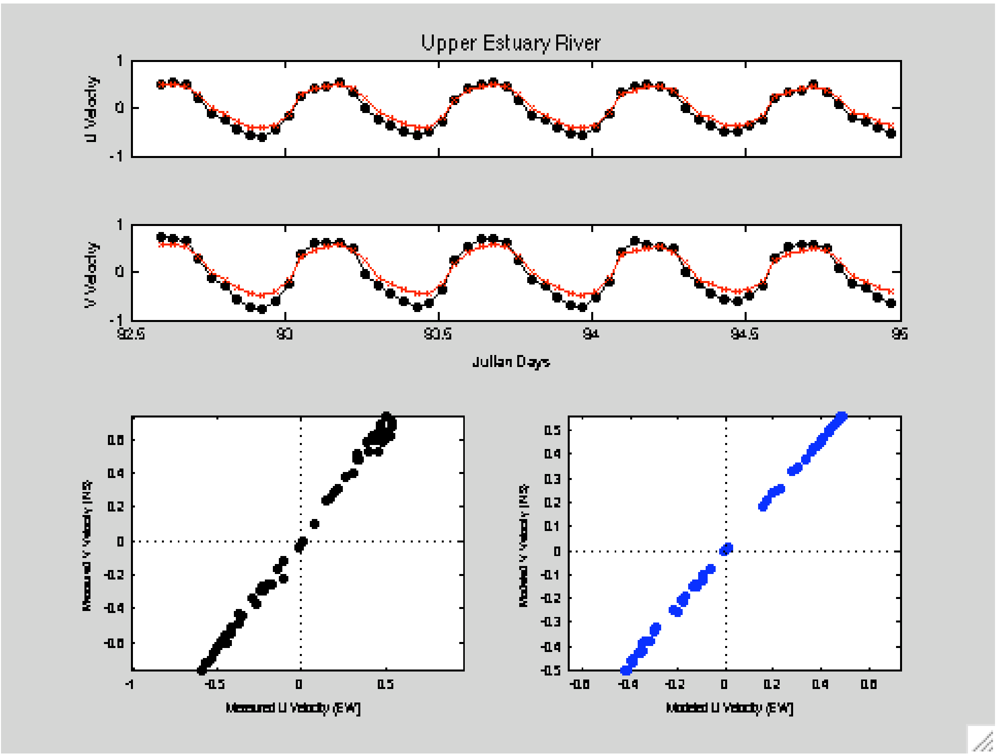

Entrance
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days


Entrance
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Rivers



Upper Estuary River
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days

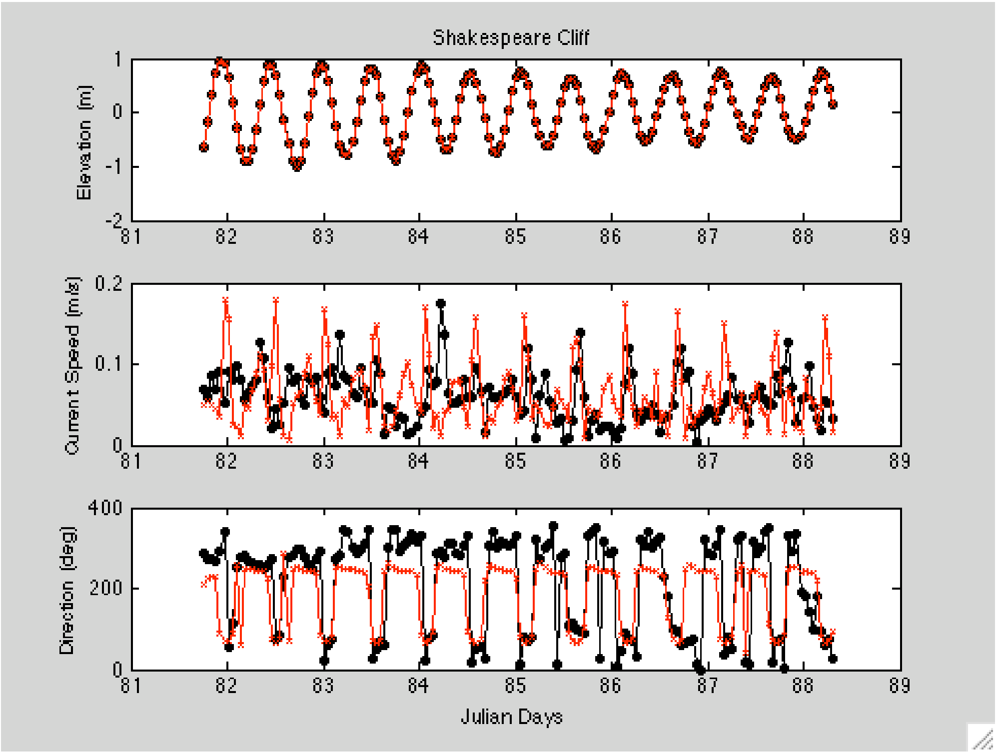


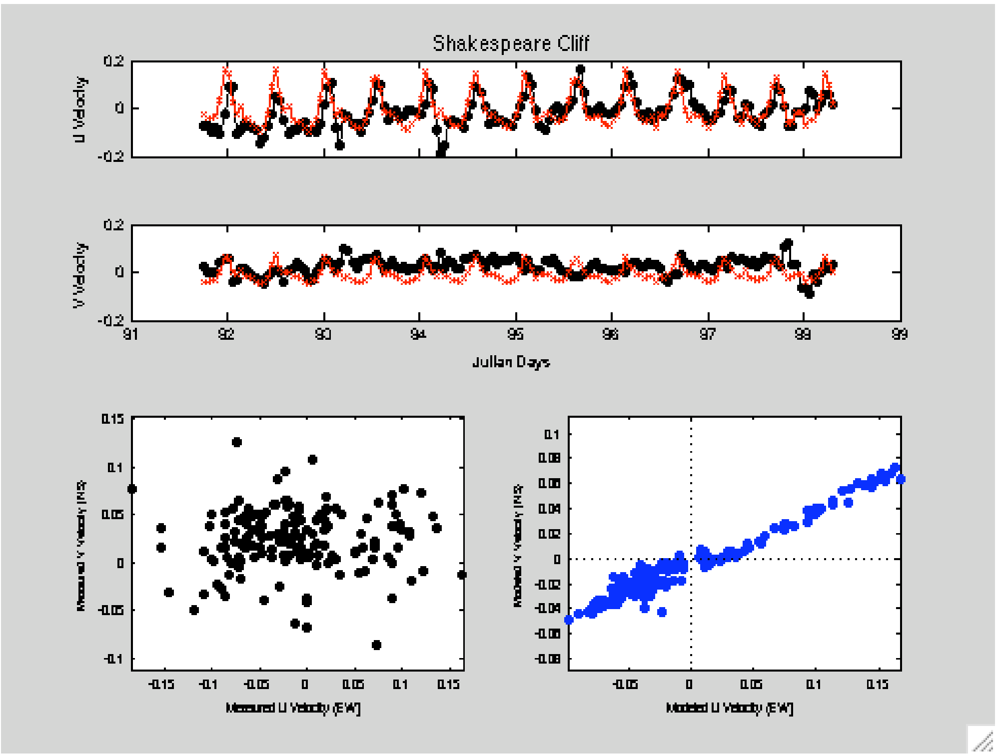
Upper Estuary River
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

Calibration Run 5

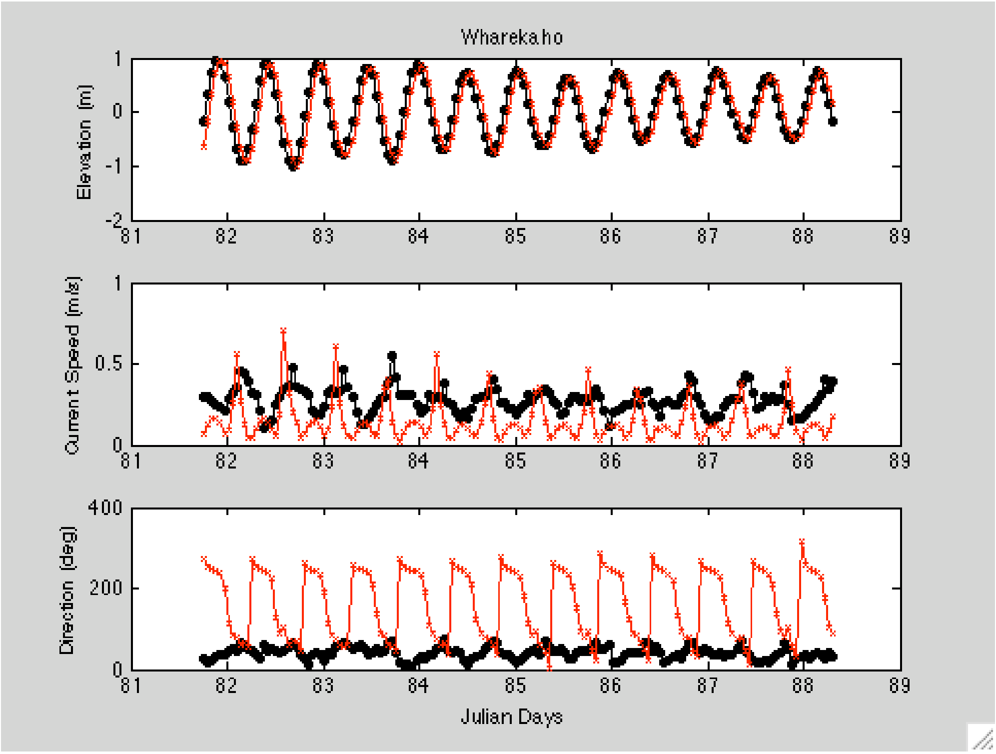
Bed Roughness Map

Shakespeare Cliff

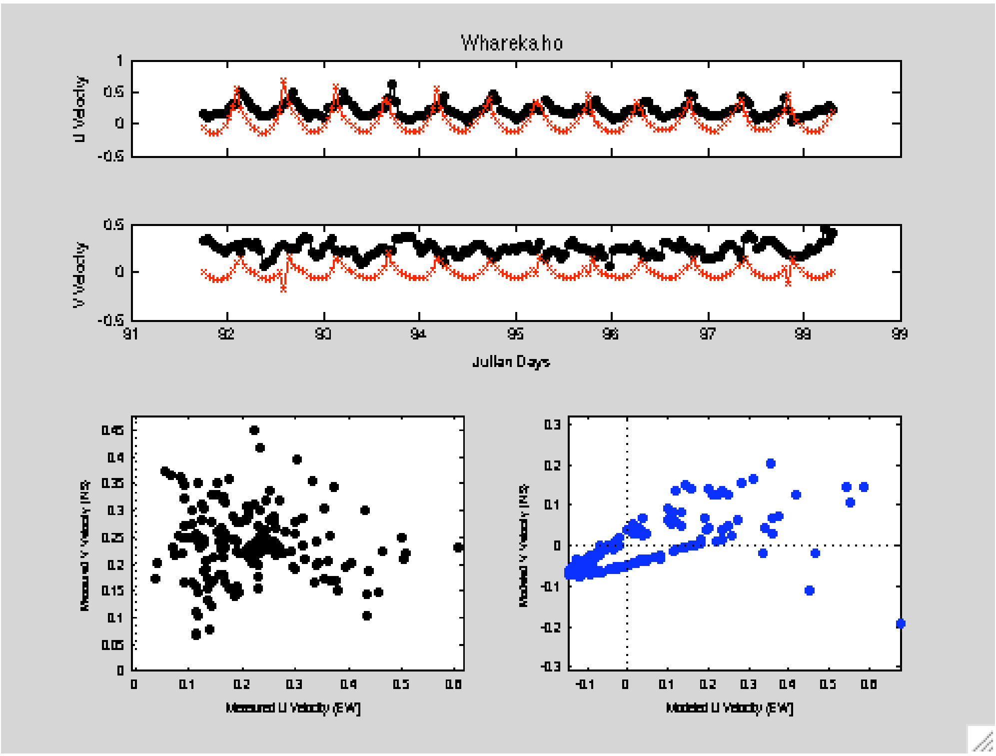




Wharekaho

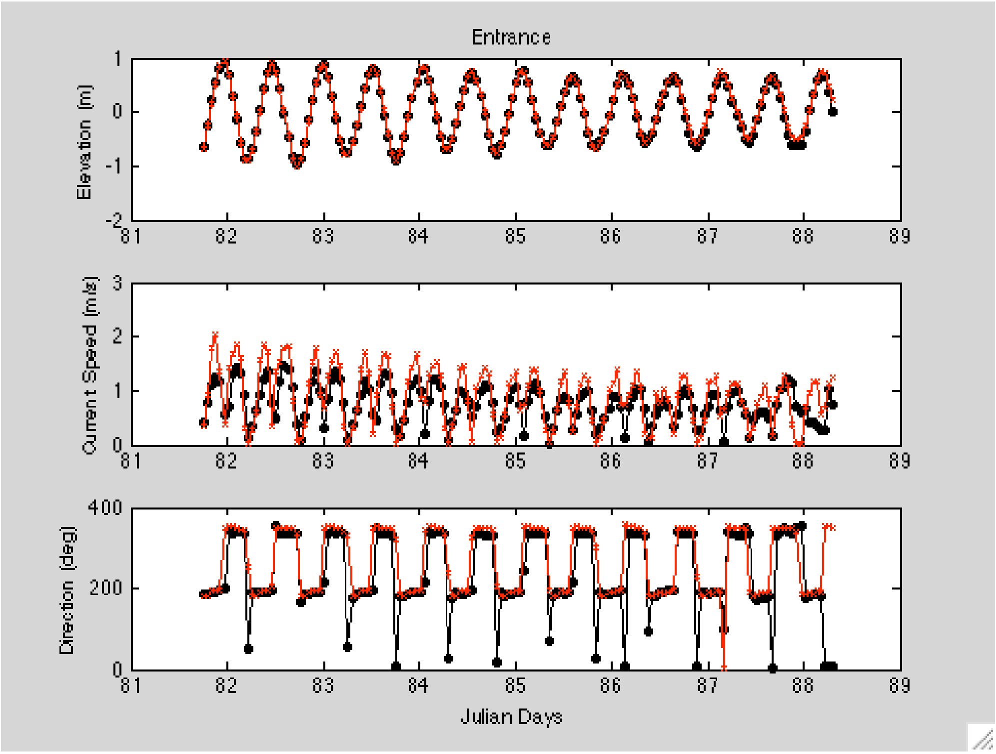


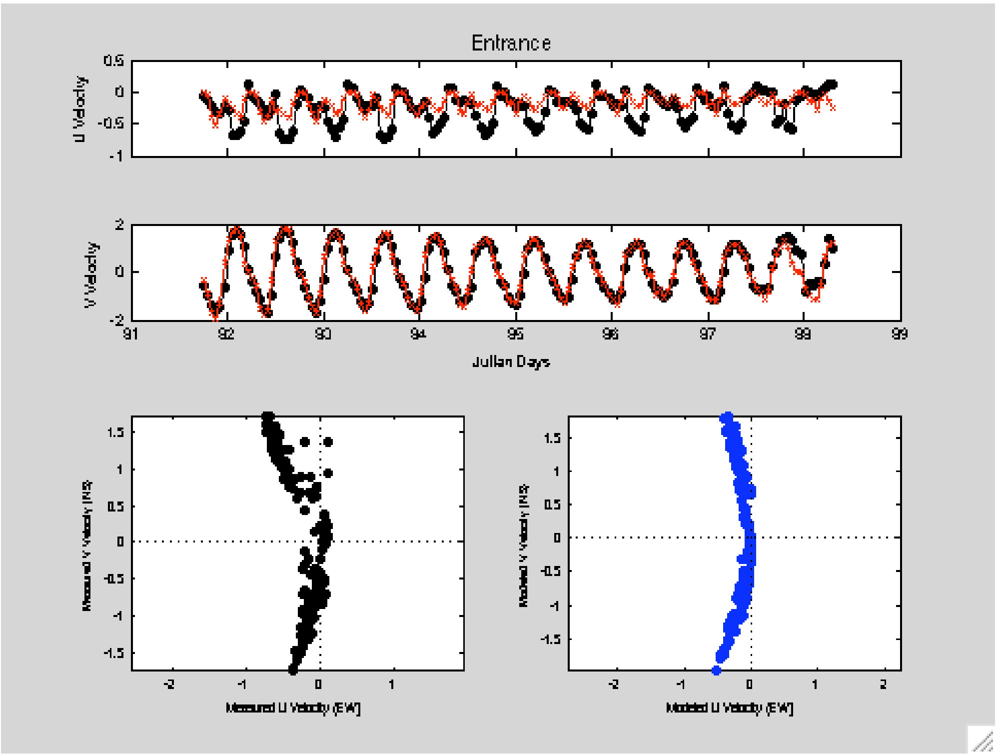
Wharekaho
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days



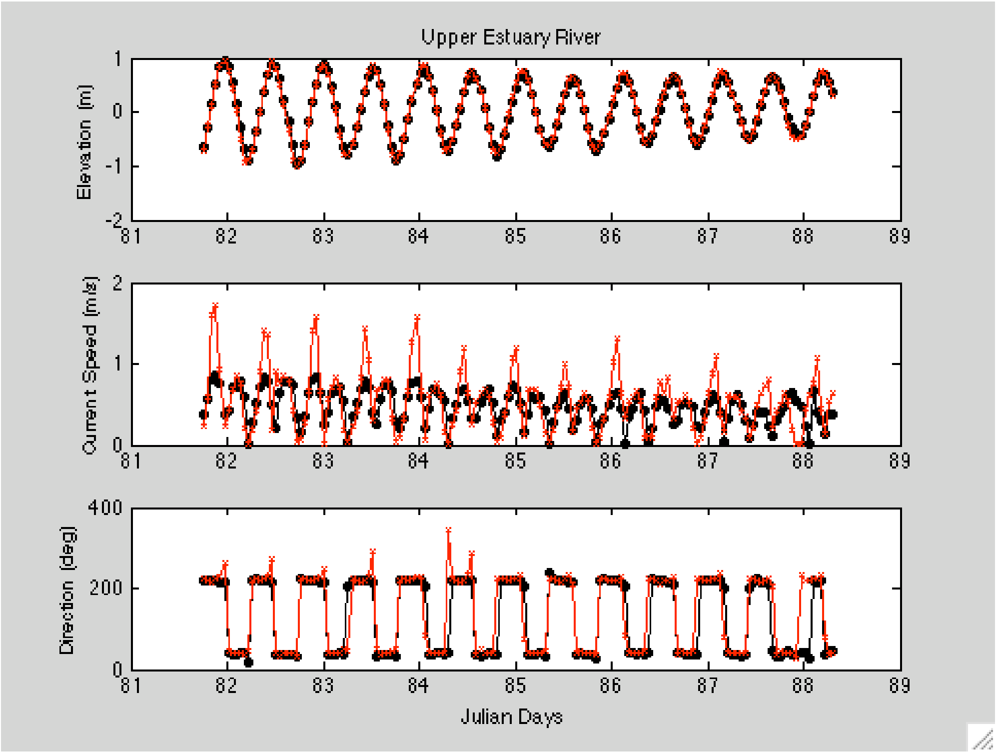
Wharekaho
U Velocity
V Velocity
Julian Days
Measured U Velocity (EW)
Modeled U Velocity (EW)

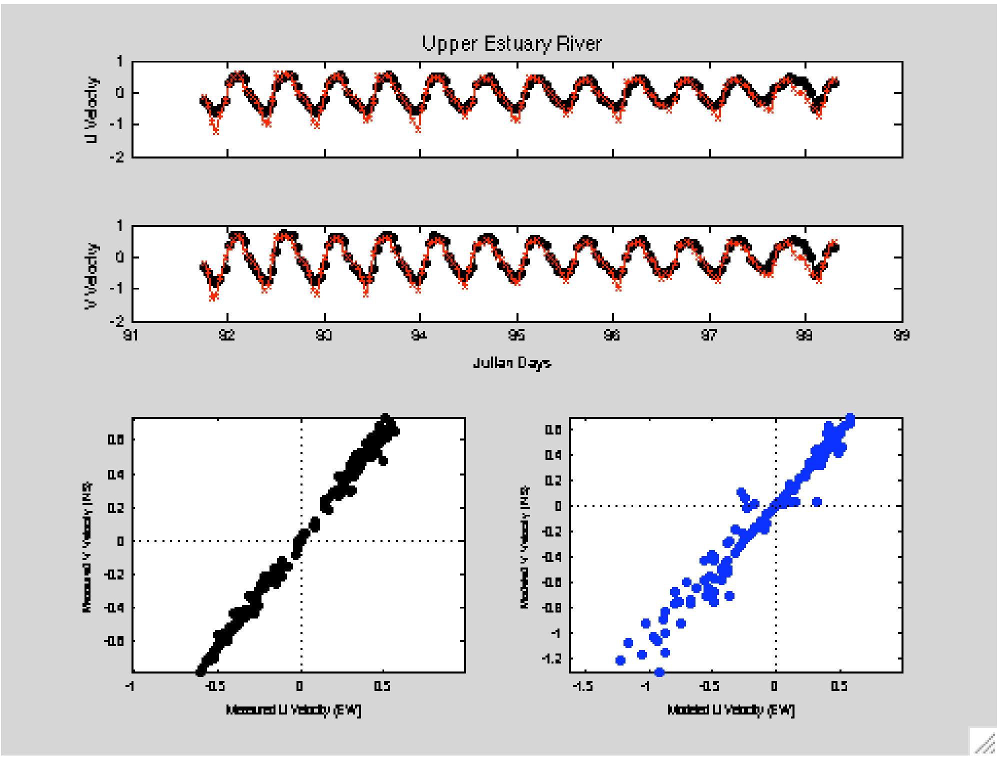
Entrance


Entrance
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days

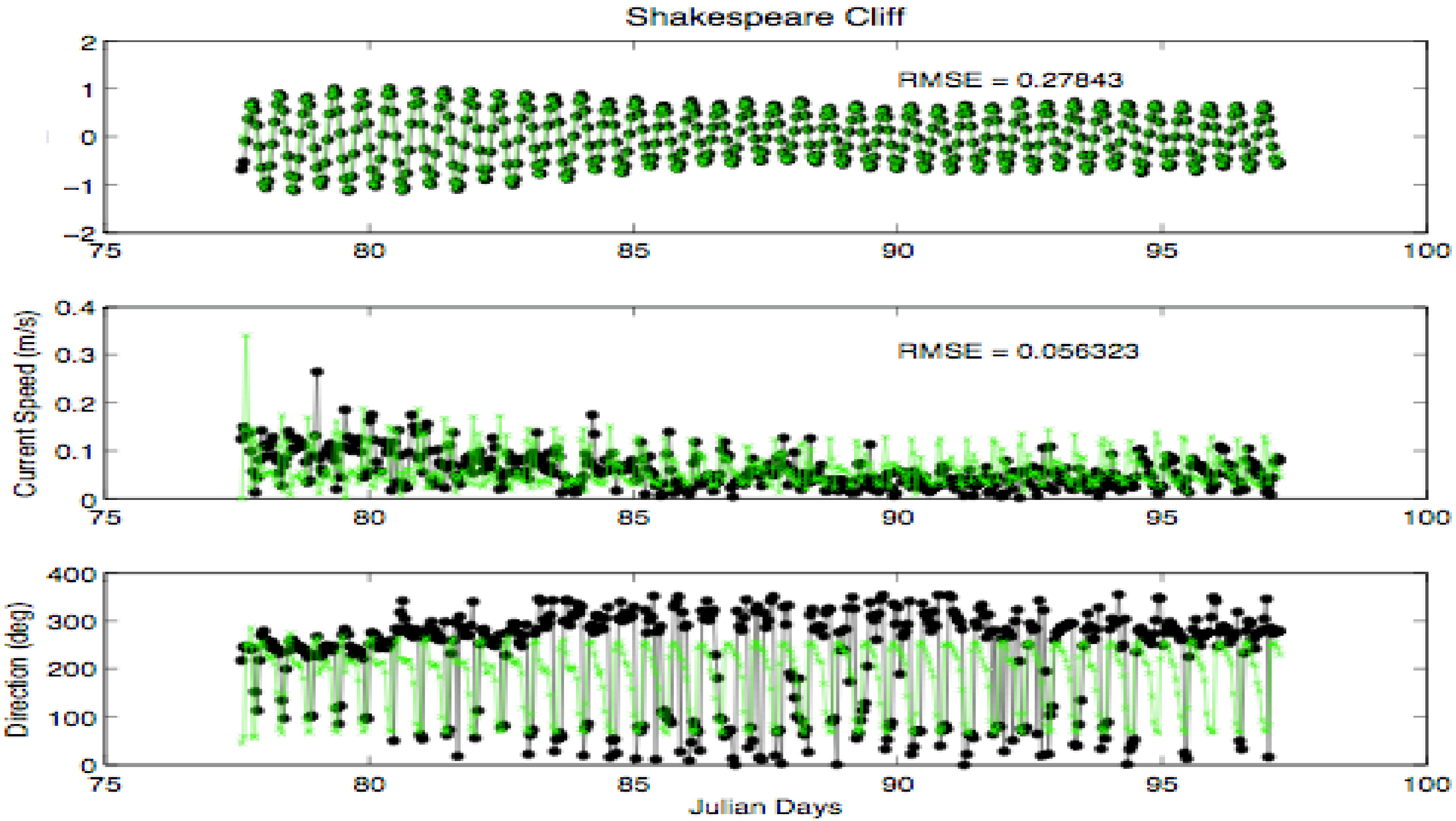

Entrance
U Velocity
V Velocity
Julian Days

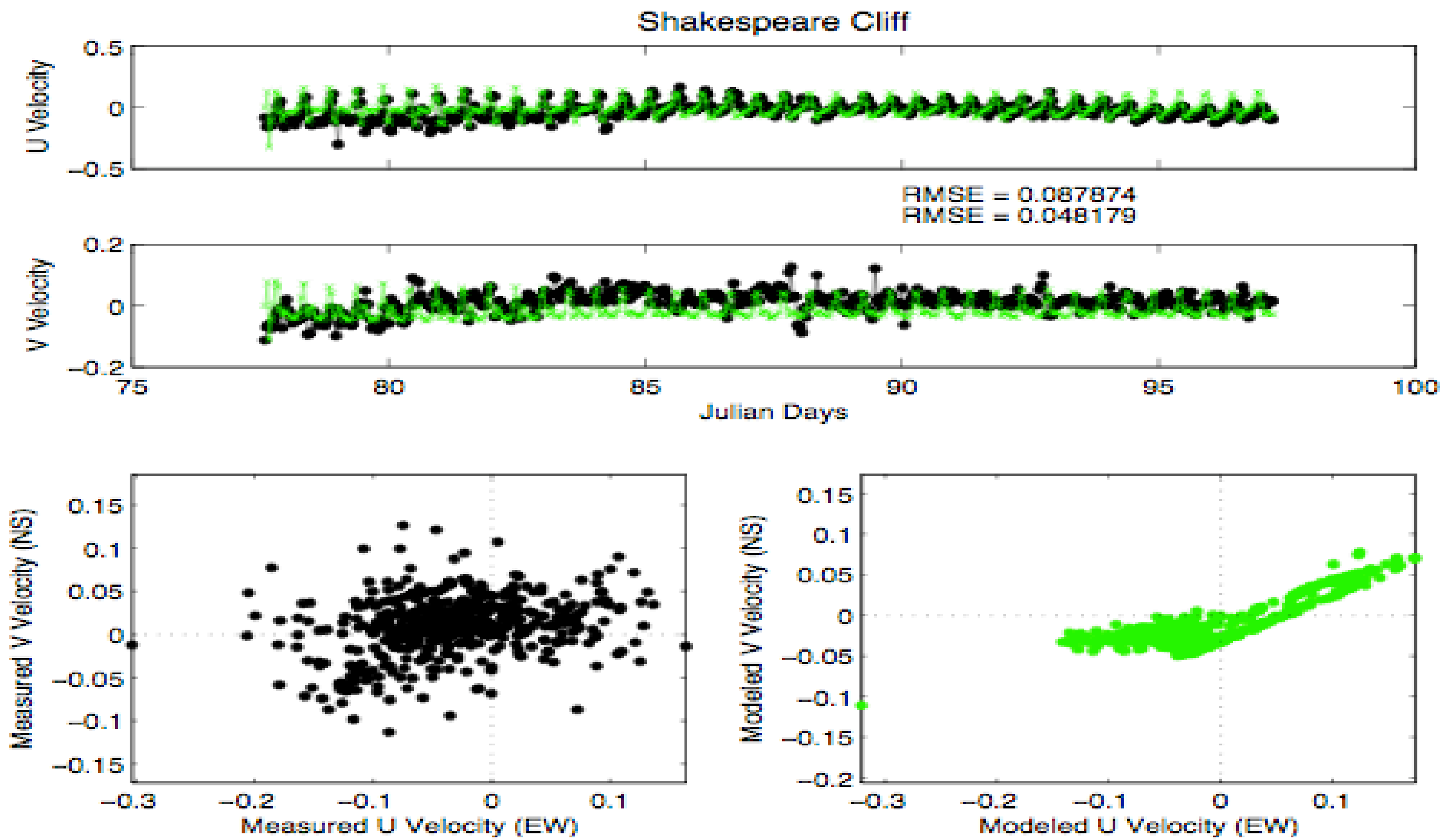
Rivers


Upper Estuary River
Elevation (m)
Current Speed (m/s)
Direction (deg)
Julian Days

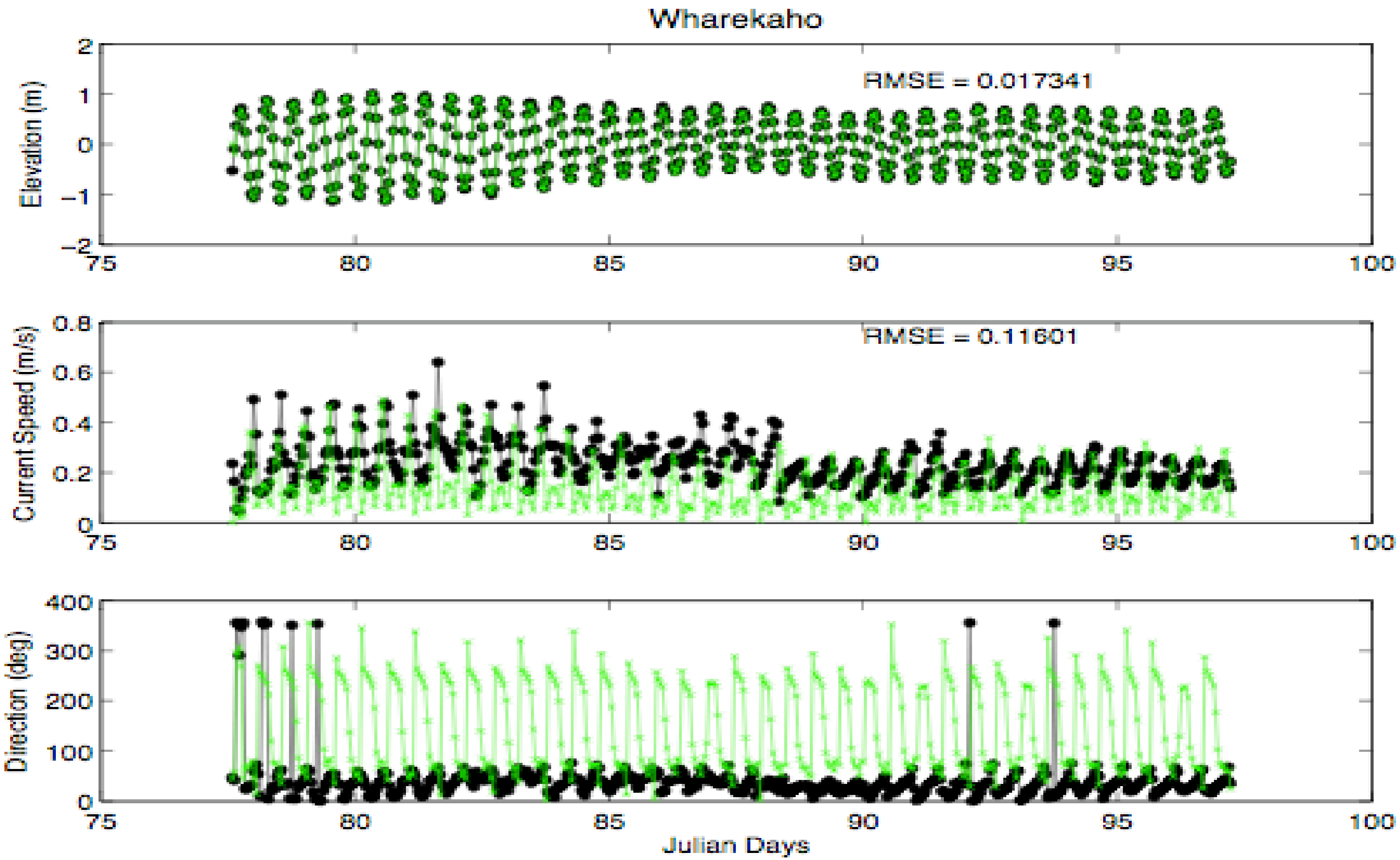

Upper Estuary River
U Velocity
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

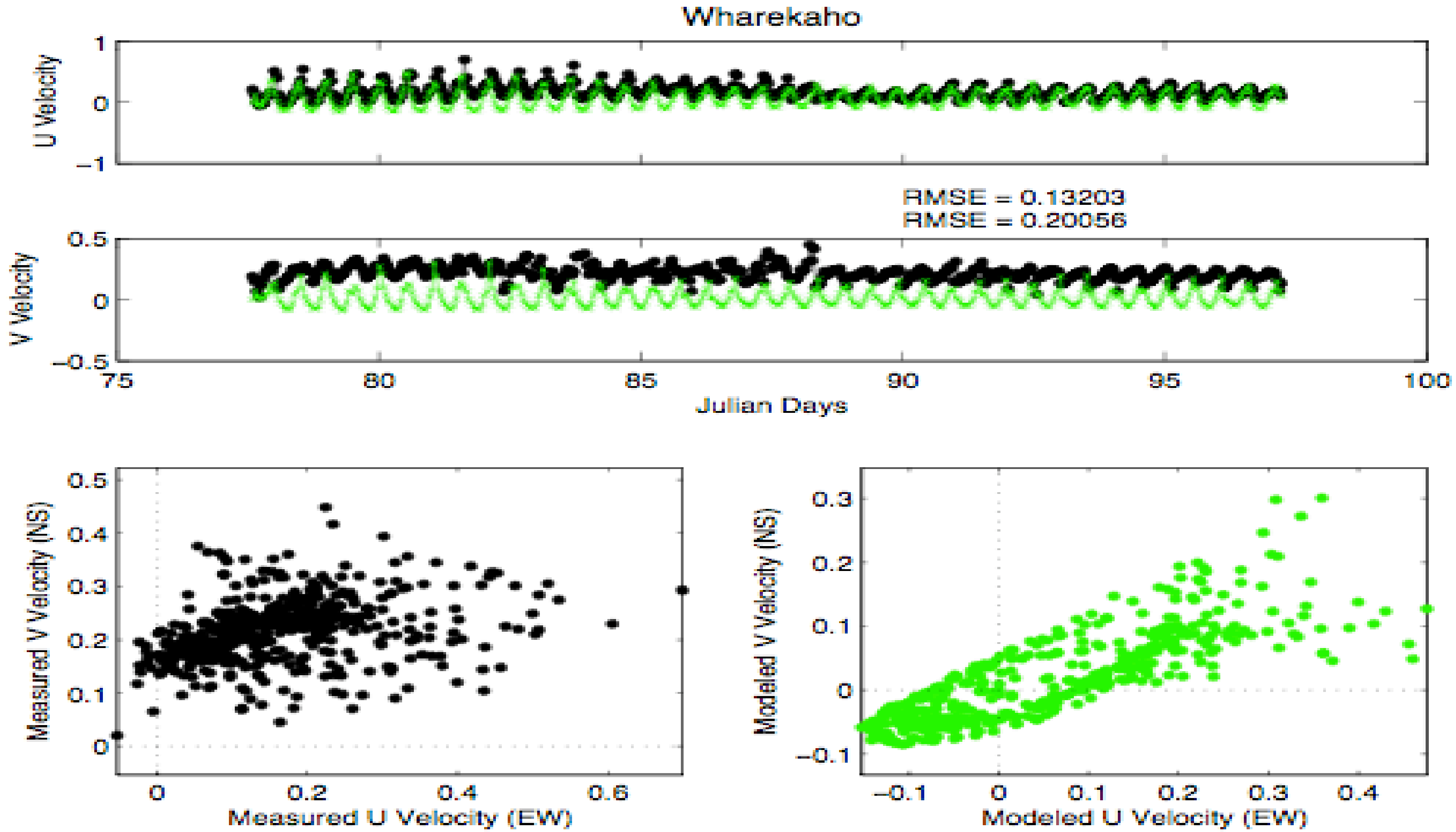
Bed roughness and Phase difference boundary final calibration.



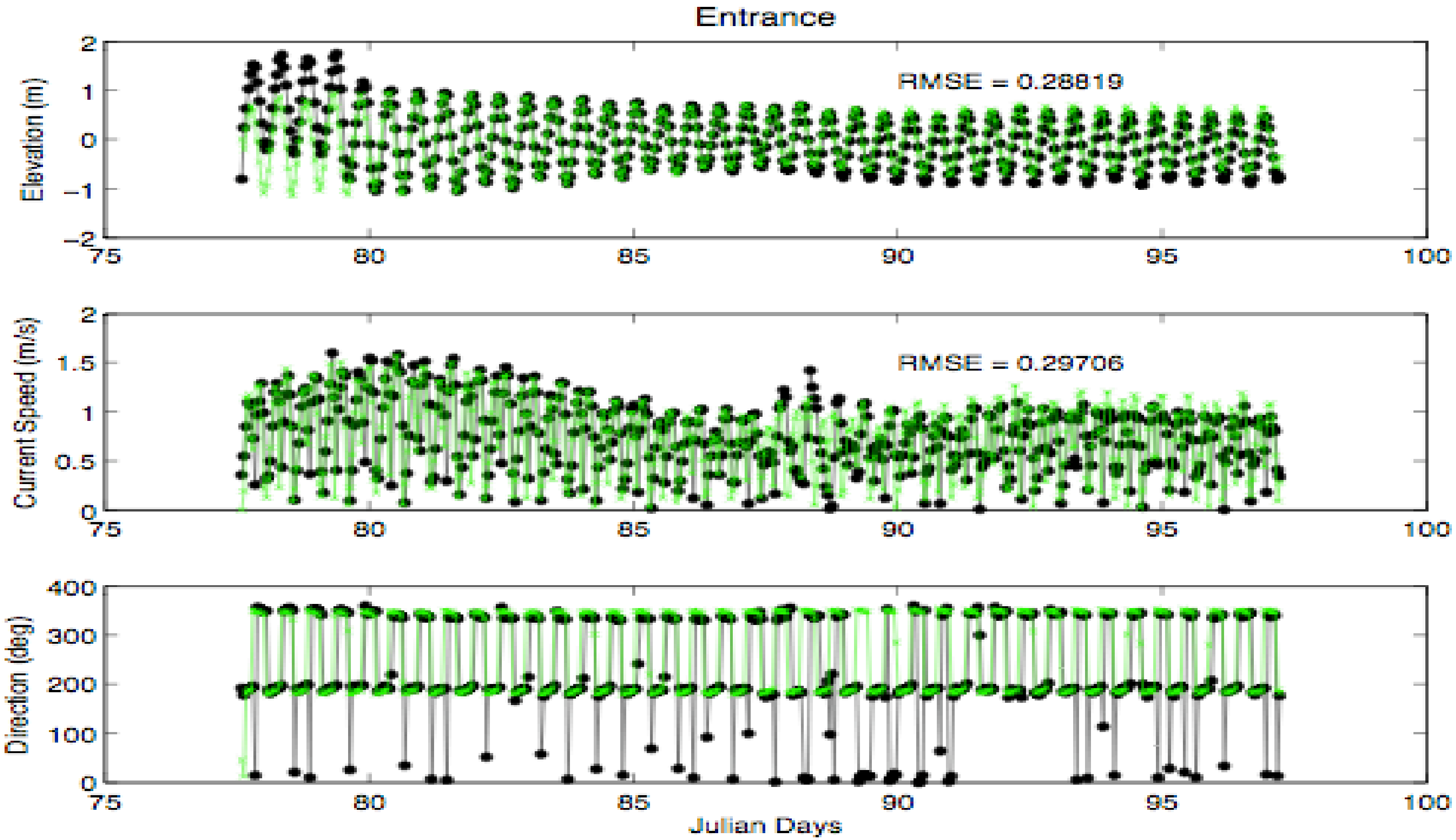


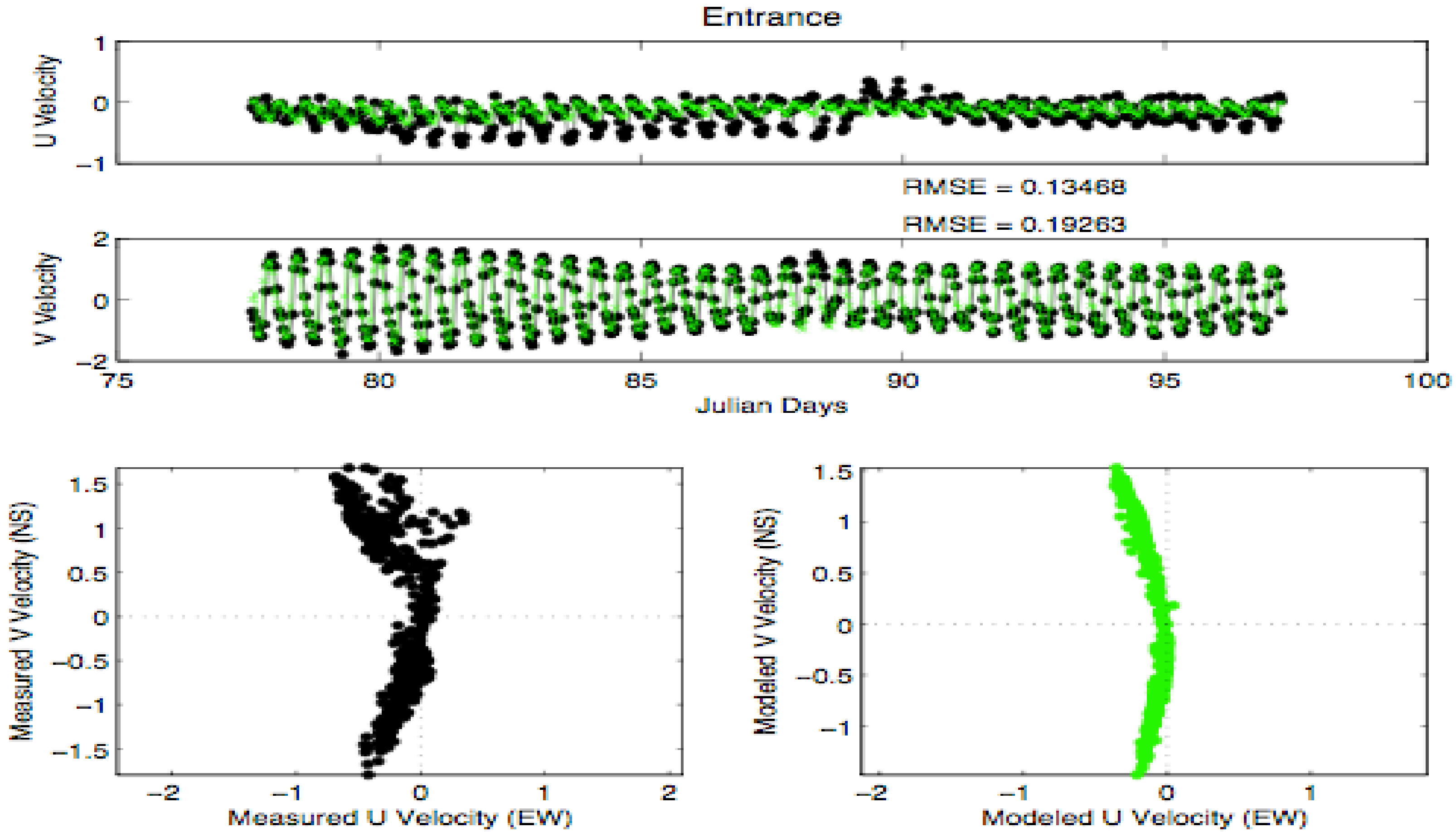
Shakespeare Cliff
U Velocity
V Velocity
RMSE = 0.087874
RMSE = 0.048179
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

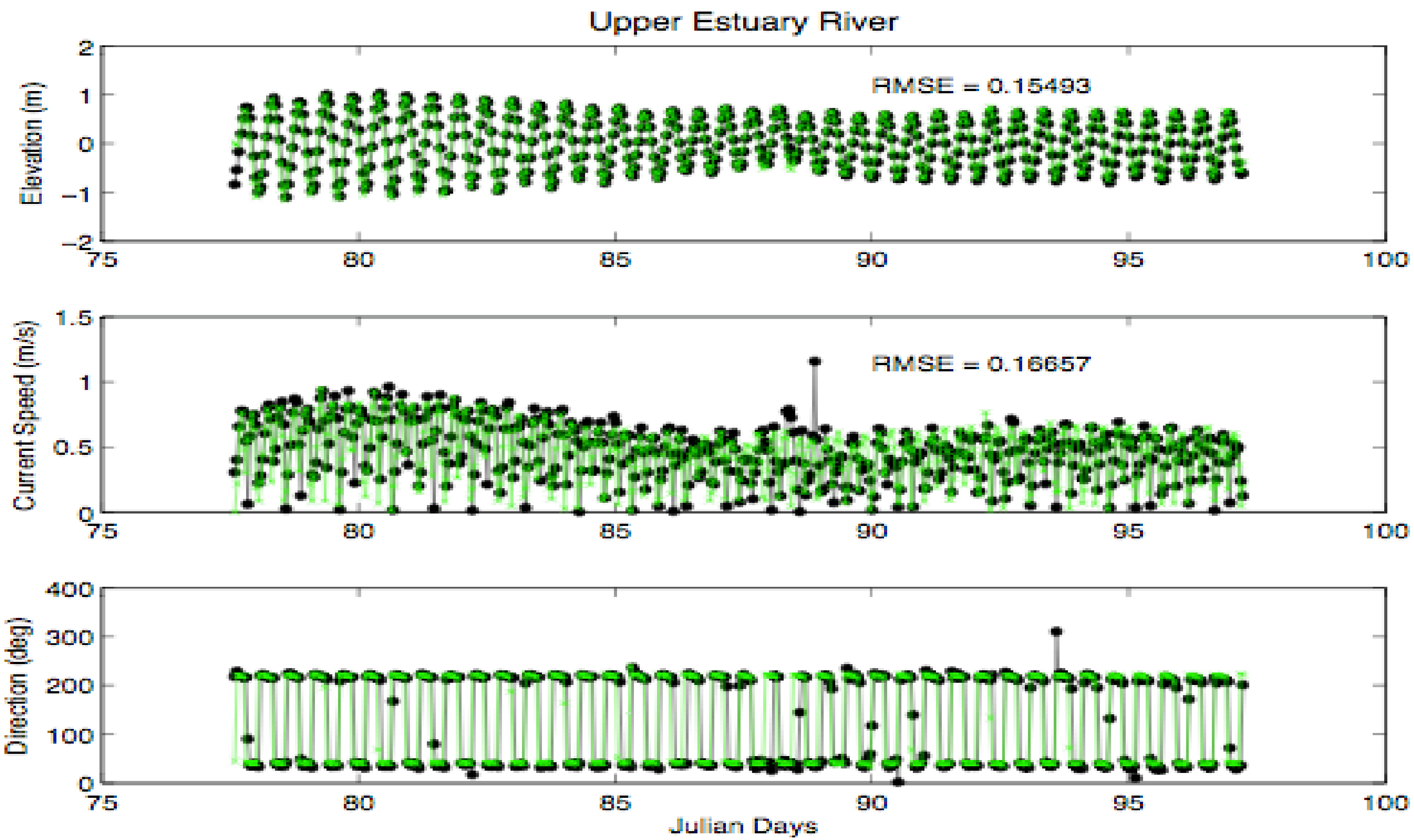

Wharekaho
Elevation (m)
RMSE = 0.017341
Current Speed (m/s)
RMSE = 0.11601
Direction (deg)
Julian Days
2
1
0
−1
−2
0.8
0.6
0.4
0.2
0
400
300
200
100
75
80
85
90
95
100

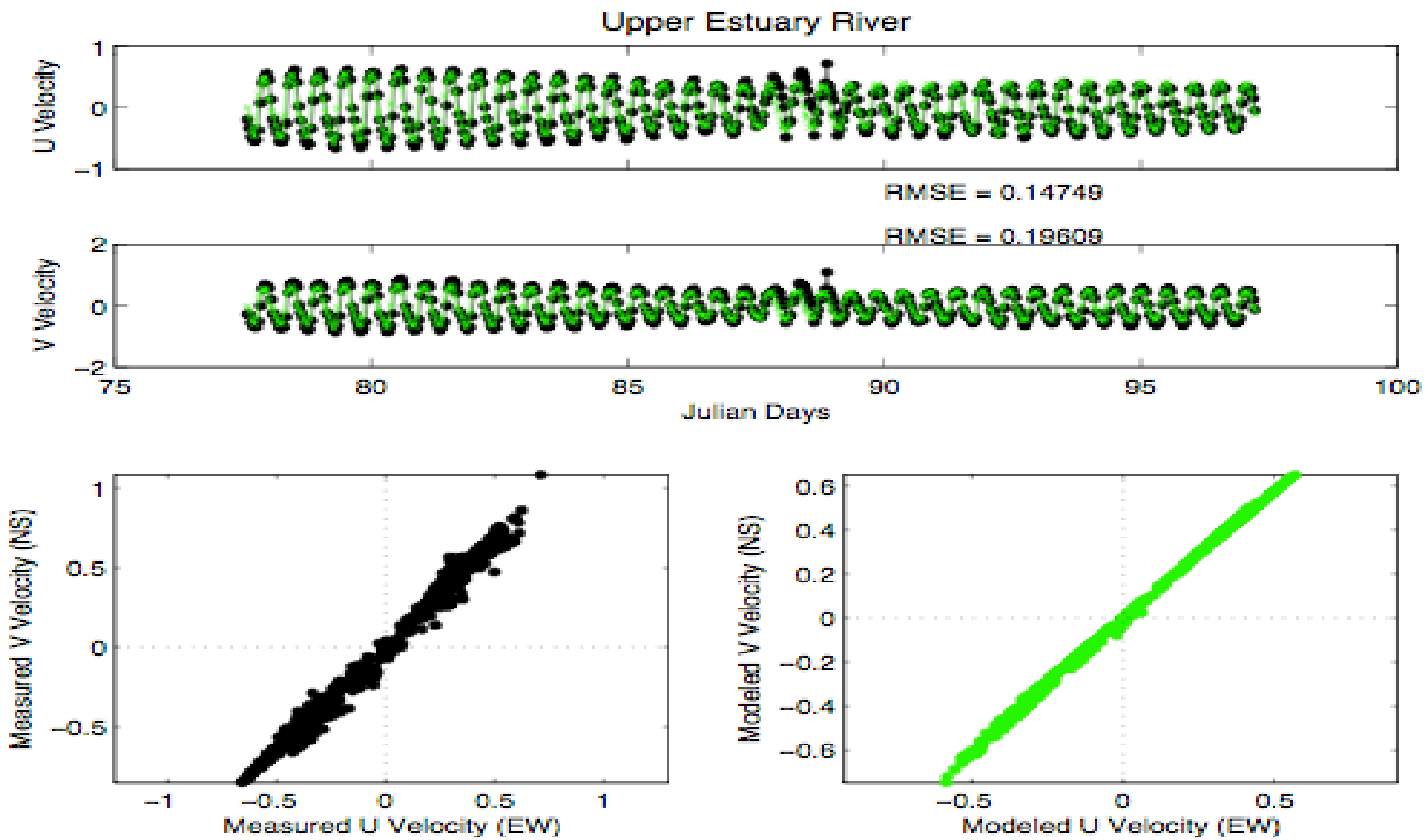


Wharekaho
U Velocity
RMSE = 0.13203
RMSE = 0.20056
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

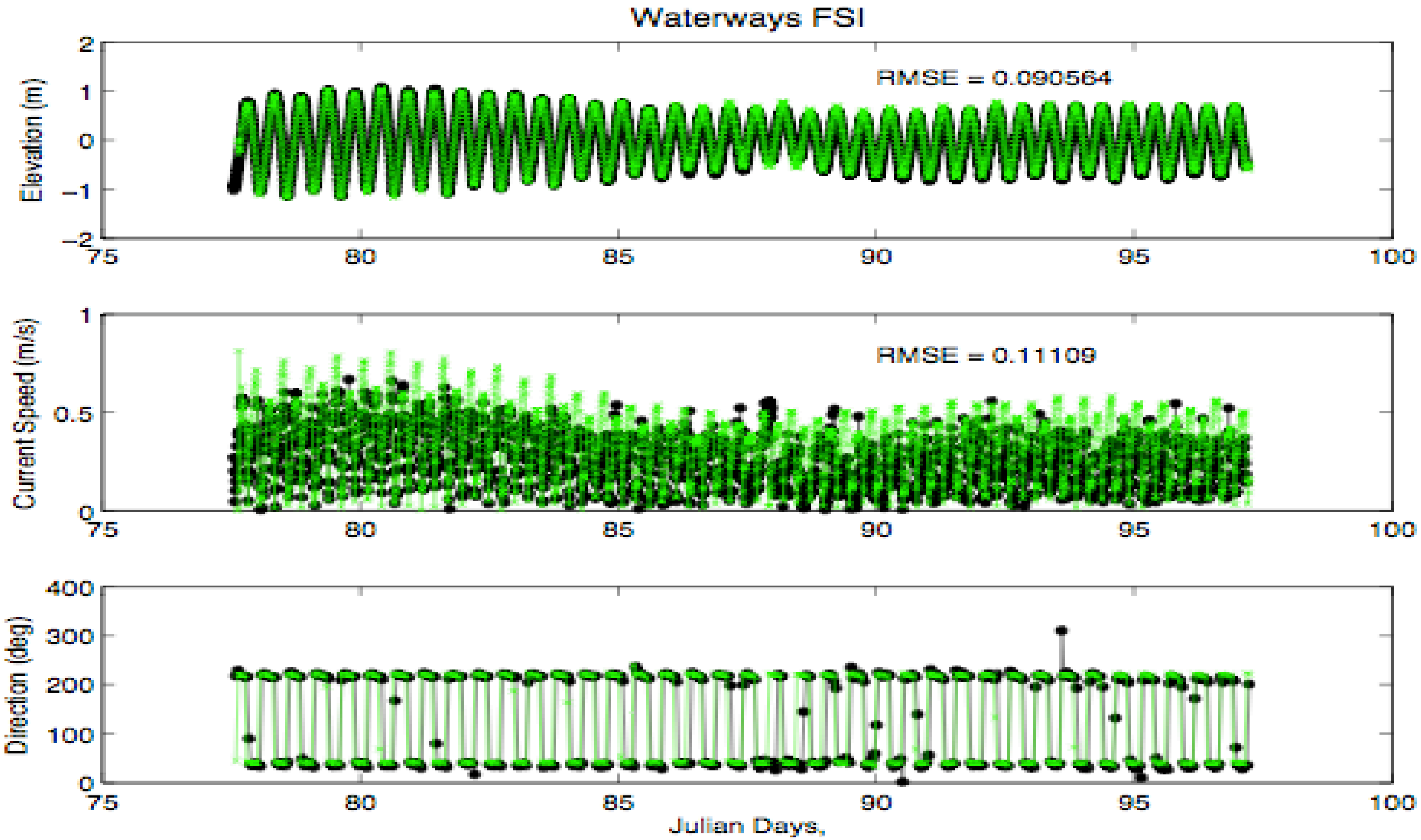

Entrance
Elevation (m)
RMSE = 0.28819
Current Speed (m/s)
RMSE = 0.29706
Direction (deg)
Julian Days
75
80
85
90
95
100

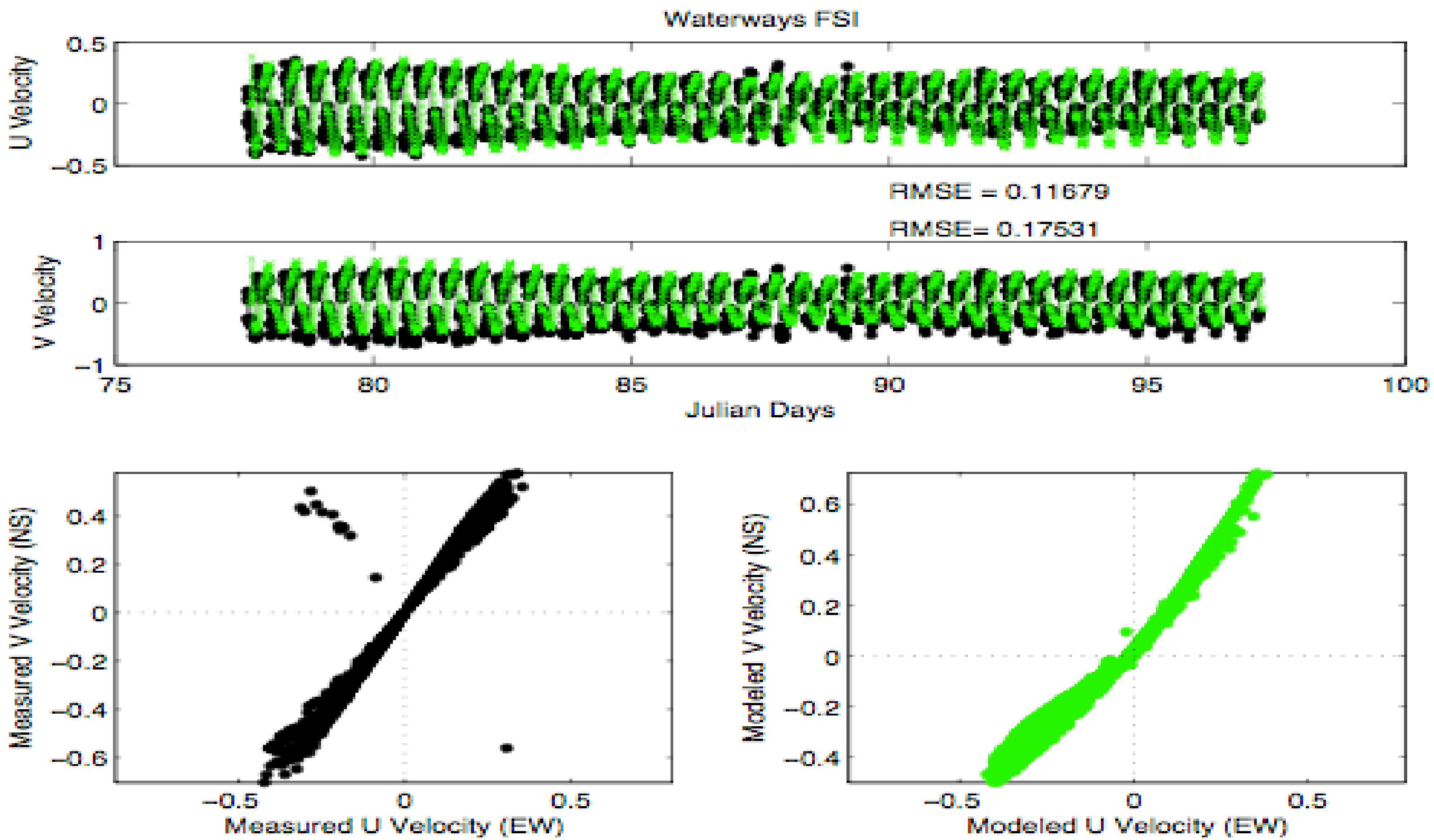

Entrance
U Velocity
RMSE = 0.13468
RMSE = 0.19263
V Velocity
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)


Upper Estuary River
Elevation (m)
RMSE = 0.15493
Current Speed (m/s)
RMSE = 0.16657
Direction (deg)
Julian Days
75
80
85
90
95
100



Upper Estuary River
U Velocity
V Velocity
RMSE = 0.14749
RMSE = 0.19609
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)


Waterways FSI
RMSE = 0.090564
Elevation (m)
RMSE = 0.11109
Current Speed (m/s)
Direction (deg)
Julian Days,
75
80
85
90
95
100



Waterways FSI
U Velocity
0.5
0
−0.5
RMSE = 0.11679
RMSE= 0.17531
V Velocity
1
0
−1
75
80
85
90
95
100
Julian Days
Measured V Velocity (NS)
Measured U Velocity (EW)
Modeled V Velocity (NS)
Modeled U Velocity (EW)

APPENDIX IV
EDDY VISCOSITY VALIDATION

Eddy Viscosity Validation

The ebb tidal jet that can be seen to exit at the harbour entrance into Mercury Bay has a peak spring velocity of 2.5 m/s. The discharge jet diffuses as it enters the bay and velocities decrease (Figures A1, A2, A3). The out flowing estuarine water is forced to flow to the northern side of Mercury Bay where it exits the model grid. The ebb tidal jet can be seen in Figure A1 to cause two eddies to form; one anticlockwise eddy which causes a small circulation cell to flow back along Buffalo beach back towards the entrance and a second clockwise eddy into central Buffalo Bay adjacent to Whakapenui Point. As the ebb tidal jet velocities increase and the jet disperses into the bay, the eddies can be seen to move in a northern direction from Wharapenui Point further into Mercury Bay (FiguresA1-A3).

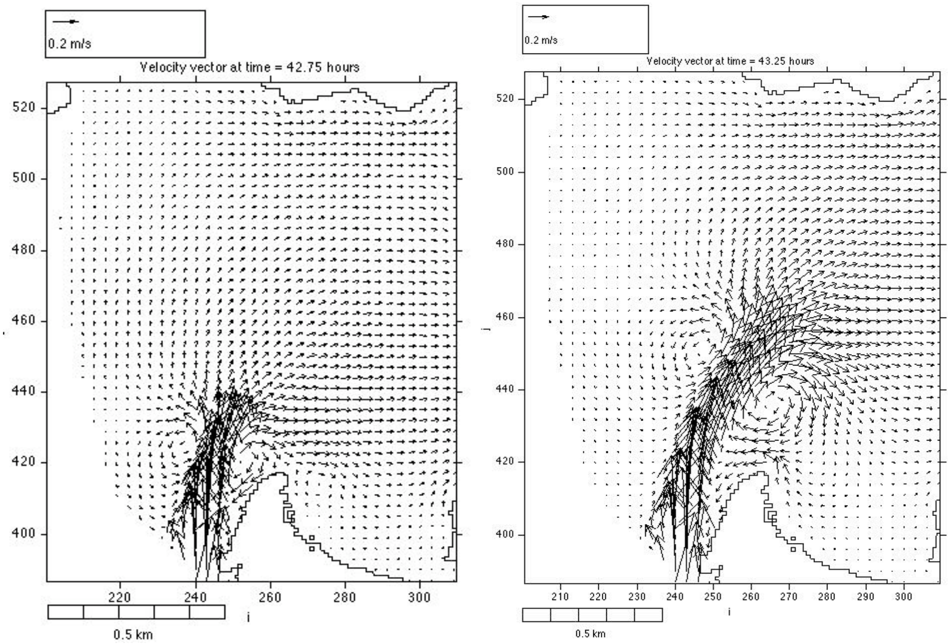


Figure A1: Ebb tidal jet exiting Whitianga Harbour. Note the Clockwise and anti-clockwise eddies forming either side of the ebb jet

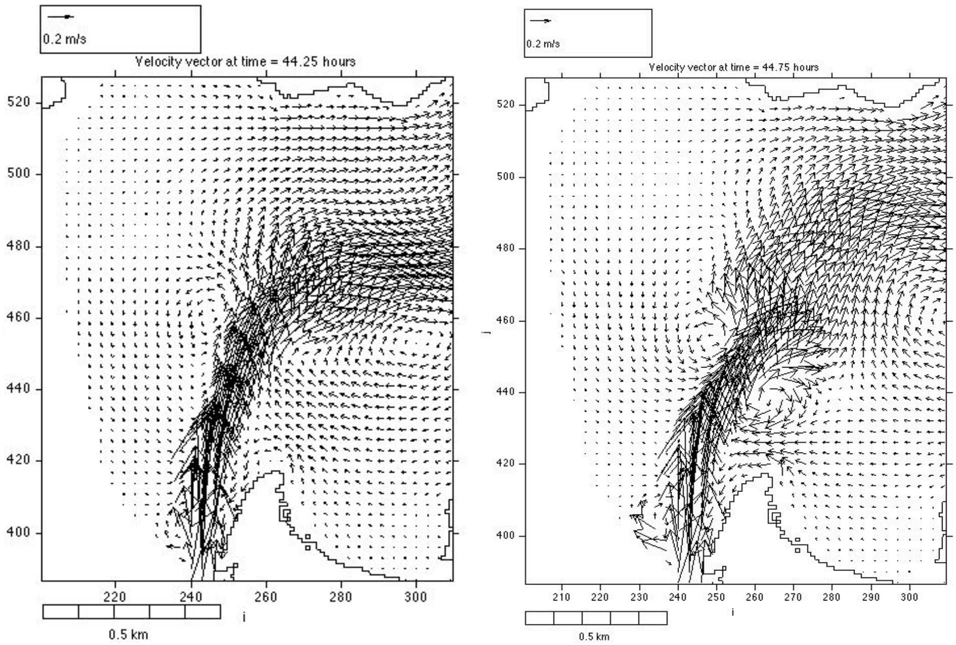


Figure A2: Ebb jet during mid out going tide when velocities are at their peak. Note the mushroom formation in velocities caused by the eddies shifting further into central Buffalo Bay as ebb velocities increase.

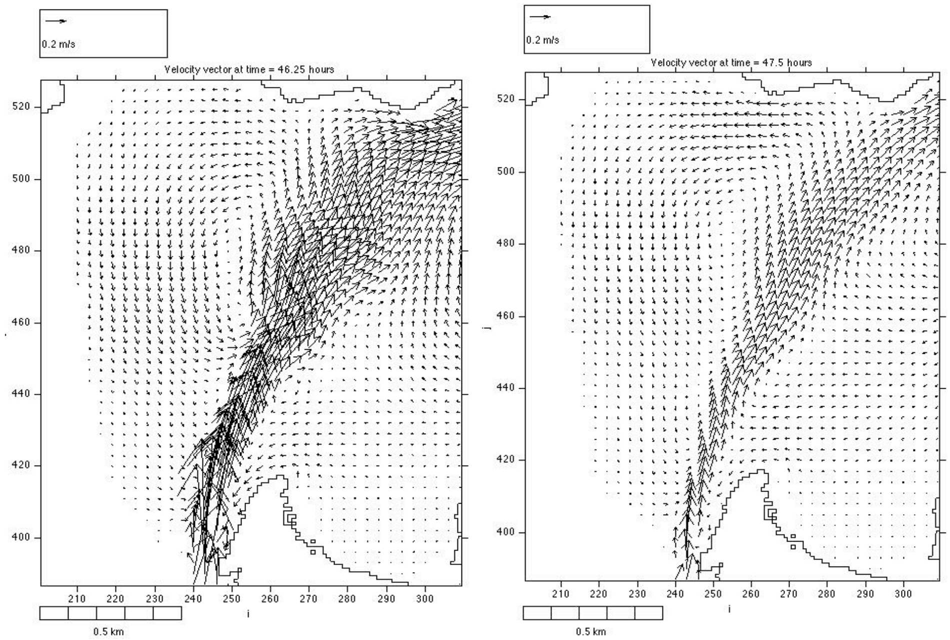


Figure A3: Ebb tidal jet exiting the entrance of Whitianga Harbour into Mercury Bay as velocities slow down coming into slack tide.

Figure A4: Ebb velocity vectors output by the 3DD model predicting an ebb tidal suspended sediment plume entering Mercury Bay.

Figure A4 shows a snapshot of ebb velocities as they disperse into Mercury Bay. The aerial photograph shown in Figure A4 was used to validate eddy viscosity. When the velocity vectors are compared with the aerial photograph showing a sediment plume into the bay, the eddy patterns can clearly be distinguished as mushrooming within the suspended sediment plume. Overall, the modelled prediction of this artefact is surprisingly good considering that weather data has not been included in the modelled scenario.

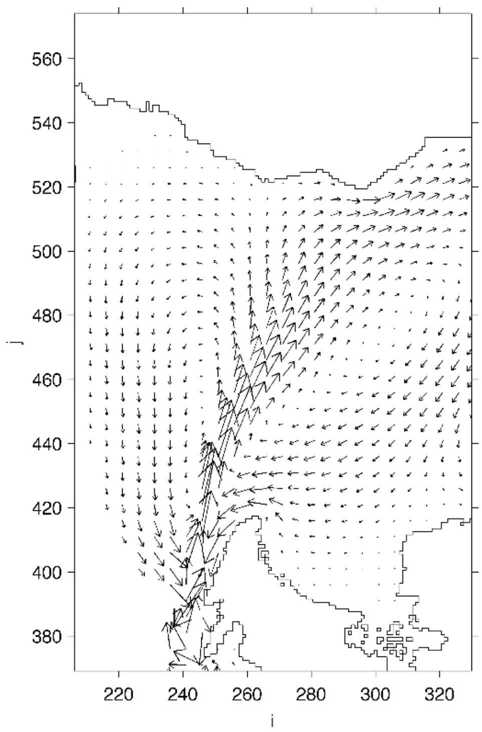


Figure A5: Residual circulation over a tidal cycle in Mercury Bay, showing the development of residual eddy formations driving return currents back towards the entrance.

Steeghs (2007) also describes the development of eddies due to the ebb tidal jet. Figure A4 depicts two eddy formations on either side of the ebb tidal discharge as it exits into Mercury Bay. The western side of the ebb tidal jet forms an eddy that moves in an anti-clockwise direction, whilst the eastern side of the ebb tidal jet forms an eddy that moves in a clockwise direction. An eddy is a zone of re-circulating flow that has a very low flow velocity relative to the current. As these eddy formations diffuse further into the bay the extent of the eddies and the velocity decreases as shown in Figures A2 and A3.

Figure A5 shows the residual circulation in Buffalo Bay. Note the prominent residual eddy formations. The counter-rotating eddy responsible for the transport of sediment along Buffalo beach towards the mouth of the estuary is causing the development of a spit. The clockwise eddy is situated over the approximate location of the developing offshore bar. These results confirm findings found by Steeghs (2007).

APPENDIX V
MODELLING MOVIES
(REFER TO DVD – BACK COVER)