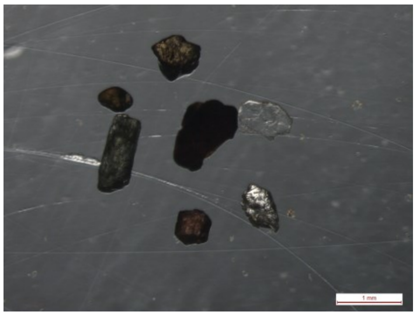

Environmental analysis of sedimentological parameters and heavy mineral sediments in the supply of the beaches in the region of Porto (Northern Portugal)

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Todas as correções determinadas pelo júri, e só essas, foram efetuadas.

O Presidente do Júri,

Porto, ______/______/_________

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ABSTRACT

Heavy minerals are invaluable evidence with regards to the genesis, transportation and final deposition of sediments in fluvial systems. Mineralogical traces in relation to coastal dynamics and fluvial systems were investigated. The study consisted of a sampling area, sedimentological analysis of the samples, heavy minerals separation, identification and rock provenance analysis, and plotting of the data in a cartographic basis as a means to locate sediment sources of the Douro coastline.

All the samples collected consisted of gravel ranging from very fine gravel to medium gravel. More than half of the samples analysed were very fine gravel that was moderately sorted to moderately well-sorted. The overall distribution was that 50% of the sample was fine skewed, 25 % was very fine skewed and the other 25% was symmetrical. Kurtosis varied from very platykurtic to leptokurtic, that is, 25% of the sample was very platykurtic, 50% was platykurtic, 17% was mesokurtic and 8% was leptokurtic.

The heavy minerals identified at all four sampling stations is consistent with the geological setting of the study area. The heavy minerals identified consisted predominantly of quartz, muscovite, biotite and zircon. In addition to this, other less common minerals were identified that included garnet, tourmaline, amethyst, amazonite, amphibole, chlorite and topaz.

The heavy minerals identified and the statistical treatment of particle size analysis suggests the stability of sedimentary processes on all beaches studied. With these considerations and given the data resulting from this study, the conclusion is that the lateral sediment flow (N-S) in this region is strongly constrained by the geomorphological configuration that is not conducive to sediment dispersion.

Keywords: sedimentological parameters; heavy minerals; sediment distribution; Porto.

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ABBREVIATIONS

H.F - Heavy fraction

HWL – High water line

LWL – Low water line

L.F – Light fraction

Chapter 1

INTRODUCTION

1.1 Motivation

In many parts of the world, there is a tendency for people to settle in coastal areas. This increasing demand for shoreline properties has led to the detriment of the coastal environment. Often at times, development will continue despite the already obvious signs of accelerated beach/cliff erosion and/or possible flooding. To counter these emerging issues, short-sighted solutions that only further compound the problem are usually installed. Thus, this clear lack of understanding of short-term and long-term coastal dynamics raises the need for in-depth studies.

Heavy minerals are invaluable evidence with regards to the genesis, transportation and final deposition of sediments in fluvial systems. Sediments transported by rivers and streams contribute significantly to the sediment budget in coastal zones. For most large scale coastal regions, heavy minerals occur with a less than one percent mass percentage (de Meijer 1998). In this study, the Douro River is a major supplier of sediments to the Northwest coast of Portugal that has suffered from severe erosion. Heavy minerals studies will hopefully provide some of the groundwork needed for a comprehensive understanding of the sediment dynamics. Hence, environmental analysis provides a closer look into the processes and parameters that govern the supply of beaches in the region of Porto.

1.2 Goals and Outline

The work carried out in this thesis, aims to provide insight into the sedimentology of the coastal zone in the Porto area. The specific goals of the investigations were:

1) The identification of the heavy minerals present.

2) Rock provenance analysis.

3) Plotting of the data in a cartographic basis.

Chapter 2

LITERATURE REVIEW

2.1 Grain Size

Grain size analysis often provides an overview of the basic characteristics of sediment and sedimentary rocks. This measure is vital in comprehending the various processes acting on the sediments during transportation and deposition. The transfer of erosional products from headlands to sea level by the conveyor belt of the sediment cycle (Figure 1) is an important process that ensures coastlines are continuously supplied with sediments. Using the parameter of grain size, insight is gained into the distance travelled and the processes that have been undergone by the sediments.

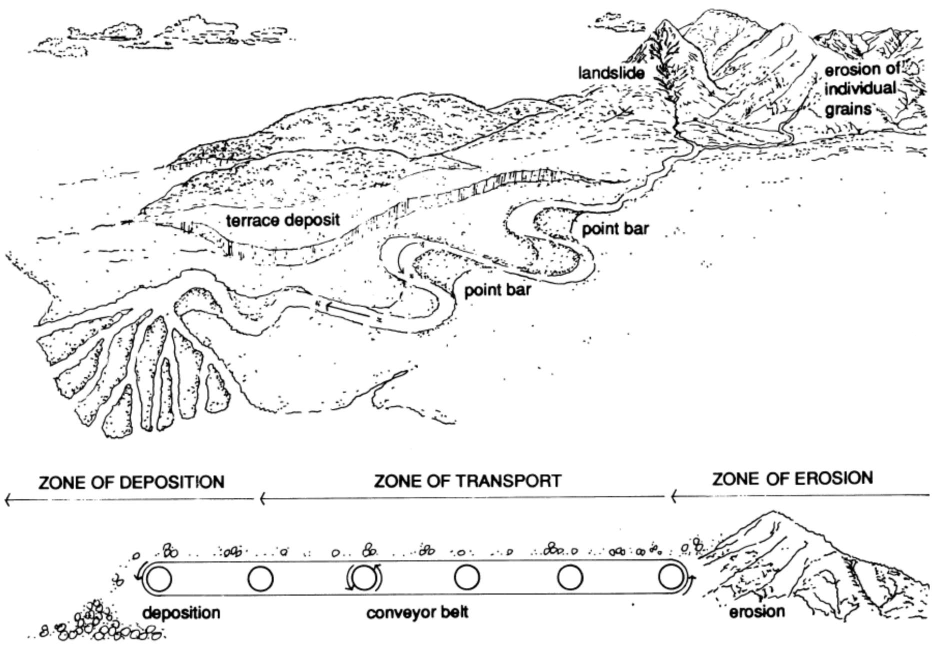


Figure 1. Zones of erosion, transport and deposition, and the river channel as a conveyor belt for sediment (Kondolf, 1997).

Also, grain size is often associated with additional characteristics such as permeability that have huge economic consequences. Hence, grain size analysis although fundamental is an important measure in sediment related research.

2.1.1 Sedimentological Parameters

The parameters used to describe a grain size distribution can be summarised into four main categories, that is, those that measure the average size mean, the spread of sizes around the average (sorting), the symmetry or preferential spread to one side of the average (skewness) and the degree of concentration of grains relative to the average (kurtosis). The four parameters can be acquired by mathematical or graphical methods. The mathematical `method of moments' (Krumbein and Pettijohn 1983; Friedman and Johnson, 1982) provides the most precise descriptions since it uses the whole sample population. Due to this, the results are greatly influenced by the outliers in the tails of the distribution so use of this method is recommended for use only when the size distribution is fully known (McManus, 1998 as cited in Blott and Pye, 2001).

Estimations of the parameters by the graphical method are carried out by plotting frequency data as a cumulative frequency curve, identifying the established values and entering these into the prescribed formulae. Numerous formulae have been put forward (e.g. Trask 1932; Krumbein, 1938; Otto; 1939; Inman, 1952; McCammon, 1962), however the most popularly used formulae are those suggested by Folk and ward (1957). Both the mathematical and graphical methods for obtaining grain size distribution description can now be acquired through the use of GRADISTAT (Blott and Pye, 2001), a grain size distribution and statistics package. Furthermore, the graphical method can also be carried out using Excel.

2.2 Heavy Minerals

Heavy minerals are a distinct group that consists of minerals with a density higher than quartz (the most common rock mineral) and is usually restricted between 2.8-2.9 g cm^{-3}. Most heavy minerals are bound to particular source rocks making them useful indicators of provenance (on the condition that there are statistically noticeable differences between sediment source areas). Heavy mineral analysis provides insight into the various rocks that supply detritus to siliciclastic sediments.

Heavy minerals comprise of the most diverse and intricate part of terrigenous rocks. They are affected by a numerous factors which must be properly assessed if the right conclusion regarding their provenance and distribution is to be obtained. Although the controlling factor is source-rock composition, other crucial considerations are mineral shape, specific gravity and size, in addition to stability during weathering and diagenesis. Generally, the heavy mineral assemblage is less diverse that the suite of minerals obtained from the source rock due to selective sorting and the destruction of less stable species.

The source of many heavy mineral species is restricted to specific rock types. Hence heavy minerals offer insight into the lithology of the source area. The heavy mineral suites are listed in Table 1.

***Table 1**. Detrital heavy mineral suites characteristic of source rock types (modified from Pettijohn 1975:487 as cited in Lindholm 1985)*

Reworked sediments	rutile, rounded tourmaline, and rounded zircon
Low-rank metamorphic	biotite, chlorite, epidote, glaucophane, and tourmaline (small pale brown euhedra)
High-rank metamorphic	andalusite, chloritoid, diopside, epidote, garnet, hornblende (blue-green variety), kyanite, sillimanite, and staurolite
Silicic igneous	apatite, hornblende (brownish green variety), monazite, sphene, tourmaline (small pink euhedra), and zircon (euhedra)
Mafic igneous	anatase, augite, enstatite, hypersthene, hornblende (reddish brown variety), and olivine

2.2.1 Studies in Heavy Minerals

In the past, heavy minerals were studied as a means for stratigraphic correlation but this has been replaced by microfossils and geophysical methods. Recently, heavy mineral analysis is used to aid in sediment provenance, dispersal and correlation studies as well as grain-sorting processes on present and past beaches. The aggregation of heavy minerals often signifies selective transport processes. Studying the mechanisms that control this process can offer invaluable insight into sediment transport in coastal regions.

2.2.2 Spatial variations in the distribution of Heavy Minerals

The spatial variability in the distribution of heavy minerals is a result of its grain size, a product of initial crystalline structure. The orderly arrangement of atoms provides minerals with physical properties that have a wide range of values. Minerals vary strongly in electric conductivity, magnetic susceptibility, density, grain size and many more. This wide range of properties is a prominent factor in the spatial distribution of heavy minerals. In particular, specific density is a chief factor in determining which grain sizes of a particular mineral will be placed alongside each other in the same sediment (de Meijer et al., 1985 as cited in de Meijer 1998).

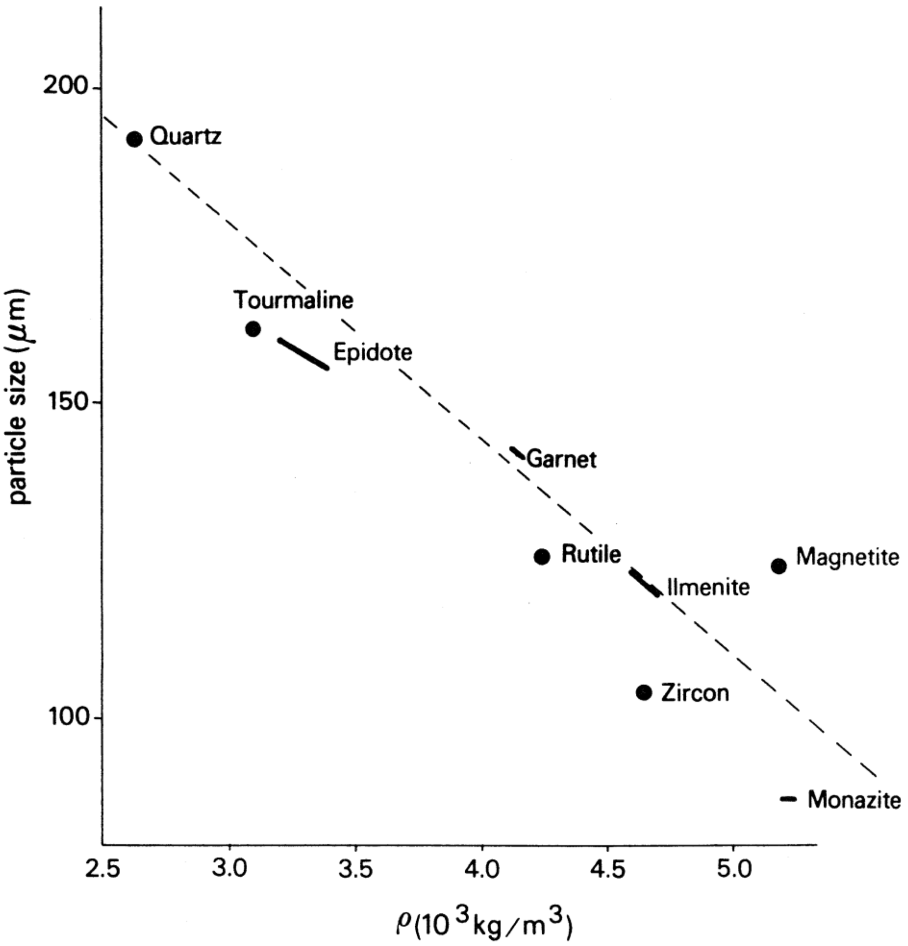


Figure 2. Average grain sizes for various minerals as function of their specific density (de Meijer et al., 1985 as cited in de Meijer 1998).

2.2.3 Heavy Minerals in relation to accretion and erosion

Closely linked with coastline movements (erosion/accretion) is selective transport of various minerals. Waves and currents selectively distribute and aggregate mineral grains into their varying sizes, densities and shapes (Rittenhouse, 1943; Rao, 1957; Van Andel, 1959; Komar, 1989; Komar el al., 1989; Li and Komar, 1992 cited in Frihy, 2003). Areas of shoreline erosion are usually concentrated with higher density minerals whereas the lower density minerals are deposited in areas of shoreline accretion (Frihy and Komar 1991). Those studies by the previously cited authors found that this sorting process takes place both alongshore and cross-shore.

Chapter 3

BACKGROUND OF STUDY AREA

The study was carried out on both shorelines, North and South of the Douro River mouth. The coast in this area is supplied with sediments from the Douro River. Sediments discharged at the River mouth are carried southward by the longshore system. The watershed of the Douro River (Figure 1), which covers an area of 97,000 km^2 is shared between Spain (80%) and Portugal (20%). The river springs from the Serra de Urbión Mountains in Spain and stretches a total of 850 km to the North Atlantic. The river's course through mountainous regions means that sediments consist mostly of sand and gravel with some smaller traces of silt constituents (Netzband 2007).

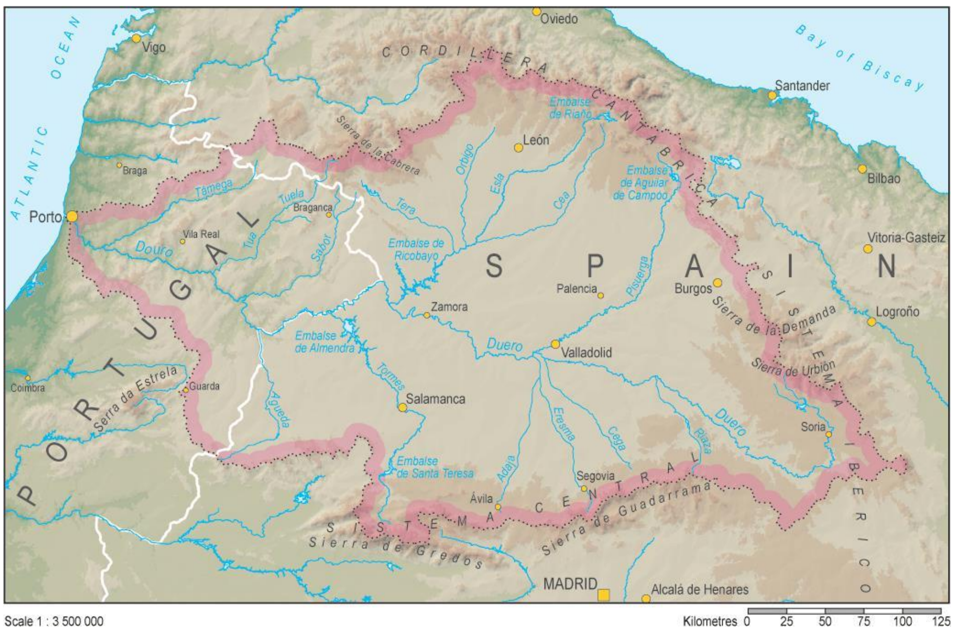


Figure 3. Catchment area of the Rio Duero (Spain) or Rio Douro (Portugal) (Netzband 2007).

3.1 Local Setting

Along its length, the Douro River has a total of 39 multi-functional dams that can hold up to 1080 hm^3, this has significantly reduced the current velocity and sediment load that is moved downriver. In addition to this, sand and gravel is also extracted along the river for the construction sector. In the recent past, close to 2 million tonnes of sand and gravel was removed annually from the Douro riverbed that is equivalent to about four percent of the total land-based and aquatic aggregate production in Portugal (Netzband 2007). Over the past couple of years, due to changes noted in the depth of the Douro River as well as the collapse of a 100 year old bridge, limitations have been placed on the activity.

At the mouth of the Douro River, is a sand spit that acts as a protective barrier for the river banks and beaches in the inner zone from the oncoming waves. The Douro estuary is a high energetic zone as a result of tides, waves and river discharge (Figure 2). To retain the nautical depth, dredging is conducted regularly only within the 22km estuary and is relocated within the estuary or made available for construction (Netzband 2007).

Figure 4. Hydrologic processes at the mouth of the Douro River (Netzband 2007).

3.2 Geological Setting

Along its route, the Douro River cuts multiple and very diverse formations with varied lithologies. However, this study is concerned mainly with those located to the east of the Crestuma-Lever Dam (Figure 3) given the strong sediment retention that takes place in several existing dams up river and the absence major tributaries between the Crestum-Lever Dam and the mouth of the Douro River. Thus, although there are occasional floods, the major contribution of sediment that reaches the coast is mainly from sediment eroded, transported and deposited after Crestum-Lever Dam.

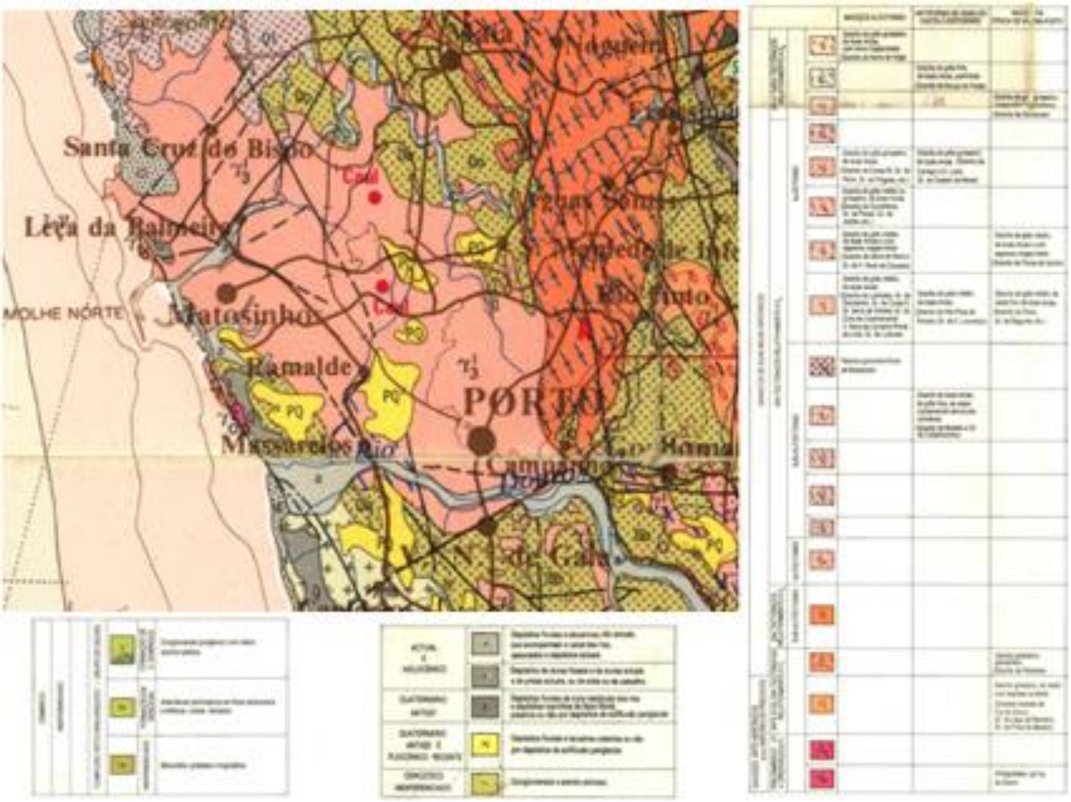


Figure 5. Stretch of the Douro River after Crestuma-Lever Dam and the respective surrounding geology. Retrieved from leaf 1 Geological map of Portugal 1:200,000 scale (Pereira et al., 1989).

Thus, the lithologies traversed by the Douro River, throughout this section (Figure 5) include Quaternary sediments (sedimentary terraces), Super Grupo Douro Beiras (conglomerates, sandstones, mudstones and greywackes with flysch organization) of the lower Cambrian, granites of different ages and types, and at the mouth, the Foz do Douro Metamorphic Belt (gneisses ocelados, gneisses biotitico, gneisses leucocrata, metasediments and amphibolites).

The erosive action of the sea apart from acting on the terraces and Quaternary dunes focuses on the same lithologies with the exposure of the Foz do Douro Metamorphic Complex (Figure 4) at the Mouth of the Douro. A key element is the geometry of the Foz do Douro Metamorphic Complex in relation to the coastline that is much more extensive compared to area cut by the river.

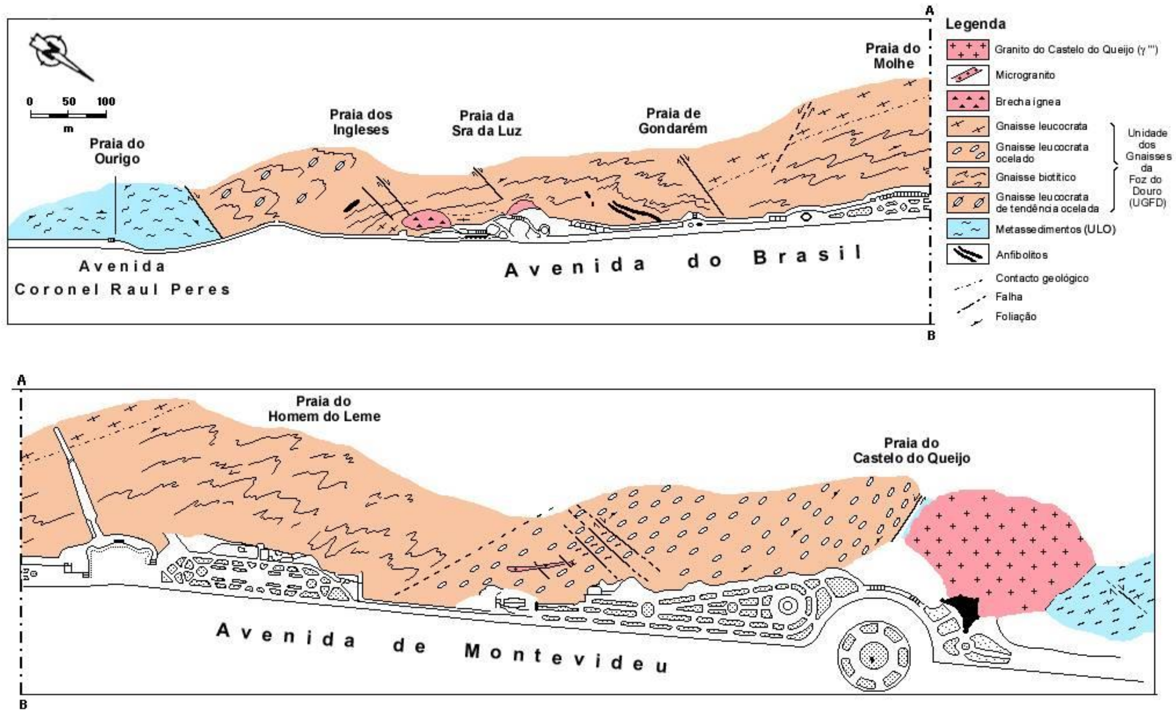


Figure 6. Foz do Douro Metamorphic Belt (Borges et al., 1985).

Chapter 4

OBJECTIVES

The main objective of this study was to analyze the distribution of heavy minerals at the nearby beaches of the estuary of the Douro River. Based on the heavy minerals, the sediment flux along the coastline could be evaluated.

Despite the predominate granitic geological environment, the occurrence of metamorphic rocks from the Metamorphic range of Foz do Douro, mainly amphibolites, led us to study the possible breakdown of the various heavy minerals existing in the Foz do Douro Metamorphic Rock Belt, and, in particular, the possible existence and breakdown of amphiboles in the sediments of the beaches north and south of that metamorphic belt.

Through this study and respective analysis it is intended to assess sediment mobility along the beaches and thus, deduce the direction of the prevailing sedimentary flow worked by the waves, tides, currents and littoral drift, coupled with that induced by the Douro River.

Chapter 5

MATERIALS AND METHODS

Mineralogical traces in relation to coastal dynamics and fluvial systems were investigated. The study consisted of a sampling area, sedimentological analysis of the samples, heavy minerals separation and identification, rock provenance analysis, and plotting of the data in a cartographic basis as a means to locate sediment sources of the Douro coastline.

5.1 Study Area and Location of Sampling Sites

Samples were collected from four sites (Table 2) near the mouth of the Douro, that is, two samples were collected from the north shore and two samples from the south shore (Figure 7). Transects were made at each sample site from the upper to the lower section of the beach. Each sample site had three collection points which were the upper, mid and lower points along the beach transect. The upper zone was the high tide level; the mid zone was the mean sea level and the lower zone was the low tide level (Figure 8).

Table 2. Sampling stations with co-ordinates

Sampling Station	**Co-ordinates**
Praia da Memória (Figure 9)	41.23027˚N, 8.722018˚W
Praia do Homem do Leme (Figure 10)	41.162113˚N, 8.686139˚W
Praia do Cabedelo da Foz do Douro (Figure 11)	41.137132˚N, 8.667577˚W
Praia de Lavadores (Figure 12)	41.12691˚N, 8.667769˚W

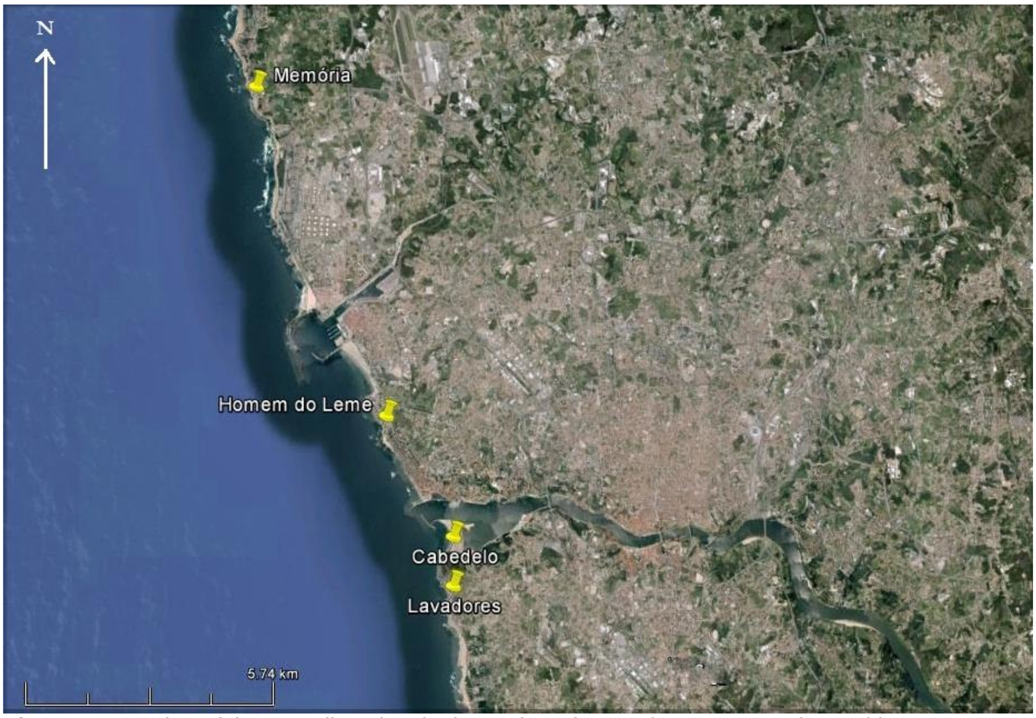


Figure 7. Location of the sampling sites in the region of Porto (Source: Google Earth).

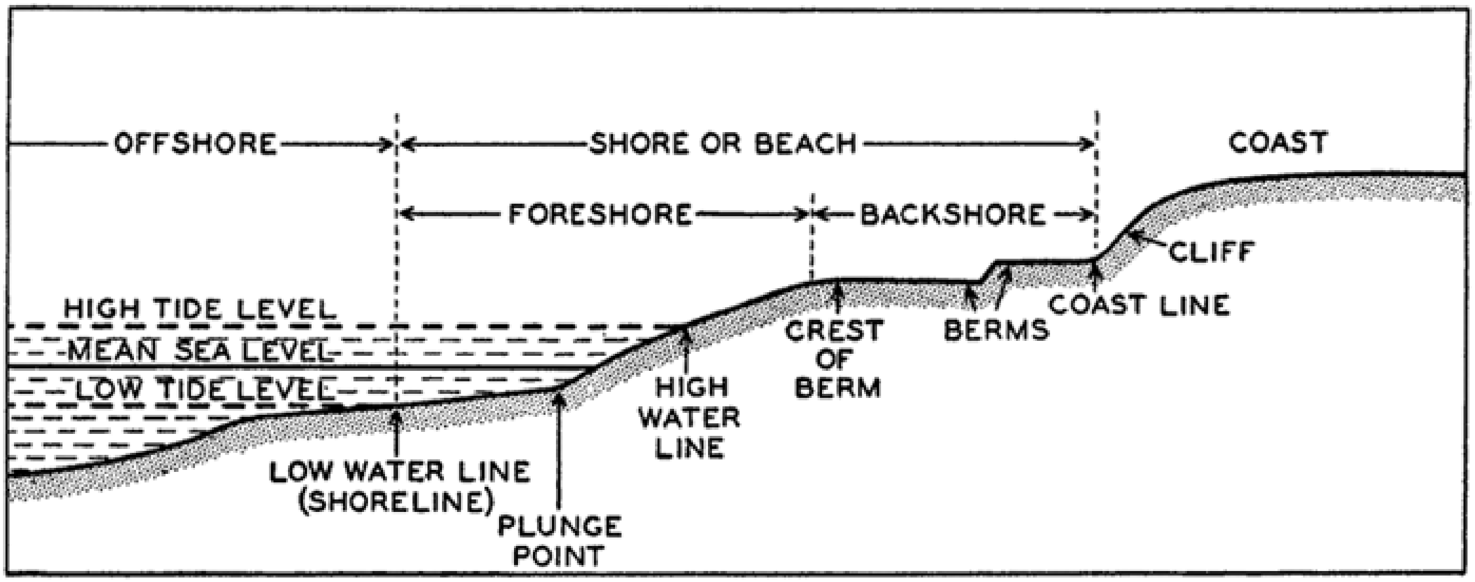


Figure 8.Diagram of the beach profile with the upper (HWL), mid (plunge point) and lower (LWL) zones (Sverdrup et al. 1942).

Figure 9. Aerial photograph of the sampling zones at Memória (Source: Google Earth).

Figure 10. Aerial photograph of the sampling zones at Homem Leme (Source: Google Earth).

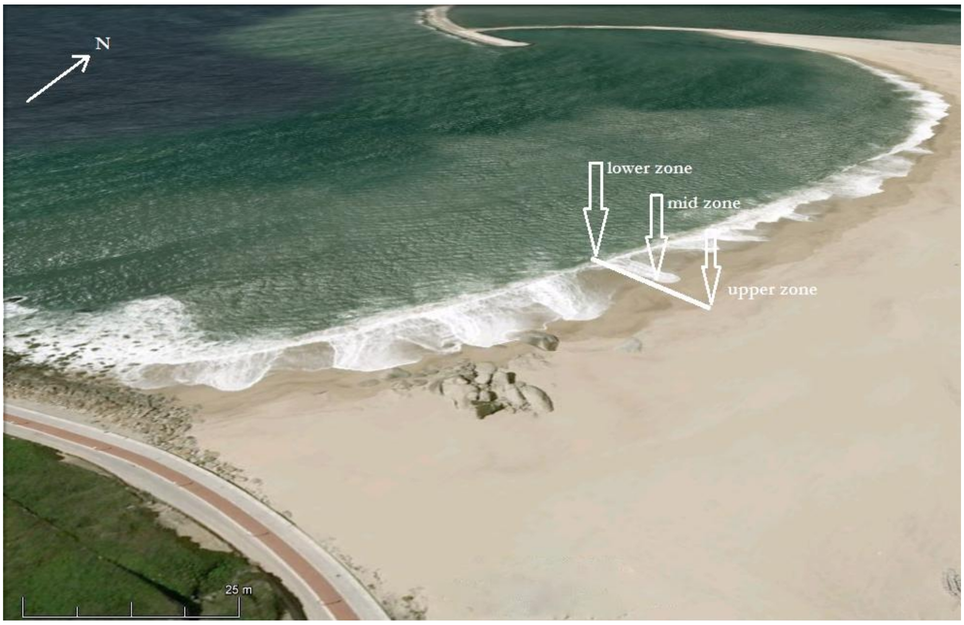


Figure 11. Aerial photograph of the sampling zones at Cabedelo (Source: Google Earth).

Figure 12. Aerial photograph of the sampling zones at Lavadores (Source: Google Earth).

5.2 Laboratory Procedure

Grain Size Analysis*:* In the laboratory, a sample splitter was utilised to evenly divide the samples. A sieving machine was then used to separate the sample into the desired size fractions. The size fractions chosen for the sieving stack were 16mm, 8mm, 4mm, 2mm,1mm, 0.5mm, 0.25mm, 0.125mm and 0.063mm. The weight obtained for each sieve fraction (Annex 1) was recorded and statistically analysed (Section 5.3).

Heavy Mineral Separation and Analysis*:* For this procedure, the excess of the evenly divided samples that were obtained from the sample splitter was utilised. Once again, a sieving machine was used to separate the samples into the desired size fractions. The size fractions chosen for the sieving stack were 1mm, 0.5mm, 0.25mm and 0.125mm. Following this, a gravity separation was carried out using bromoform on the sample fractions of 0.50-0.25mm and 0.25-0.125mm. The separated light and heavy mineral fractions were then weighed and the percentages of the heavy and light mineral fractions at each sampling site were calculated (Annex 3). Due to the lack of heavy minerals obtained after separation (available for analysis), the process was carried out twice (for some of the samples).

Next, the light mineral grains were observed under the microscope to determine its roundness as well as its percentage composition within each zone at each of the sampling sites (Annex 4) whereas the heavy mineral fraction was observed under a loop and a polarised microscope to identify the minerals present. Any doubts regarding the mineral species was verified by further observations under a polarised microscope.

5.3 Statistical Analysis

Grain size analysis of the sediments collected from the coastal zone was carried out using Microsoft Excel. The weight of the various size fractions obtained after the separation of each sample was entered into excel. The following was carried out:

a) The percentage weights of the total sample were calculated for each location.

b) The percentage weight of the total sample was then used to calculate cumulative percentage that was plotted on a graph of grain size versus cumulative percentage (Annex 2).

c) From the graphs, the statistical parameters of grain size were then calculated using the formulas and verbal scales for graphic size parameters (after Folk & Ward 1957).

Graphic Mean (M):

$$M = \frac{\phi 16 + \phi 50 + \phi 84}{3}$$

M Values:

Values from	To	Equal
-5 Φ	-6 Φ	Very coarse gravel
-4 Φ	-5 Φ	coarse gravel
-3 Φ	-4 Φ	medium gravel
-2 Φ	-3 Φ	fine gravel
-1 Φ	-2 Φ	very fine gravel
-1	0 Φ	very coarse sand
+0	+1 Φ	coarse sand
+1	+2 Φ	medium sand
+2	+3 Φ	fine sand

Inclusive Graphic Standard Deviation (D):

$$D = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

D Values:

Values from	To	Equal
0.00	0.35 Φ	very well sorted
0.35	0.50 Φ	well sorted
0.50	0.70 Φ	moderately well sorted
0.70	1.00 Φ	moderately sorted
1.00	2.00 Φ	poorly sorted
2.00	4.00 Φ	very poorly sorted
4.00	∞ Φ	extremely poorly sorted

Inclusive Graphic Skewness (S):

$$S = \frac{\phi 84 + \phi 16 - 2(\phi 50)}{2(\phi 84 - \phi 16)} + \frac{\phi 95 + \phi 5 - 2(\phi 50)}{2(\phi 95 - \phi 5)}$$

S Values:

Values from	To	Skewness
+0.30	+1.00	Very fine skewed
+0.10	+0.30	Fine skewed
+ 0.10	- 0.10	Symmetrical
- 0.10	- 0.30	Coarse skewed
- 0.30	- 0.10	Very coarse skewed

Graphic Kurtosis (K):

$$K = \frac{\phi 95 - \phi 5}{2.44 (\phi 75 - \phi 25)}$$

K Values:

Values from	To	Equal
0.00	0.67	very platykurtic
0.67	0.90	platykurtic
0.90	1.11	mesokurtic
1.11	1.50	leptokurtic
1.50	3.00	very leptokurtic
3.00	∞	extremely leptokurtic

For comparison, statistical parameters for grain size were also calculated using GRADISTAT (Blott and Pye, 2001). In order to comprehend and visualise the results obtained, values were converted from phi to millimetres.

Chapter 6

RESULTS AND DISCUSSION

6.1 Sedimentological Parameters

In assessing sediment supply to beaches, grain size analysis is a vital tool for understanding and classifying sedimentary environments. The sedimentological parameters of the samples collected from the sampling locations were determined using grain size and percentage composition. In addition to this, statistical analysis was used to further summarize and interpret the data.

6.1.1 Praia da Memória

In all the zones, the sedimentary substrate was composed predominantly of very fine gravel (Table 3) that is being reworked with no evidence of rocky zones being eroded (moderately well sorted). The very positive skewness supports this analysis by highlighting the strong hydrodynamic regime that reworks the coarser sediments into finer particles. The kurtosis together with other parameters, in the absence of lithological contrasts with a resistance to erosion, leads us to consider that the mixture in grain size populations is a result of the significant wind action.

The marine hydrodynamics extends to all zones considered, and is more lasting in the lower zone where the platykurtic sedimentary distribution is less than in the others.

TABLE 3. SEDIMENTOLOGICAL PARAMETERS OF SAMPLES COLLECTED FROM PRAIA DA MEMÓRIA

SAMPLING STATION	ZONE	Mean Diameter	Sorting	Skewness	Kurtosis
Praia da Memória	Upper	**2.07 mm** (very fine gravel)	**0.638** (moderately well sorted)	**0.928** (fine skewed)	**0.596** (platykurtic)
	Mid	**2.25 mm** (very fine gravel)	**0.649** (moderately well sorted)	**0.876** (fine skewed)	**0.572** (platykurtic)
	Lower	**2.26 mm** (very fine gravel)	**0.631** (moderately well sorted)	**0.895** (fine skewed)	**0.541** (platykurtic)

6.1.2 Praia do Homem do Leme

Gravel is predominant in all areas (Table 4); the mid and upper zones are moderately well sorted with medium gravel whereas the lower zone is only moderately sorted with fine gravel. No significant sedimentological differences noted between the zones in which there is a positive to very positive skewness and platykurtic distributions in relation to mobilization and sedimentary incorporation of sediments in the lower, mid and upper zones.

It is noted that the finer sediment fractions of this beach are clearly removed (it is unknown whether from the spray zone and mobilization by littoral drift or by continental projection against low walls and other buildings [It seems that the latter is the more plausible hypothesis given that it is a closed rocky beach], so the marine hydrodynamic actions extends to the whole beach, although for the lower and upper zones it is periodic). In summary, the beach tends to be increasingly pebbly.

TABLE 4. SEDIMENTOLOGICAL PARAMETERS OF SAMPLES COLLECTED FROM PRAIA DO HOMEM DO LEME

SAMPLING STATION	ZONE	Mean Diameter	Sorting	Skewness	Kurtosis
Praia do Homem do Leme	Upper	**8.75 mm** (medium gravel)	**0.673** (moderately well sorted)	**0.776** (very fine skewed)	**0.680** (very platykurtic)
	Mid	**8.72 mm** (medium gravel)	**0.656** (moderately well sorted)	**0.858** (fine skewed)	**0.550** (platykurtic)
	Lower	**6.16 mm** (fine gravel)	**0.543** (moderately sorted)	**0.516** (very fine skewed)	**0.725** (very platykurtic)

6.1.3 Praia do Cabedelo da Foz do Douro

The predominant particle size in all areas consists mainly of fine gravel and moderately sorted sediments (Table 5). The sediments are incorporated from marine and fluvial sediment contributions that are responsible for both the platykurtic and mesokurtic distribution with the symmetrical skewness. The hydrodynamic process of the fluvial and marine environments also plays a huge role in the sediment characteristic. The finer sediments noted in the upper zone are due mainly to fluvial contributions. However, the coarser sediments could hardly be explained by fluvial contribution since the predominant grain size fraction is not compatible with the sediments at the mouth of the river, unless there is a strong hydrodynamics related to floods; therefore the incorporation of fine sediments to generate a platykurtic distribution, in this context, suggests that the incorporated sediments are transported by the river. Accordingly, we must take into account the predominant fluvial hydrodynamic effect relative to the sea. Overall, there is equilibrium with regards to the processes occurring at this sampling location but the constant wave action, currently appears to be exclusively related to the lower zone, being ephemeral (perhaps at the height of spring tides and/ or flood) in other areas.

SAMPLING STATION	ZONE	TABLE 5. SEDIMENTOLOGICAL PARAMETERS OF SAMPLES COLLECTED FROM PRAIA DO CABEDELO DA FOZ DO DOURO			
		Mean Diameter	Sorting	Skewness	Kurtosis
Praia do Cabedelo da Foz do Douro	Upper	**4.10 mm** (fine gravel)	**0.506** (moderately sorted)	**0.932** (fine skewed)	**0.469** (mesokurtic)
	Mid	**4.01 mm** (fine gravel)	**0.515** (moderately sorted)	**0.970** (symmetrical)	**0.476** (mesokurtic)
	Lower	**2.91 mm** (very fine gravel)	**0.507** (moderately sorted)	**1.030** (symmetrical)	**0.547** (platykurtic)

6.1.4 Praia de Lavadores

The grain size of the sediments of the upper zone varies from the grain size in the mid and lower zone with a predominance of very fine gravel as compared to fine gravel in the other two zones (Table 6). The grain size distribution suggests strong hydrodynamics and the slight prevalence of erosive phenomenon on the rock masses in the upper zone that are poorly sorted due to the incorporation of finer sediments (positive skewness) generated and/or processed by other sedimentary environments evident in the mixture of sedimentary populations(platykurtic distribution). In the mid zone, the combination of poor sorting and a very positive skewness with a very platykurtic distribution results from reworking and consequently, the mixing of grain size by waves and tides. The marine action in the lower zone is strongly selective (leptokurtic distribution) generating moderately sorted shoreline that consists of fine gravel; the symmetrical skewness is possibly the result of the redistribution of finer sediments by wind action.

TABLE 6. SEDIMENTOLOGICAL PARAMETERS OF SAMPLES COLLECTED FROM PRAIA DE LAVADORES

SAMPLING STATION	ZONE	Mean Diameter	Sorting	Skewness	Kurtosis
Praia de Lavadores	Upper	**3.05 mm** (very fine gravel)	**0.383** (poorly sorted)	**0.908** (fine skewed)	**0.583** (platykurtic)
	Mid	**4.60 mm** (fine gravel)	**0.467** (poorly sorted)	**0.687** (very fine skewed)	**0.724** (very platykurtic)
	Lower	**5.74 mm** (fine gravel)	**0.572** (moderately sorted)	**0.967** (symmetrical)	**0.385** (leptokurtic)

It is noted that the sedimentary distribution in the various zones is typical of closed beaches (protected by rock masses) in which the rocks in the breaker zone (surf zone) tends to produce most of the sedimentary mass by rock erosion, reworking them and spreading the less coarse sediments out of the spray zone whereas the fine gravel are retained as there isn't sufficient hydrodynamic energy to mobilize them to other zones.

6.2. Statistical parameters of sediment samples

6.2.1 Mean Diameter

The grain size parameters obtained for the four sampling stations highlight the sediment flow along the coast in the study region. The grain size statistics is particularly useful in distinguishing between high and moderate energy environments (Nordstrom, 1977 as cited in Dora, 2011). All the samples collected consisted of gravel ranging from very fine gravel, fine gravel and medium gravel. More than 50% of the samples analysed were very fine gravel with a mean diameter between 2 and 4mm (-1 to -2ϕ). The other half of samples were made up of fine gravel (4-8mm) and medium gravel (8-16mm) at 33% and 16% respectively. The majority of the very fine gravel in the sample was collected from Praia da Memória. The very fine sediments are most likely due to the high wave energy at the sampling location. Other locations that recorded a presence of very fine gravel sediments are the sample collected from the lower zone sampling station at Cabedelo and the upper zone sample from Lavadores. The fine sediment morphology at these two locations is probably due to close proximity of the mouth of the Douro where sediments transported from the headlands are being deposited. Fine gravel was noted in samples collected from Homem do Leme, Cabedelo and Lavadores. Also, Praia de Lavadores was the only sampling station that recorded medium gravel that are likely contribution from the erosion of rock masses at the location.

6.2.2 Sorting

Sorting is a measure of the degree of deviation from the sample mean. The sorting in the sample ranged from poorly sorted, moderately sorted and moderately well sorted. Over three-quarter of the samples was moderately sorted (41.67%) to moderately well-sorted (41.67%) highlighting the high wave energy condition along the coastline. The only locations to register poor sorting (16.67%) were the upper and mid zones at Lavadores that can be attributed to the erosion of the rock masses at that particular location due to the high wave energy.

6.2.3 Skewness and Kurtosis

Skewness measures the spread of the sample on one side of the average and kurtosis measures the convergence of the mean value relative to the normal distribution. The beach sediments varied between fine skewed, very fine skewed and symmetrical. The overall distribution was that 50% of the sample was fine skewed, 25 % was very fine skewed and the other 25% was symmetrical. The general fine skewness indicates the introduction of finer sediments or the removal of the coarser material.

Kurtosis varied from very platykurtic to leptokurtic, that is, 25% of the sample was very platykurtic, 50% was platykurtic, 17% was mesokurtic and 8% was leptokurtic. The leptokurtic distribution for the sample collected from the lower zone at Memória is probably due to the incorporation of finer sediments.

6.3 GRADISTAT versus Percentile Measures

To ensure that the results for sedimentological parameters obtained using percentile measures in Excel truly expressed the characteristics of the sediments collected from sampling locations, a second statistical treatment was carried out using GRADISTAT. The output of the previously mentioned statistical treatment versus that obtained using Excel is displayed in Table 7. Comparison of the results obtained using the two statistical treatments showed a difference in the values for skewness and kurtosis but similarities for mean diameter and sorting. Blott and Pye (2001) recommend that if skewness or kurtosis needs to be determined, Folk and Ward measures provide the best possible interpretation and summarization for methodical comparisons of compositionally variable sediments.

		GRADISTAT Results								Percentile measures using Excel							
Sampling station	Zone	Mean Diameter		Sorting		Skewness		Kurtosis		Mean Diameter		Sorting		Skewness		Kurtosis	
		ϕ	mm	ϕ	mm	ϕ	mm	ϕ	mm	ϕ	mm	ϕ	mm	ϕ	mm	ϕ	mm
Praia da Memória	Upper	-1.052	2.07	0.648	0.638	0.108	0.928	0.747	0.596	-1.05	2.07	0.65	0.64	0.30	0.81	0.62	0.65
	Mid	-1.172	2.25	0.623	0.649	0.191	0.876	0.806	0.572	-2.15	4.44	0.62	0.65	0.52	0.70	0.72	0.61
	Lower	-1.179	2.26	0.664	0.631	0.16	0.895	0.885	0.541	-1.15	2.22	0.67	0.63	0.42	0.75	0.86	0.55
Praia do Homem do Leme	Upper	-3.129	8.75	0.572	0.673	0.365	0.776	0.557	0.680	-3.13	8.77	0.65	0.64	0.38	0.77	0.80	0.57
	Mid	-3.124	8.72	0.609	0.656	0.221	0.858	0.862	0.550	-3.20	9.19	0.61	0.65	0.67	0.63	0.70	0.62
	Lower	-2.623	6.16	0.882	0.543	0.954	0.516	0.463	0.725	-2.60	6.06	1.24	0.42	2.23	0.21	2.86	0.14
Praia do Cabedelo da Foz do Douro	Upper	-2.034	4.10	0.982	0.506	0.101	0.932	1.091	0.469	-2.05	4.14	0.97	0.51	1.01	0.50	1.94	0.26
	Mid	-2.003	4.01	0.958	0.515	0.044	0.970	1.071	0.476	-2.02	4.05	0.94	0.52	0.59	0.66	1.74	0.30
	Lower	-1.539	2.91	0.979	0.507	-0.042	1.030	0.87	0.547	-1.55	2.93	0.98	0.51	-0.15	1.11	1.72	0.30
Praia de Lavadores	Upper	-1.609	3.05	1.386	0.383	0.14	0.908	0.779	0.583	-1.63	3.10	1.50	0.35	0.18	0.89	4.36	0.05
	Mid	-2.203	4.60	1.097	0.467	0.542	0.687	0.466	0.724	-2.23	4.70	1.40	0.38	0.94	0.52	3.52	0.09
	Lower	-2.521	5.74	0.807	0.572	0.048	0.967	1.376	0.385	-2.70	6.50	0.93	0.53	0.14	0.91	0.95	0.52

Table 7. Statistical analysis of sedimentological parameters using GRADISTAT versus percentile measures using excel.

6.4 Heavy Mineral Sediments

The purpose of varietal heavy mineral analysis was to approximate sediment sources supplying the coast north and south of the Douro River mouth. The heavy minerals identified at all four sampling stations is consistent with the geological setting of the study area. It should be noted that the possible contribution of other sources such as Leixoes to the heavy mineral sediments found at the study sites has been excluded due to the lack of heavy minerals found at Memória, the first sampling site after the said location and the general geomorphology of the coastline in the study region that is not conducive to the movement of sediments.

The heavy minerals identified consisted predominantly of quartz, muscovite, biotite and zircon (Table 8). In particular, zircon which persists in the resulting sediments when weathered from parent rocks (such as granites, gneisses and schists) due to its hardness (de Meijer 1998) showed low percentage composition in Memória and Lavadores, sites associated with high wave energy. In addition to this, other less common minerals were identified at each of the sampling stations and will be discussed in turn according to its location from north to south in terms of its mineral association.

6.4.1 Praia da Memória

The heavy mineral separation for samples collected from Memória produced very little heavy mineral. The lack of heavy minerals is possibly due to the high wave energy that is constantly reworking and transporting sediments to other locations. As a result, data analysis for this sampling station has been excluded to avoid error in the data interpretation.

Table 8. Percentage composition of heavy mineral sediments identified at each sampling station

Sampling Station	Zone	Heavy mineral identified	Percentage composition (%)
Praia do Homem do Leme	Upper	Quartz	41
		Zircon	13
		Muscovite	23
		Biotite	23
	Mid	Quartz	15
		Zircon	20
		Muscovite	40
		Biotite	25
	Lower	Quartz	11
		Zircon	32
		Muscovite	40
		Biotite	17
Praia do Cabedelo da Foz do Douro	Upper	Quartz	20
		Zircon	20
		Muscovite	20
		Biotite	40
	Mid	Quartz	37
		Zircon	19
		Muscovite	26
		Biotite	18
	Lower	Quartz	8
		Zircon	29
		Muscovite	43
		Biotite	20
Praia de Lavadores	Upper	Quartz	22
		Zircon	16
		Muscovite	12
		Biotite	50
	Mid	Quartz	15
		Zircon	15
		Muscovite	40
		Biotite	30
	Lower	Quartz	39
		Zircon	16
		Muscovite	28
		Biotite	17

6.4.2 Praia do Homem do Leme

Located south of Memória is the next sampling station at Praia do Homem do Leme. Unlike Memória, heavy mineral separation of the sample collected from this location produced quite a large amount heavy mineral with a predominance of micaceous minerals (Figure 13). The micaceous minerals were composed mostly of biotite and muscovite. There were two types of biotite observed in the sample from the mid zone, that is, a dark coloured biotite (Figure 14.B) from a metamorphic origin and a pale coloured biotite from an igneous source (Figure14.C). The zircon observed in the samples showed a marked difference with impurities noted in those from the lower zone and an increase in zircon in the upper zone as compared to the other two zones. The presence of zircon with impurities and those without highlights the difference in the source rock of the zircon. The upper zone also lacked any other heavy mineral except that already mentioned. This is most likely due to the periodic wave action in the upper zone that either reworks or transports the heavy minerals to other areas.

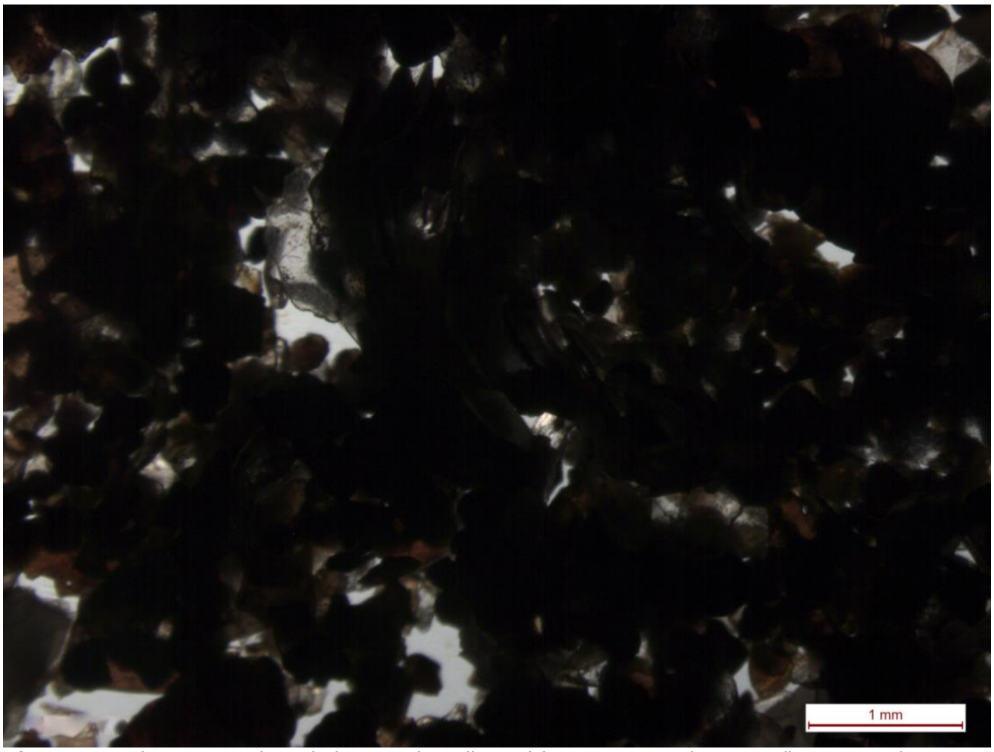


Figure 13. Micaceous minerals in sample collected from Homem do Leme (lower zone).

Heavy minerals obtained from the samples collected from the mid and lower zones of Homem do Leme showed a variety of other heavy minerals (Figure 14 and 15). These minerals included amazonite, amethyst, tourmaline, garnet and chlorite. In particular, tourmaline which was present in both the mid and lower samples was more prevalent in the lower zone. Also, the roundedness of the tourmaline mineral is indicative of the large degree of reworking undergone by the mineral due to its distance of transportation from the source rock.

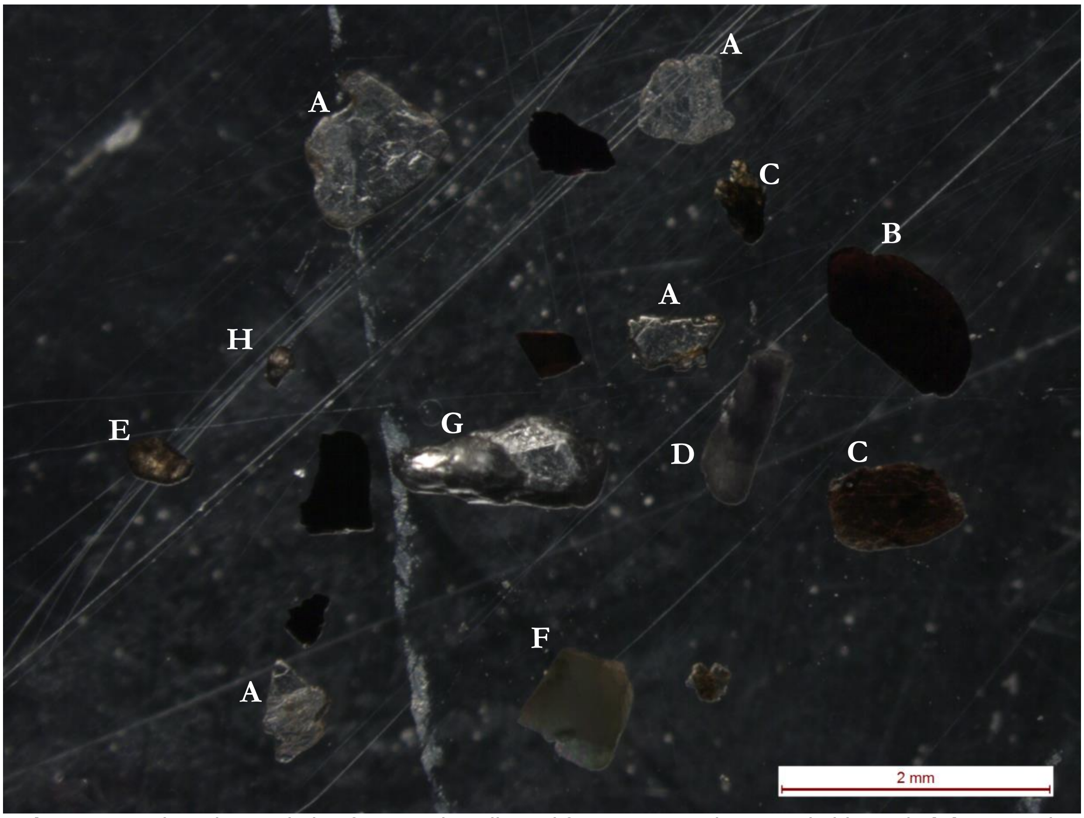


Figure 14. Mineral association for sample collected from Homem do Leme (mid zone). **(A)** Muscovite, **(B)** Biotite (dark coloured), **(C)** Biotite (pale coloured), **(D)** Amethyst, **(E)** Tourmaline, **(F)** Amazonite, **(G)** Zircon (colourless), **(H)** Zircon (pale yellow)

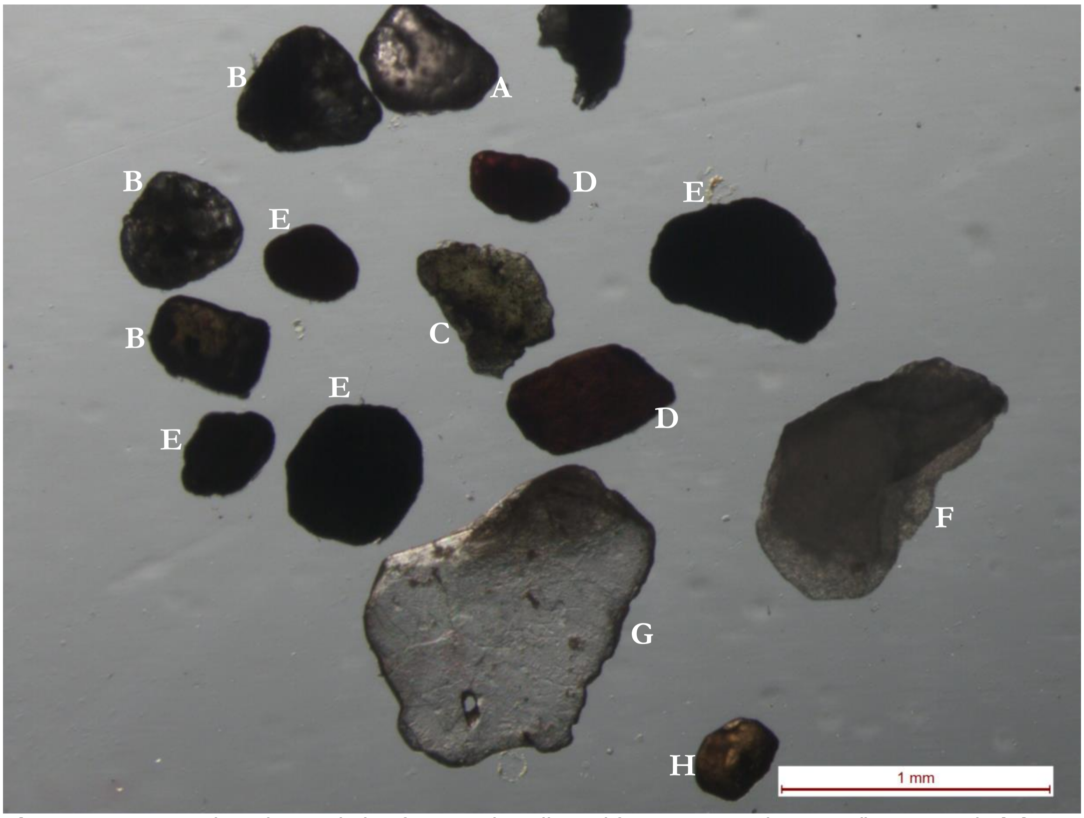


Figure 15. Heavy mineral association for sample collected from Homem do Leme (lower zone). **(A)** Zircon (colourless), **(B)** Metamict zircon, **(C)** Chlorite, **(D)** Garnet **(E)** Tourmaline, **(F)** Quartz, **(G)** Muscovite, **(H)** Zircon (pale yellow coloured).

6.4.3 Praia do Cabedelo da Foz do Douro

Following Homem do Leme, the next sampling station is at the mouth of the Douro River, Cabedelo. Heavy mineral analysis of samples from this location showed high micaceous minerals (biotite and muscovite) composition especially in the lower zone but the most notable difference recorded at Cabedelo (that was absent in the two previously discussed sampling stations) was the presence of amphibole minerals and lithic fragments that originate from schist. Other heavy minerals observed in the samples included tourmaline, zircon, garnets and quartz with impurities (Figure 16, 17 and 18).

The amphibole minerals present in the samples most likely originate from the Foz do Douro Metamorphic Belt (Figure 6) and is indicative of the north to south sediment movement occurring along the coastline in the region of Porto as the Foz do Douro

Metamorphic Belt is located north of Cabedelo. It is also important to note that the amphibole minerals could possibly originate from some other location (transportation via the Douro River) due to its absence in the samples from the previously discussed sampling stations. The lithic fragments present in the sample could also be used to verify the sediment transport direction but as the source rock cannot be determined it is more prudent to use amphibolites.

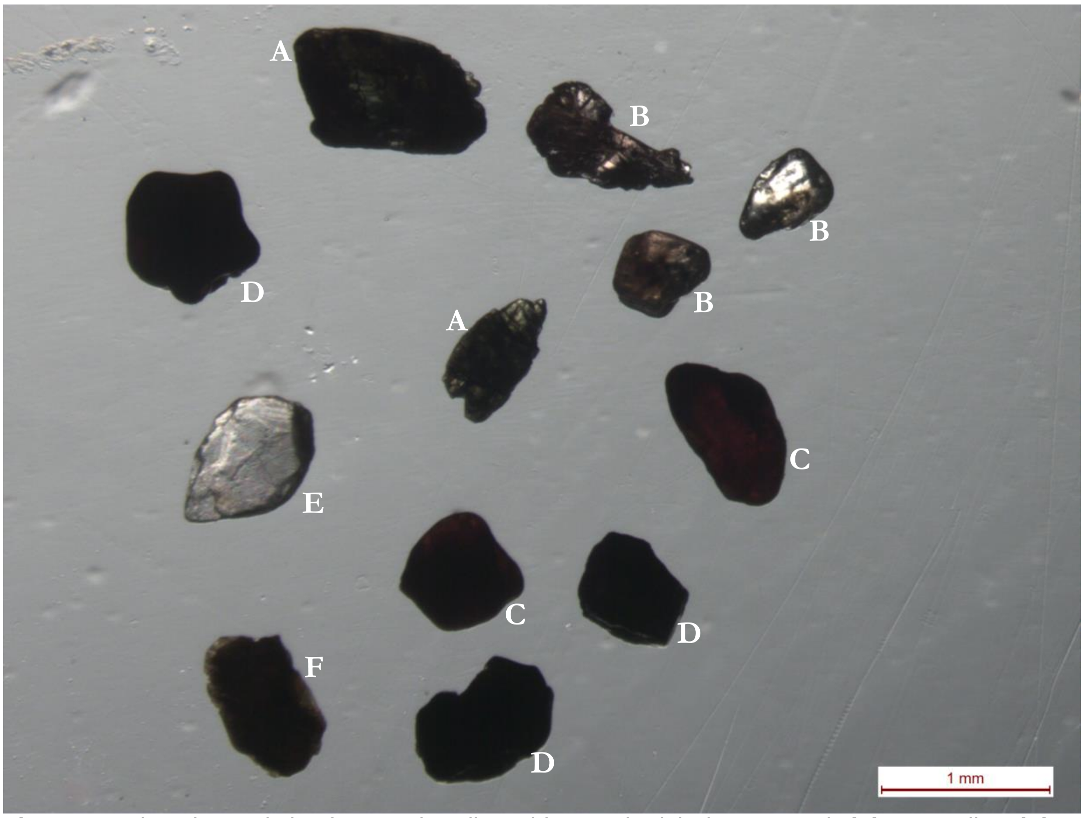


Figure 16. Mineral association for sample collected from Cabedelo (upper zone). **(A)** Tourmaline, **(B)** Zircon, **(C)** Garnet, **(D)** Lithic fragments, **(E)** Muscovite, **(F)** Biotite.

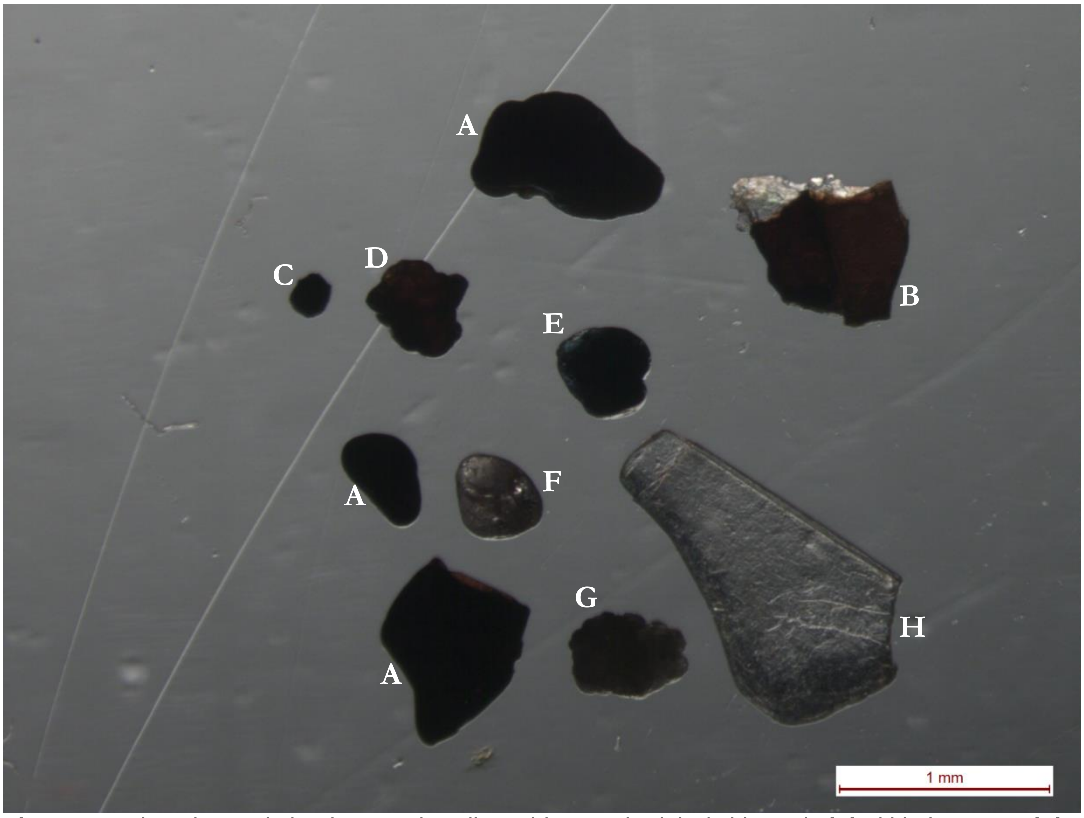


Figure 17. Mineral association for sample collected from Cabedelo (mid zone). **(A)** Lithic fragment, **(B)** Biotite, **(C)** Amphibole, **(D)** Garnet, **(E)** Tourmaline, **(F)** Zircon, **(G)** Quartz with impurities, **(H)** Muscovite.

Also prominent in the samples is the presence of garnet in the upper and mid zone. It is present in relatively a large amount in the upper zone but is absent from the lower zone. The irregular shape of the garnet in the mid zone (Figure 17.D) compared to those in the upper zone (Figure 16.D) could possibly indicate its transportation from two different locations, that is, the irregular morphology of the garnet present in the mid zone implies that its source area is close by whereas the more rounded garnet is from a more distant location.

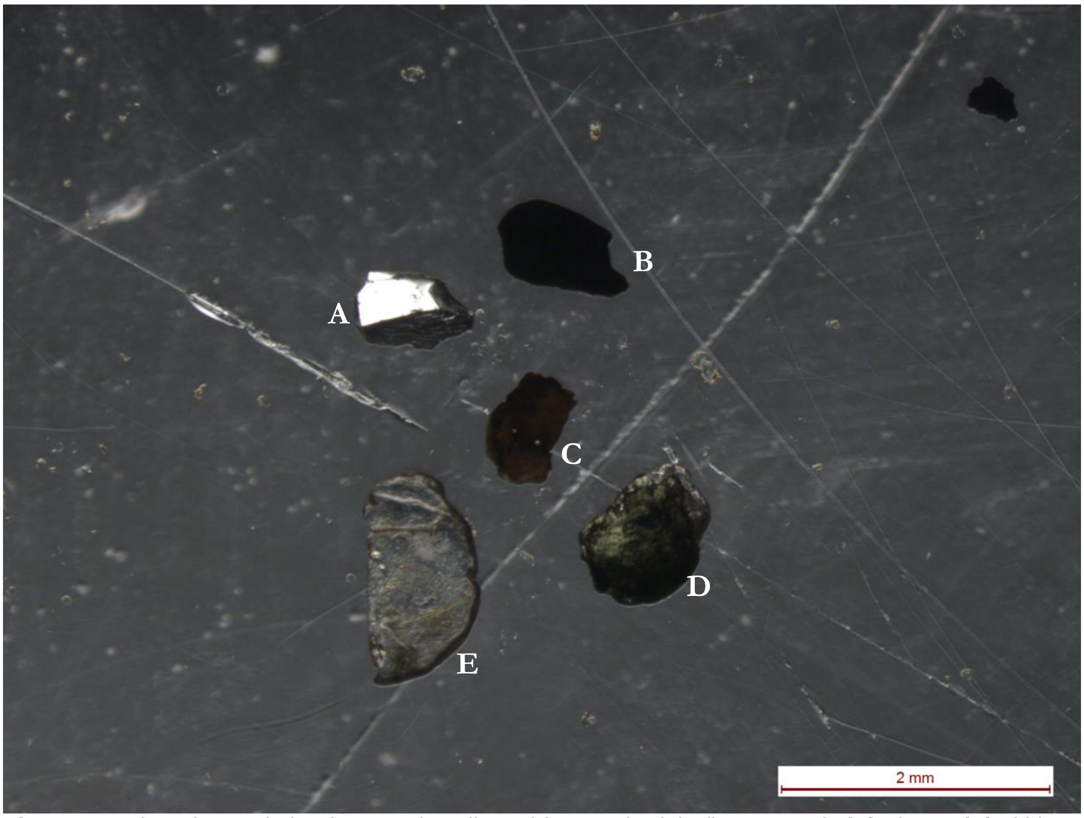


Figure 18. Mineral association for sample collected from Cabedelo (lower zone). **(A)** Zircon, **(B)** Lithic fragment, **(C)** Biotite, **(D)** Tourmaline, **(E)** Muscovite.

6.4.4 Praia de Lavadores

The final sampling station, located south of the Douro River at Lavadores, once again recorded the presence of micaceous minerals (Figure 19). The percentage composition of the micaceous minerals in each of the zones showed a difference with a larger presence of biotite minerals versus muscovite minerals in the upper zone as compared to a more even distribution in the other two zones. There is also a significant presence of tourmaline in the upper and mid zone (absent is the lower zone) that occurs in both the yellow (Figure 20.A) and green (Figure 20.B) variety.

Other heavy minerals present in the samples include zircon, quartz with impurities, lithic fragments of no great significance and lastly, the unique presence of topaz that was not recorded at any of the other sampling locations.

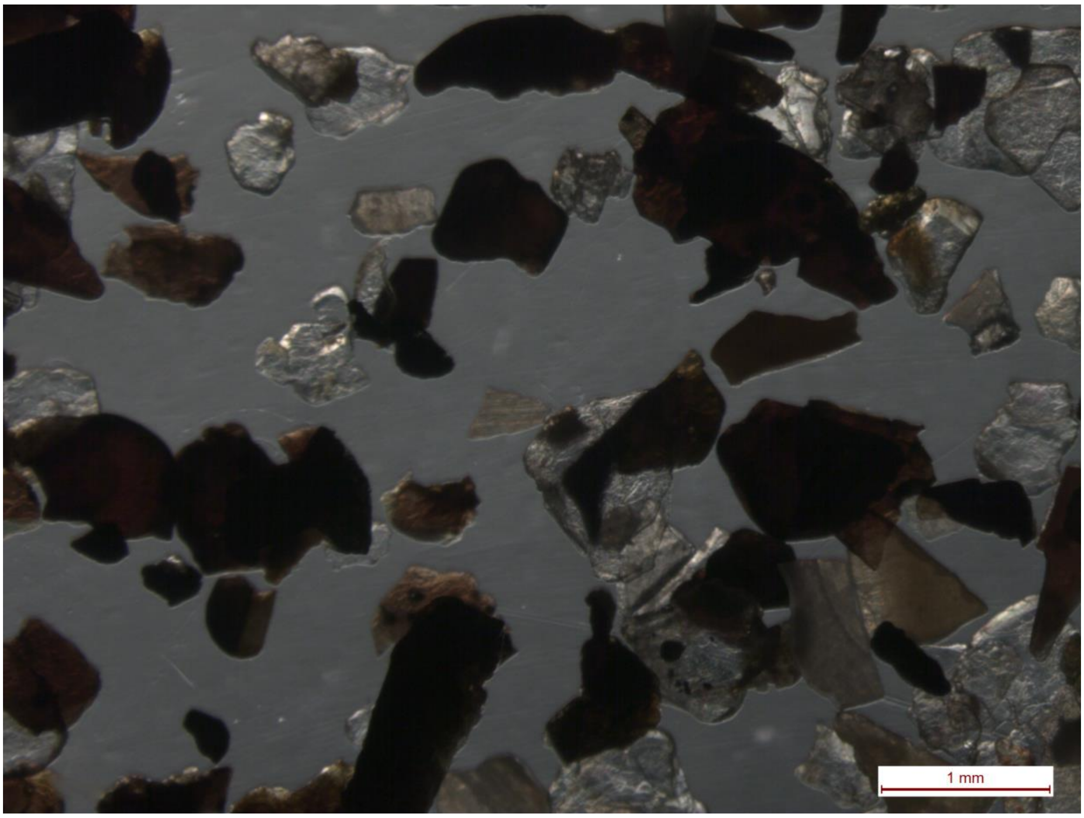


Figure 19. Micaceous minerals in the sample collected from Lavadores (mid zone).

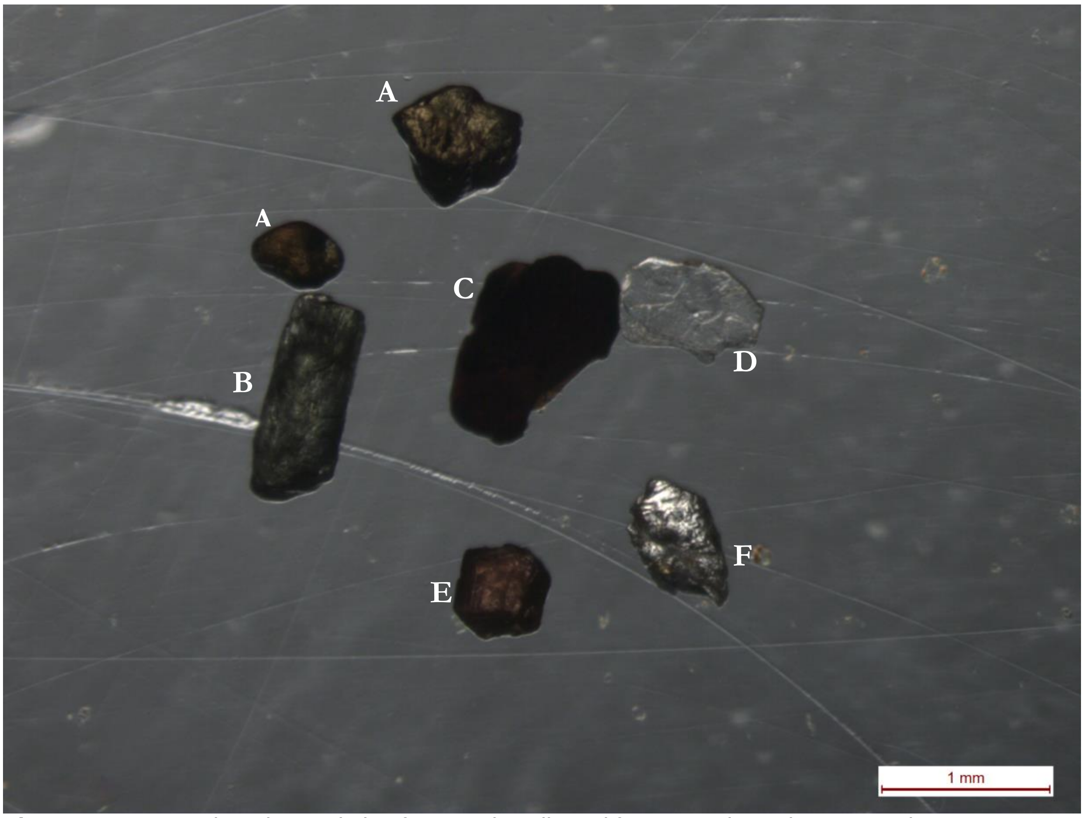


Figure 20. Heavy mineral association for sample collected from Lavadores (upper zone). **(A)**Tourmaline (yellow), **(B)** Tourmaline (green), **(C)** Biotite, **(D)** Muscovite, **(E)** Topaz, **(F)** Zircon.

Chapter 7

CONCLUSION

The results and the statistical treatment of particle size analysis, in addition to the considerations previously mentioned allows us to conclude the stability of sedimentary processes on all beaches studied. However, the positive skewness in combination with platykurtic distributions, as in the case of the samples collected from Praia da Memória and Praia do Homem do Leme is most likely due to the incorporation of fine sediments of dune origin. This disapproves dune loss resulting from the advancing sea on the coastal dune system.

The majority of minerals identified in all samples correspond to the erosion of granitic rocks due to the presence of zircon, tourmaline and also of biotite. The latter may have stemmed from the erosion of biotite gneisses of the Foz do Douro Metamorphic Belt. The accessory presence and almost vestigial chlorite seems to mark traces of erosion of schist-greywacke complex. Apart from the registered heavy minerals, there was also presence of many metal oxides.

Moreover, there is recorded presence of some amphibole that were identified in samples collected from Homem do Leme that suggests that sediment mobility in this area is very limited due to the littoral geomorphology marked by a rocky substrate and a strongly irregular link of sub aquatic isolated rocks groups further into the sea that form strong barriers to the sediment flow. It is important to note that the low heavy mineral content also affects the conclusions made. Nevertheless, the lithologies are very similar northwards and southwards with the suggested pattern for the dispersion of sediments (Figure 21) along the coastline of the study area.

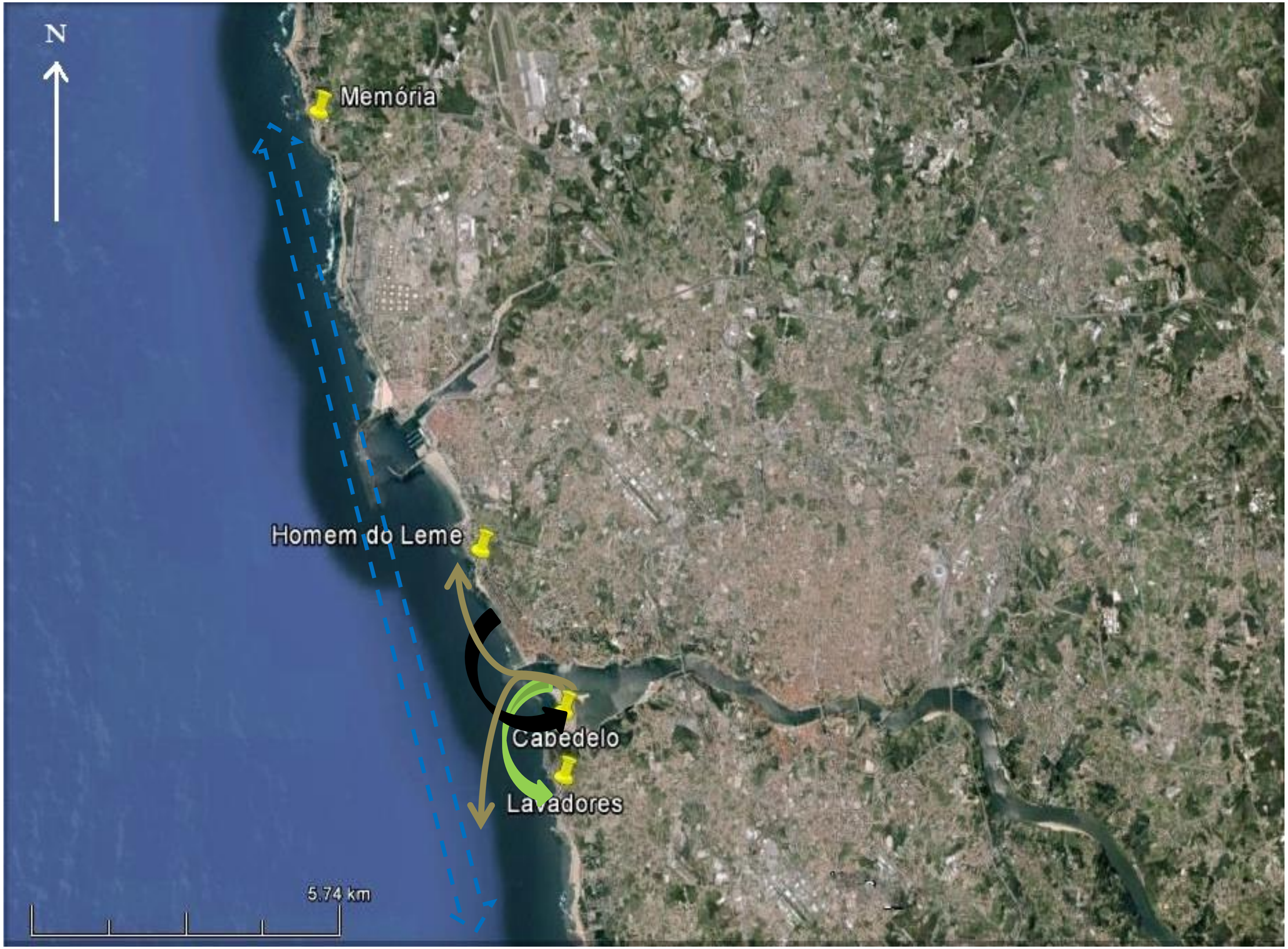


Figure 21. Dispersion of sediments in the Porto Region.

It is necessary to conduct more studies of this nature, in different weather conditions as well as further research on the elements that were addressed, mainly the identification of some heavy mineral signatures such as the origin of biotite, to determine, if possible, whether its provenance is granitic or metamorphic rocks. With these considerations and given the data resulting from this study, the consensus is that the lateral sediment flow (N-S) in this region is strongly constrained by the geomorphological configuration that is not conducive to sediment dispersion.

BIBLIOGRAPHY

Borges, F. S., Noronha, F. & Marques, M., 1985. Excursão Geológica no Complexo Gnáissico da Foz do Douro. In: Livro-guia das excursões geológicas da IX Reunião de Geologia do Oeste Peninsular, Universidade do Porto.

de Meijer, R. J., L. W. Put, R. Bergman, G. Landeweer, H. J. Riezebos, R. D. Schuiling, M. J. Scholten and A. Veldhuizen (1985). "Local variations of outdoor radon concentrations in the Netherlands and physical properties of sand with enhanced natural radioactivity." Sci.Total Environ. **45**: 101-109.

Dora, G. U., V. S. Kumar, C. S. Philip, G. Johnson, P. Vinayaraj and R. Gowthaman (2011). "Textural characteristics of foreshore sediments along Karnataka shoreline, west coast of India." International Journal of Sediment Research **26**(3): 364-377.

Frihy, O. E. and K. M. Dewidar (2003). "Patterns of erosion/sedimentation, heavy mineral concentration and grain size to interpret boundaries of littoral sub-cells of the Nile Delta, Egypt." Marine Geology **199**(1–2): 27-43.

Frihy, O. E. and P. D. Komar (1991). "Patterns of beach-sand sorting and shoreline erosion on the Nile Delta." Journal of Sedimentary Petrology **61**(4): 544-550.

Komar, P. O. (1989). "Physical processes of waves and currents and the formation of marine placers." Rev. Aquat. Sci. **1**(393-423).

Komar, P. O., Clements, K.E.,Li, Z., Shih, S.M. (1989). "The effect of selective sorting on factor analyses of heavy-mineral assemblages." J. Sediment. Petrol **59**: 590-596.

Kondolf, G. M. (1997). "PROFILE: Hungry Water: Effects of Dams and Gravel Mining on River Channels." Environmental Management **21**(4): 533-551.

Li, M. Z. and P. D. Komar (1992). "Longshore grain sorting and beach placer formation adjacent to the Columbia River." Journal of Sedimentary Petrology **62**(3): 429-441.

Lindholm, R. (1987). A Practical Approach to Sedimentology, Allen & Unwin, Inc.

McManus, J. (1988). Grain size determination and interpretation. Techniques in Sedimentology. M. Tucker. Oxford, Blackwell**:** 63-85.

Netzband, A. (2007). "Sediment Management: An essential element of River Basin Management Plans." Journal of Soils and Sediments **7**(2): 117-132.

Nordstrom, K. F. (1977). "The use of grain size statistics to distinguish between high and moderate-energy beach environments." Journal of Sedimentary Petrology **47**(3): 1287-1294.

Pettijohn, F. J. (1975). Sedimentary rocks. New York, Harper & Row.

Rao, C. B. (1957). "Beach erosion and concentration of heavy mineral sands." Journal of Sedimentary Petrology(27): 143-147.

Rittenhouse, G. (1943). Transportation and deposition of heavy minerals. B. G. S. Am. **54:** 1725-1750.

SedNet (2006). Report on the SedNet Round Table Discussion: Sediment Management-an essential element of River Basin Management Plans.

Sverdrup, H. U., M. W. Johnson and R. H. Fleming (1942). The Oceans, Their Physics, Chemistry, and General Biology. New York, Prentice-Hall.

Van Andel, T. H. (1959). "Reflection on the interpretation of heavy mineral analyses." J. Sediment. Petrol(29): 153-163.

Annex 1

Table of the weight of sieve fraction and percentage fraction of the total sample for sample collected from Praia da Memória.

Memória (lower zone)

	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	0.000	0.000	0.000
< 16 mm ; ≥ 8mm	8.270	7.850	0.787
< 8 mm ; ≥ 4 mm	51.150	50.730	5.083
< 4 mm ; ≥ 2 mm	602.660	600.725	60.190
< 2 mm ; ≥ 1 mm	319.970	318.035	31.866
< 1 mm ; ≥ 0.5 mm	21.910	19.975	2.001
< 0.5 ; ≥ 0.250 mm	2.450	0.515	0.052
< 0.250 ; ≥ 0.125 mm	2.050	0.115	0.012
< 0.125 ; ≥ 0.063 mm	2.010	0.075	0.008
< 0.063 mm	1.960	0.025	0.003
Total sample weight	1012.430	998.045	100.000

Memória (mid zone)

	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	0.000	0.000	0.000
< 16 mm ; ≥ 8mm	5.420	5.000	0.525
< 8 mm ; ≥ 4 mm	39.480	39.060	4.103
< 4 mm ; ≥ 2 mm	579.900	577.965	60.718
< 2 mm ; ≥ 1 mm	325.850	323.915	34.029
< 1 mm ; ≥ 0.5 mm	7.570	5.635	0.592
< 0.5 ; ≥ 0.250 mm	2.180	0.245	0.026
< 0.250 ; ≥ 0.125 mm	1.960	0.025	0.003
< 0.125 ; ≥ 0.063 mm	1.970	0.035	0.004
< 0.063 mm	1.940	0.005	0.001
Total sample weight	966.270	951.885	100.000

Memória (upper zone)

	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	0.000	0.000	0.000
< 16 mm ; ≥ 8mm	2.520	2.100	0.174
< 8 mm ; ≥ 4 mm	27.780	27.360	2.273
< 4 mm ; ≥ 2 mm	639.930	637.995	53.003
< 2 mm ; ≥ 1 mm	499.710	497.775	41.354
< 1 mm ; ≥ 0.5 mm	39.660	37.725	3.134
< 0.5 ; ≥ 0.250 mm	2.270	0.335	0.028
< 0.250 ; ≥ 0.125 mm	2.050	0.115	0.010
< 0.125 ; ≥ 0.063 mm	2.070	0.135	0.011
< 0.063 mm	2.090	0.155	0.013
Total sample weight	1218.080	1203.695	100.000

Table of the weight of sieve fraction and percentage fraction of the total sample for sample collected from Praia do Homem do Leme.

Leme (lower zone)

	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	113.060	112.650	11.067
< 16 mm ; ≥ 8mm	272.940	272.530	26.775
< 8 mm ; ≥ 4 mm	341.320	340.910	33.493
< 4 mm ; ≥ 2 mm	221.650	221.240	21.736
< 2 mm ; ≥ 1 mm	19.540	19.130	1.879
< 1 mm ; ≥ 0.5 mm	9.240	8.830	0.868
< 0.5 ; ≥ 0.250 mm	12.140	11.730	1.152
< 0.250 ; ≥ 0.125 mm	21.230	20.820	2.045
< 0.125 ; ≥ 0.063 mm	5.720	5.310	0.522
< 0.063 mm	5.110	4.700	0.462
Total sample weight	1021.950	1017.850	100.000

Leme (mid zone)

	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	43.410	43.000	5.004
< 16 mm ; ≥ 8mm	552.610	552.200	64.255
< 8 mm ; ≥ 4 mm	260.320	259.910	30.244
< 4 mm ; ≥ 2 mm	4.230	3.820	0.445
< 2 mm ; ≥ 1 mm	0.580	0.170	0.020
< 1 mm ; ≥ 0.5 mm	0.510	0.100	0.012
< 0.5 ; ≥ 0.250 mm	0.440	0.030	0.003
< 0.250 ; ≥ 0.125 mm	0.440	0.030	0.003
< 0.125 ; ≥ 0.063 mm	0.490	0.080	0.009
< 0.063 mm	0.460	0.050	0.006
Total sample weight	863.490	859.390	100.000

Leme (upper zone)

	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	56.900	56.490	5.741
< 16 mm ; ≥ 8mm	542.150	541.740	55.053
< 8 mm ; ≥ 4 mm	366.670	366.260	37.220
< 4 mm ; ≥ 2 mm	17.970	17.560	1.784
< 2 mm ; ≥ 1 mm	2.120	1.710	0.174
< 1 mm ; ≥ 0.5 mm	0.580	0.170	0.017
< 0.5 ; ≥ 0.250 mm	0.480	0.070	0.007
< 0.250 ; ≥ 0.125 mm	0.440	0.030	0.003
< 0.125 ; ≥ 0.063 mm	0.410	0.000	0.000
< 0.063 mm	0.420	0.010	0.001
Total sample weight	988.140	984.040	100.000

Table of the weight of sieve fraction and percentage fraction of the total sample for sample collected from Praia do Cabedelo do Foz do Douro.

Cabedelo (lower zone)

	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	0.000	0.000	0.000
< 16 mm ; ≥ 8mm	48.850	48.430	5.611
< 8 mm ; ≥ 4 mm	222.200	221.780	25.696
< 4 mm ; ≥ 2 mm	337.040	336.620	39.002
< 2 mm ; ≥ 1 mm	237.630	237.210	27.484
< 1 mm ; ≥ 0.5 mm	18.880	18.460	2.139
< 0.5 ; ≥ 0.250 mm	0.700	0.280	0.032
< 0.250 ; ≥ 0.125 mm	0.530	0.110	0.013
< 0.125 ; ≥ 0.063 mm	0.510	0.090	0.010
< 0.063 mm	0.530	0.110	0.013
Total sample weight	866.870	863.090	100.000

Cabedelo (mid zone)

	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	8.930	8.510	0.990
< 16 mm ; ≥ 8mm	89.210	88.790	10.332
< 8 mm ; ≥ 4 mm	338.890	338.470	39.387
< 4 mm ; ≥ 2 mm	322.250	321.830	37.450
< 2 mm ; ≥ 1 mm	74.880	74.460	8.665
< 1 mm ; ≥ 0.5 mm	27.050	26.630	3.099
< 0.5 ; ≥ 0.250 mm	0.850	0.430	0.050
< 0.250 ; ≥ 0.125 mm	0.500	0.080	0.009
< 0.125 ; ≥ 0.063 mm	0.480	0.060	0.007
< 0.063 mm	0.510	0.090	0.010
Total sample weight	863.550	859.350	100.000

437.03

Cabedelo (upper zone)

	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	6.450	6.030	0.720
< 16 mm ; ≥ 8mm	96.830	96.410	11.506
< 8 mm ; ≥ 4 mm	345.610	345.190	41.197
< 4 mm ; ≥ 2 mm	288.090	287.670	34.332
< 2 mm ; ≥ 1 mm	69.180	68.760	8.206
< 1 mm ; ≥ 0.5 mm	32.270	31.850	3.801
< 0.5 ; ≥ 0.250 mm	1.890	1.470	0.175
< 0.250 ; ≥ 0.125 mm	0.650	0.230	0.027
< 0.125 ; ≥ 0.063 mm	0.550	0.130	0.016
< 0.063 mm	0.580	0.160	0.019
Total sample weight	842.100	837.900	100.000

Table of the weight of sieve fraction and percentage fraction of the total sample for sample collected from Praia de Lavadores.

Lavadores (lower zone)

	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	9.370	8.950	0.914
< 16 mm ; ≥ 8mm	203.850	203.430	20.779
< 8 mm ; ≥ 4 mm	578.560	578.140	59.054
< 4 mm ; ≥ 2 mm	139.440	137.620	14.057
< 2 mm ; ≥ 1 mm	50.770	48.950	5.000
< 1 mm ; ≥ 0.5 mm	3.110	1.290	0.132
< 0.5 ; ≥ 0.250 mm	2.020	0.200	0.020
< 0.250 ; ≥ 0.125 mm	1.900	0.080	0.008
< 0.125 ; ≥ 0.063 mm	1.960	0.140	0.014
< 0.063 mm	2.030	0.210	0.021
Total sample weight	993.010	979.010	100.000

Lavadores (mid zone)

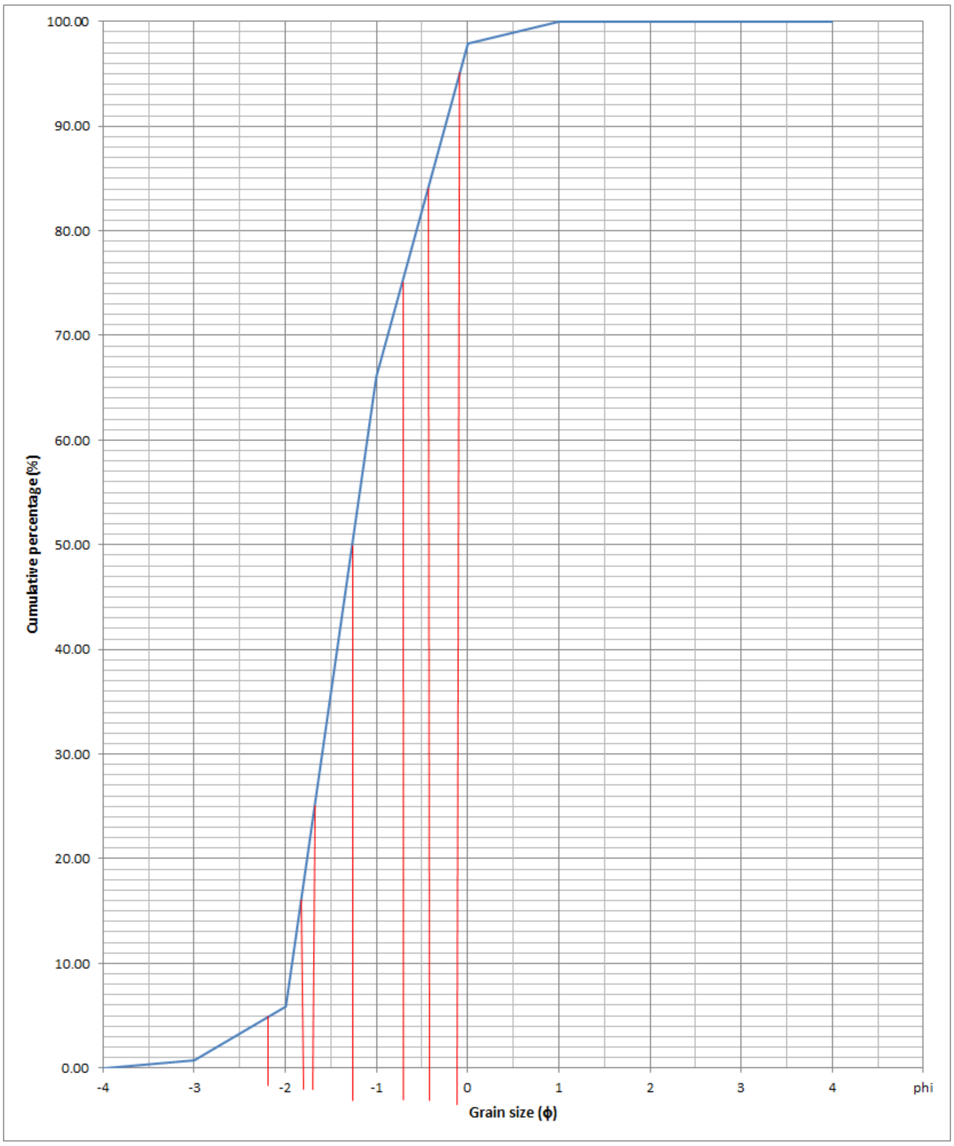
	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	71.120	70.700	8.579
< 16 mm ; ≥ 8mm	171.440	171.020	20.752
< 8 mm ; ≥ 4 mm	246.210	245.790	29.824
< 4 mm ; ≥ 2 mm	159.060	157.240	19.080
< 2 mm ; ≥ 1 mm	141.610	139.790	16.962
< 1 mm ; ≥ 0.5 mm	40.800	38.980	4.730
< 0.5 ; ≥ 0.250 mm	2.190	0.370	0.045
< 0.250 ; ≥ 0.125 mm	1.840	0.020	0.002
< 0.125 ; ≥ 0.063 mm	1.900	0.080	0.010
< 0.063 mm	1.960	0.140	0.017
Total sample weight	838.130	824.130	100.000

Lavadores (upper zone)

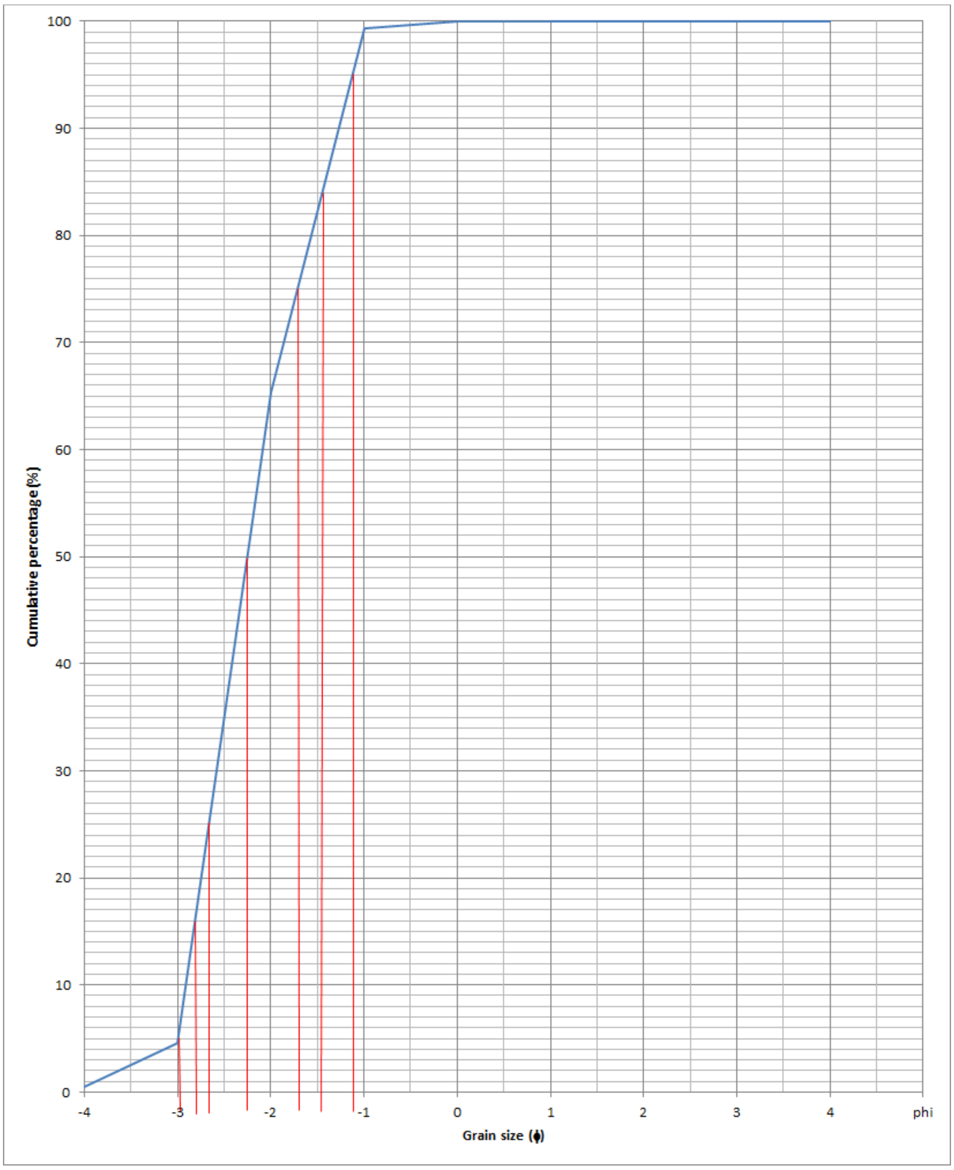
	Weight of sieve fraction (g)	Weight of sieve fraction (g) - average weight of the bag (g)	Percentage fraction of the total sample
≥ 16 mm	59.600	59.180	5.939
< 16 mm ; ≥ 8mm	110.000	109.580	10.997
< 8 mm ; ≥ 4 mm	261.600	261.180	26.211
< 4 mm ; ≥ 2 mm	227.830	226.010	22.681
< 2 mm ; ≥ 1 mm	191.120	189.300	18.997
< 1 mm ; ≥ 0.5 mm	134.470	132.650	13.312
< 0.5 ; ≥ 0.250 mm	15.300	13.480	1.353
< 0.250 ; ≥ 0.125 mm	4.070	2.250	0.226
< 0.125 ; ≥ 0.063 mm	4.020	2.200	0.221
< 0.063 mm	2.460	0.640	0.064
Total sample weight	1010.470	996.470	100.000

Annex 2

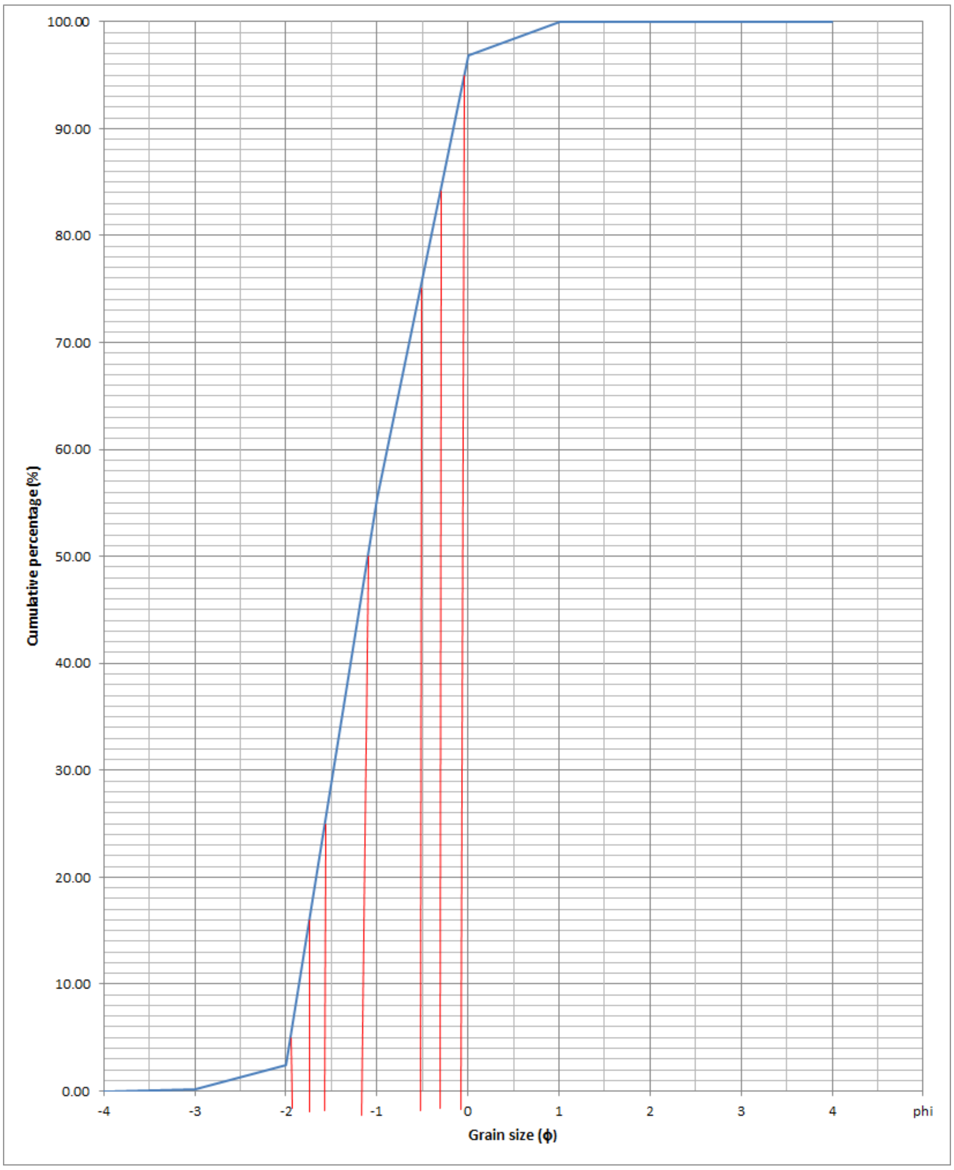
Graph of the cumulative percentage curve of sample collected from Memória (lower zone).



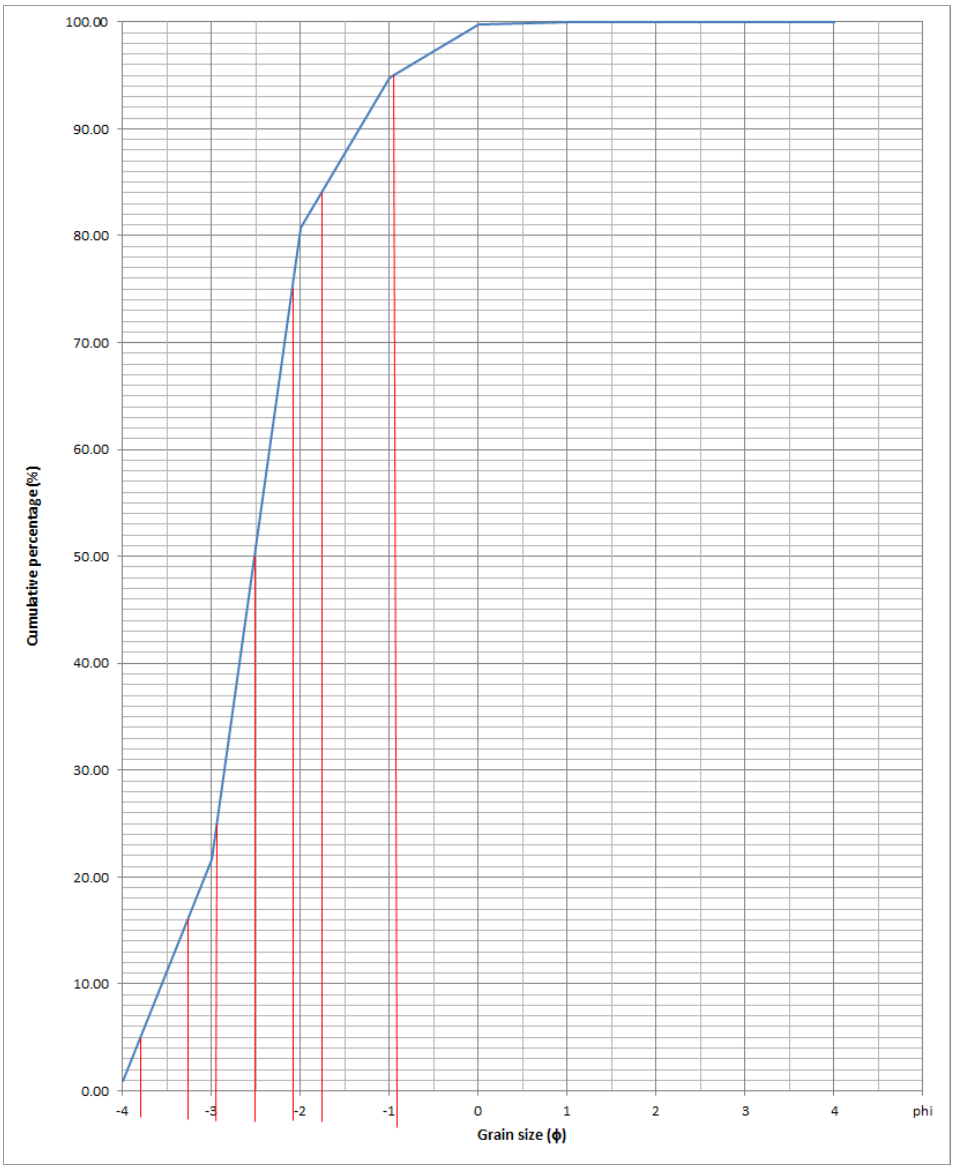
Graph of the cumulative percentage curve of sample collected from Memória (mid zone).



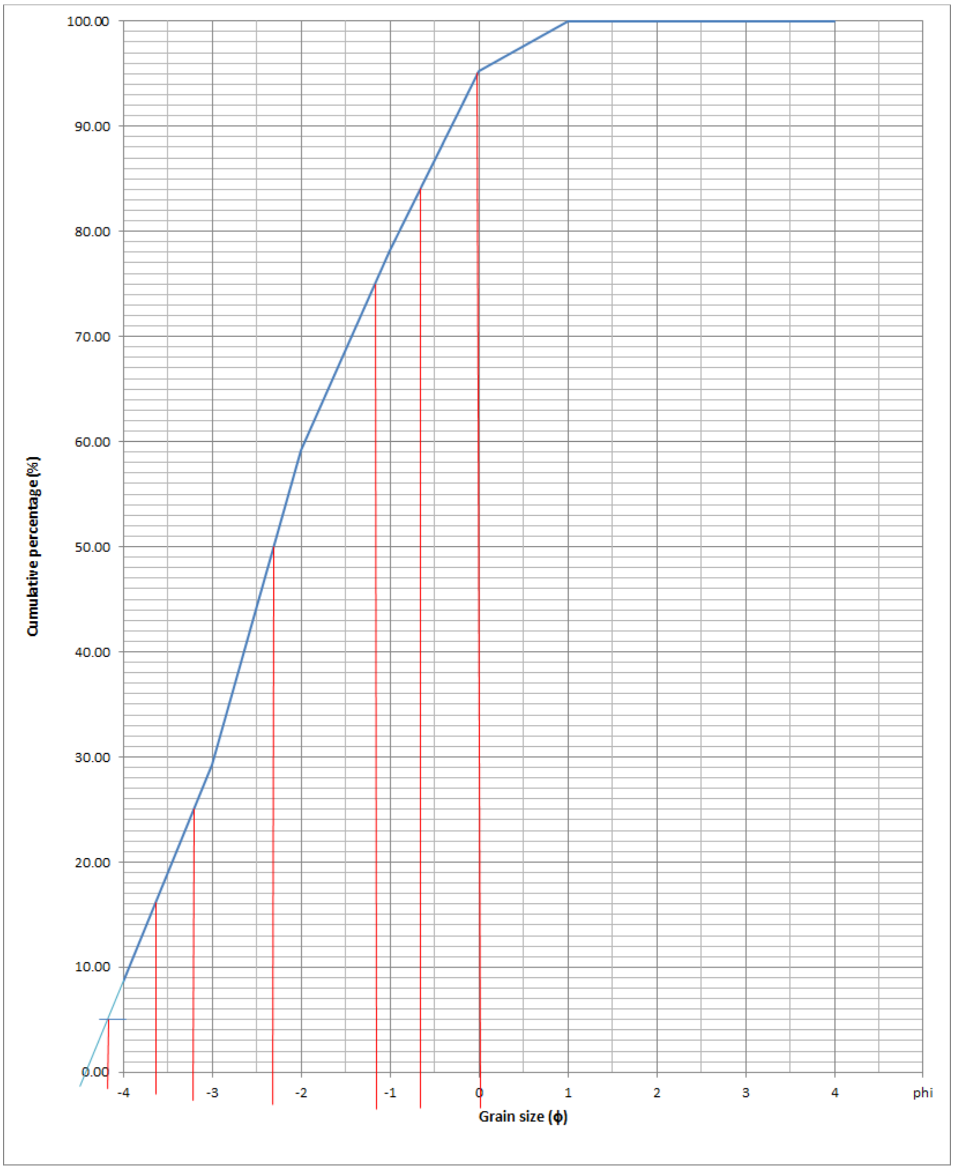
Graph of the cumulative percentage curve of sample collected from Memória (upper zone).



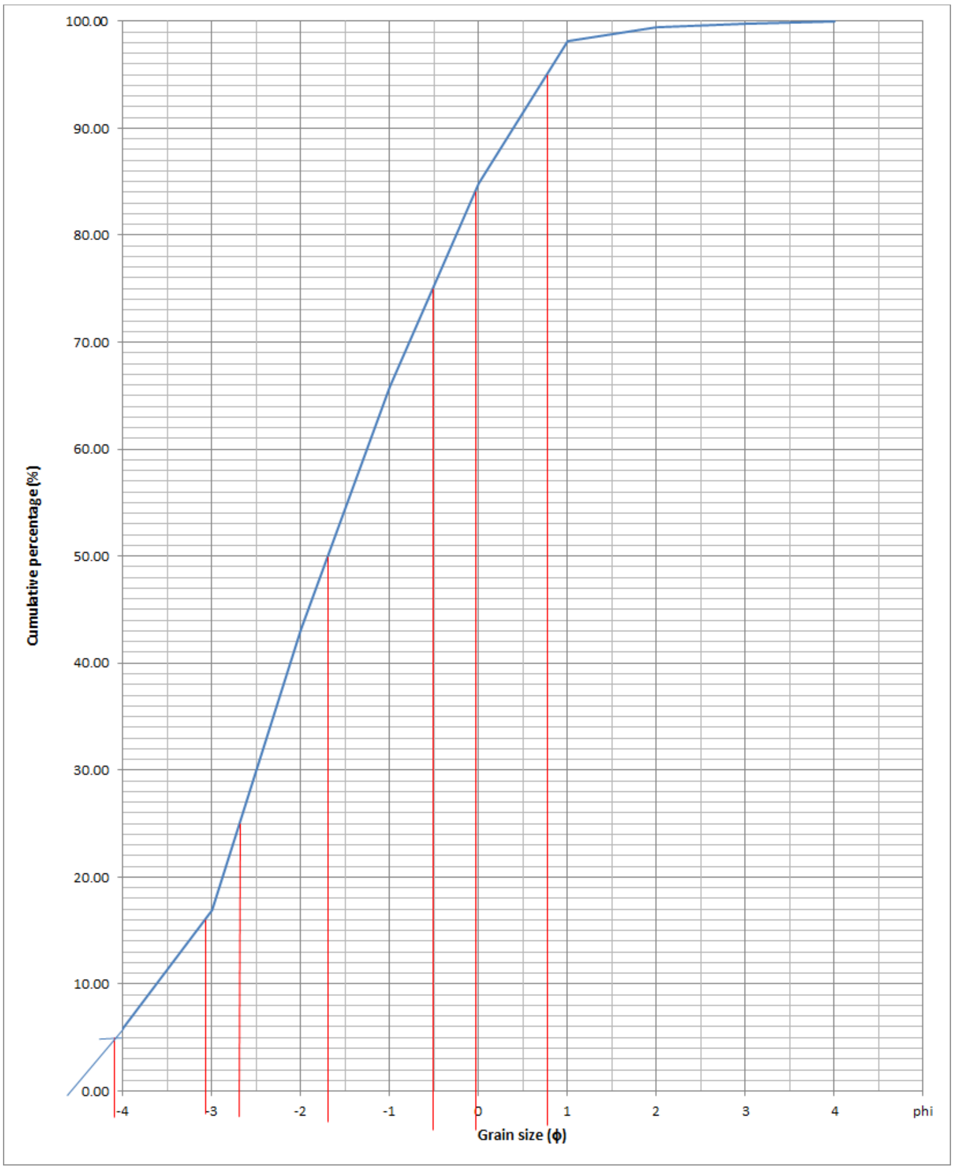
Graph of the cumulative percentage curve of sample collected from Lavadores (lower zone).



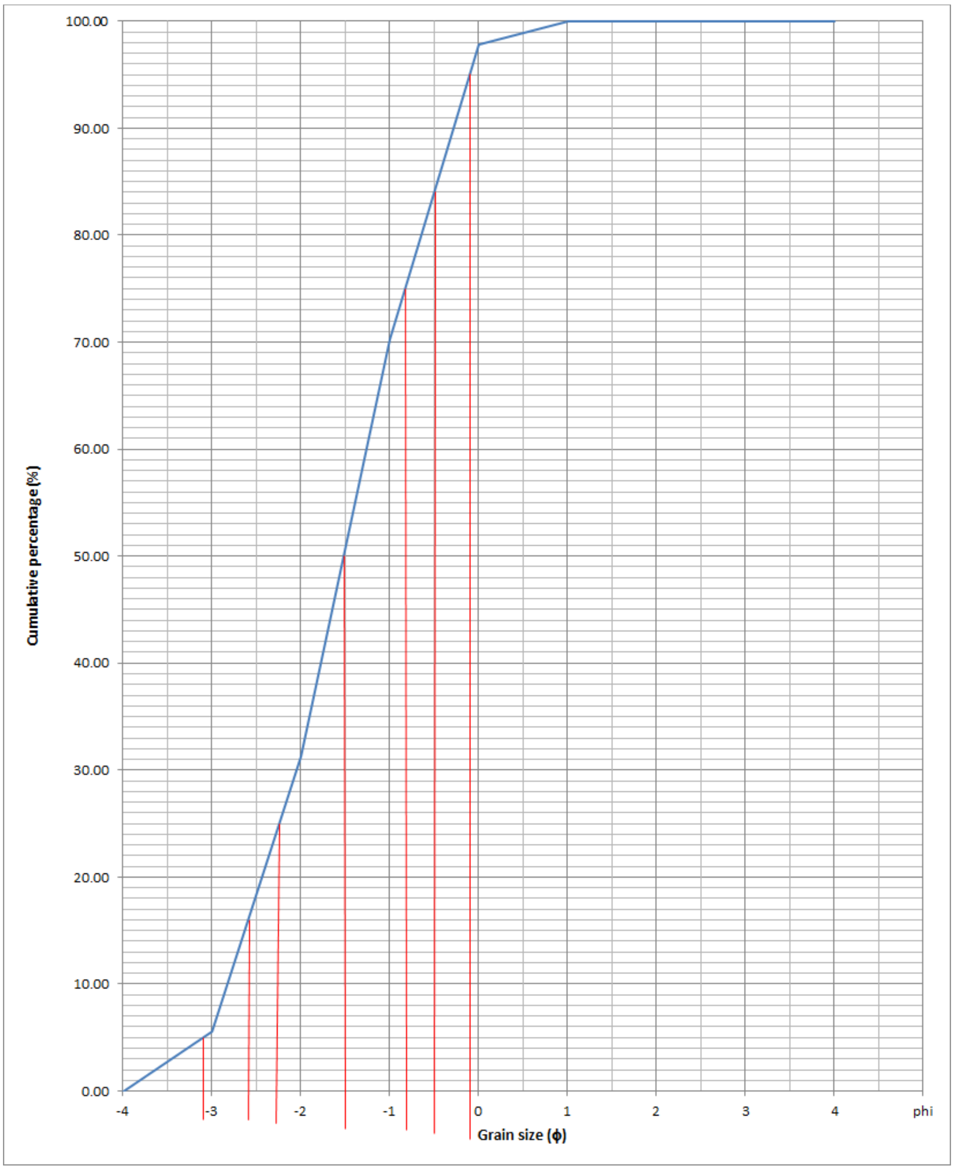
Graph of the cumulative percentage curve of sample collected from Lavadores (mid zone).



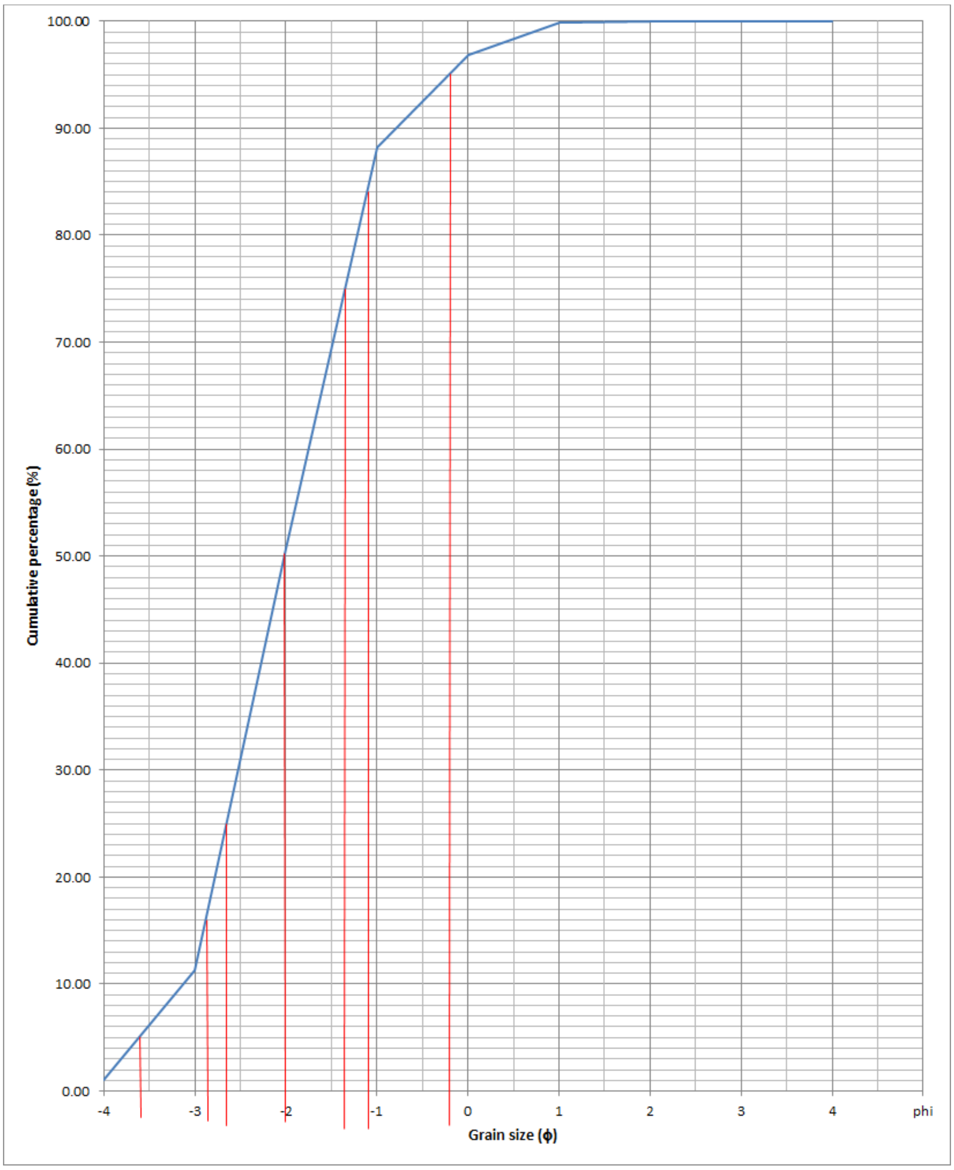
Graph of the cumulative percentage curve of sample collected from Lavadores (upper zone).



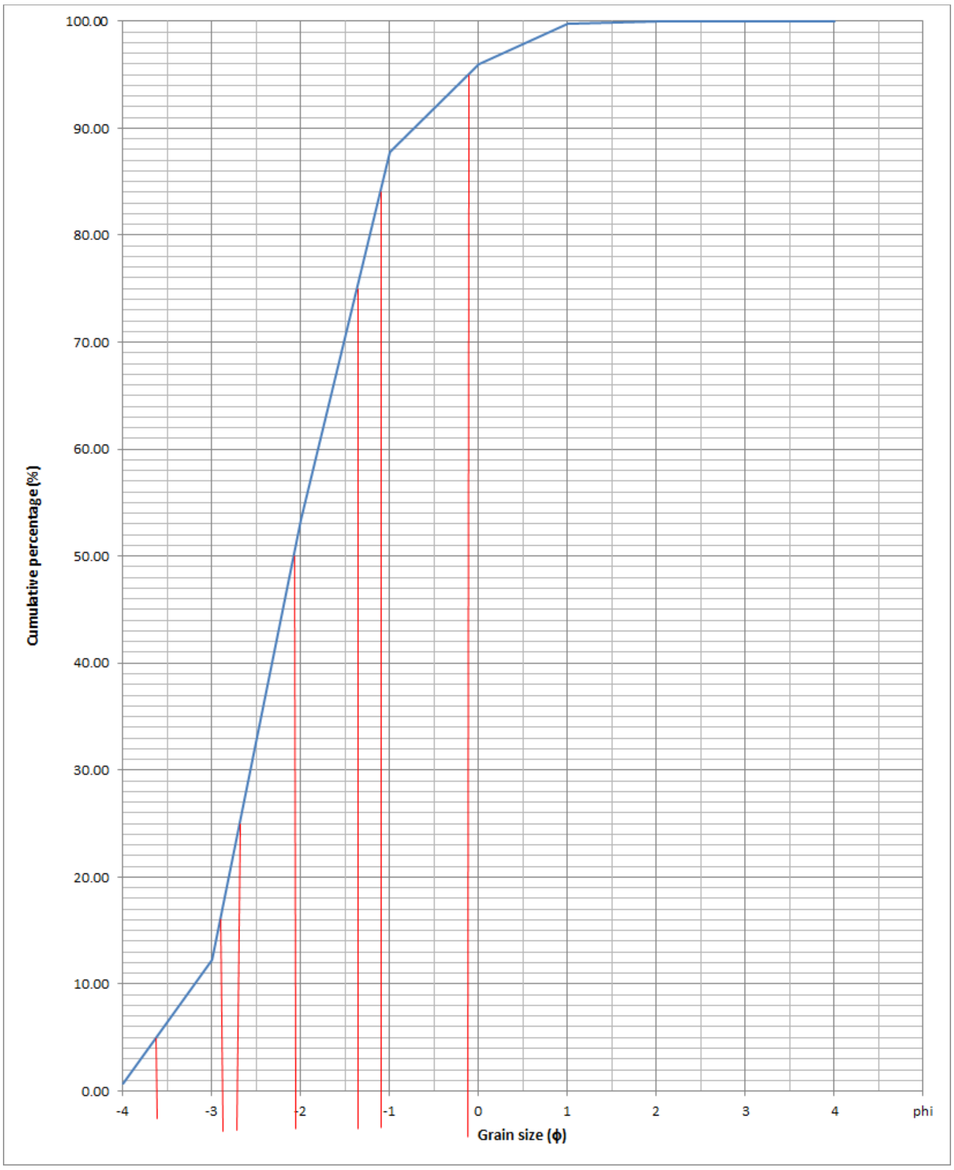
Graph of the cumulative percentage curve of sample collected from Cabedelo (lower zone).



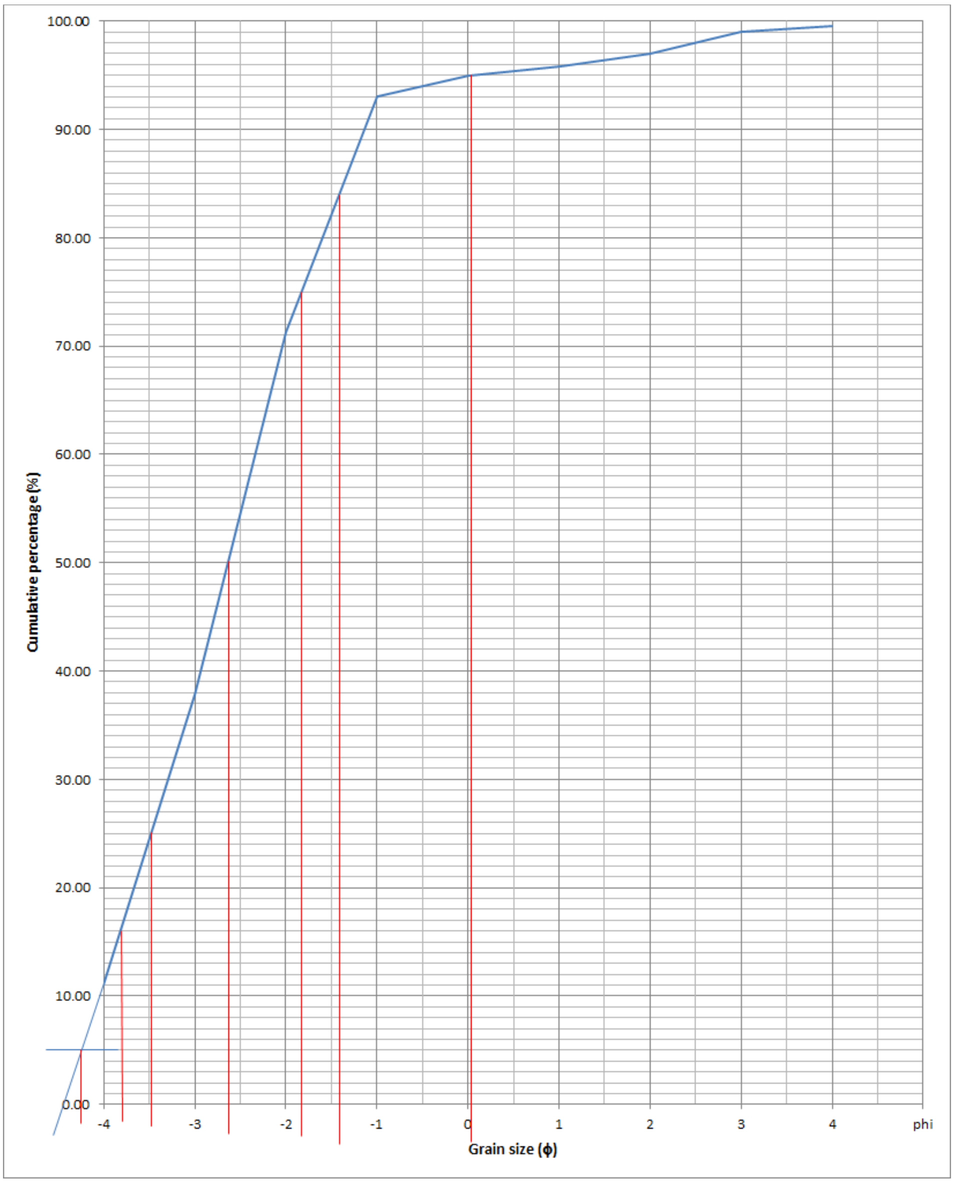
Graph of the cumulative percentage curve of sample collected from Cabedelo (mid zone).



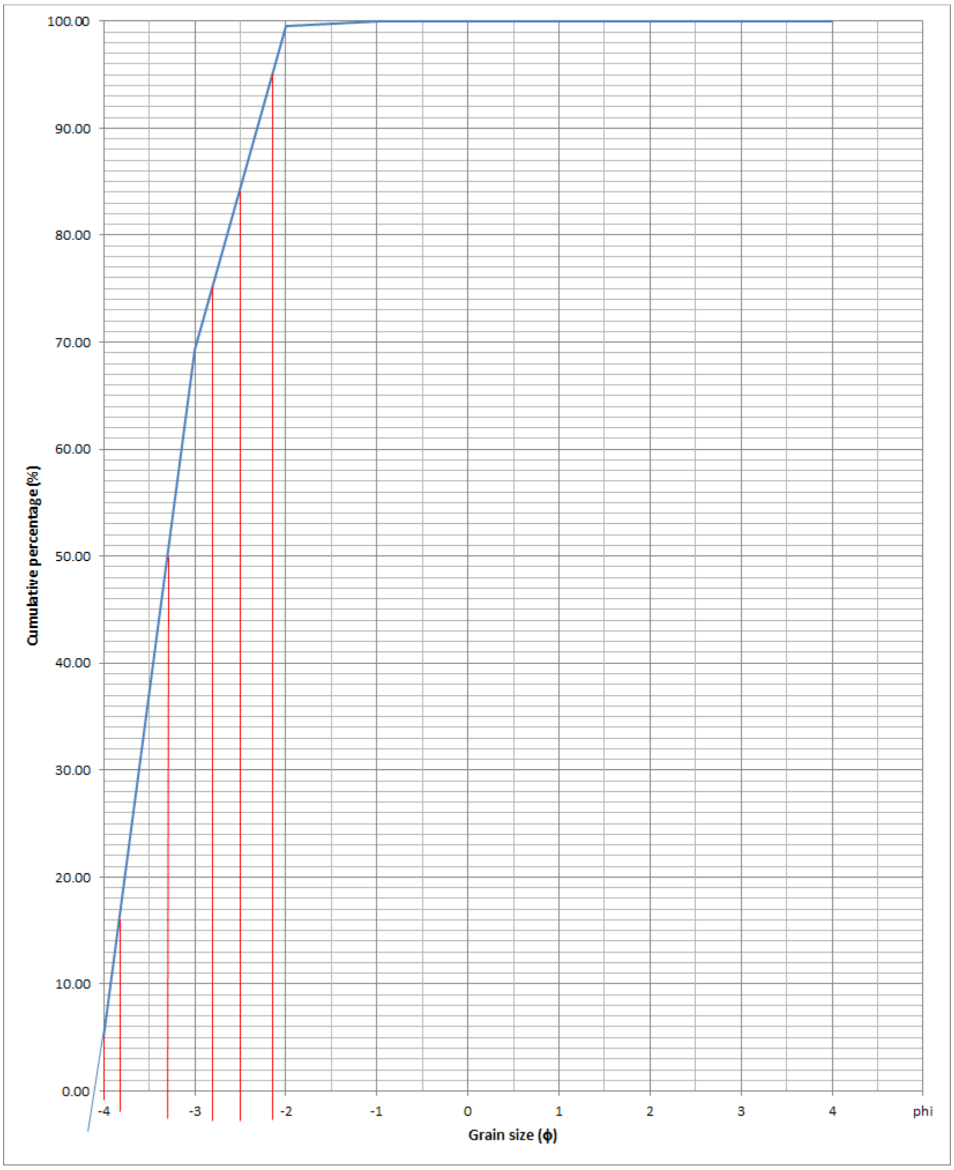
Graph of the cumulative percentage curve of sample collected from Cabedelo (upper zone).



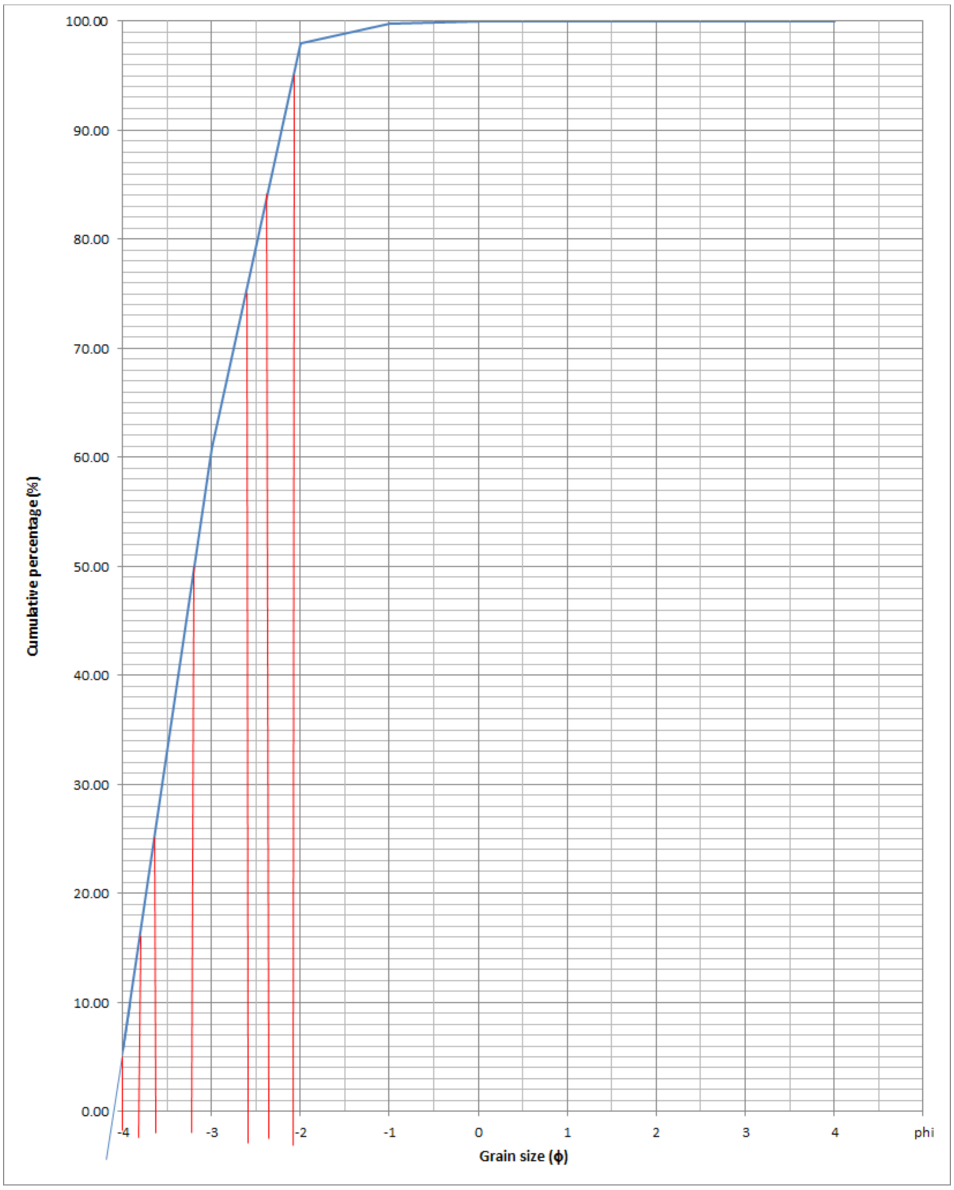
Graph of the cumulative percentage curve of sample collected from Homem Leme (lower zone).



Graph of the cumulative percentage curve of sample collected from Homem Leme (mid zone).



Graph of the cumulative percentage curve of sample collected from Homem Leme (upper zone).



Annex 3

Table of the weight and percentage composition of mineral fractions collected at each of the sampling stations.

Separation of Mineral Fractions (1)

Sampling station	Zone	Mineral Fraction	Weight (g)	Percentage Weight (%)	Prevalent fraction
Praia da Memória	Upper	H.F	1.86	49.6	L.F
		L.F	1.89	50.4	
	Mid	H.F	1.86	47.8	L.F
		L.F	2.03	52.2	
	Lower	H.F	1.93	50.3	L.F
		L.F	1.91	49.7	
Praia de Lavadores	Upper	H.F	1.98	33	L.F
		L.F	4.02	67	
	Mid	H.F	1.96	46.4	L.F
		L.F	2.26	53.6	
	Lower	H.F	1.96	49.9	L.F
		L.F	1.97	50.1	
Praia do Cabedelo da Foz do Douro	Upper	H.F	1.93	49.1	L.F
		L.F	2	50.9	
	Mid	H.F	1.94	46.5	L.F
		L.F	2.23	53.5	
	Lower	H.F	1.99	50.6	H.F
		L.F	1.94	49.4	
Praia do Homem do Leme	Upper	H.F	1.98	50.8	H.F
		L.F	1.92	49.2	
	Mid	H.F	1.96	48.8	L.F
		L.F	2.06	51.2	
	Lower	H.F	2.42	29.5	L.F
		L.F	5.79	70.5	

Table of the weight and percentage composition of mineral fractions collected at each of the sampling stations. Note that a second separation was carried out for samples that had an insufficient amount of heavy mineral required for analysis.

Separation of Mineral Fractions (2)

Sampling station	Zone	Mineral Fraction	Weight (g)	Percentage Weight (%)	Prevalent Fraction
Praia da Memória	Upper	H.F	1.97	50.4	H.F
		L.F	1.94	49.6	
	Mid	H.F	1.95	49.6	L.F
		L.F	1.98	50.4	
	Lower	H.F	1.92	49.5	L.F
		L.F	1.96	50.5	
Praia de Lavadores	Upper	H.F			
		L.F			
	Mid	H.F	2.07	43.2	L.F
		L.F	2.72	56.8	
	Lower	H.F	1.94	46.5	L.F
		L.F	2.23	53.5	
Praia do Cabedelo da Foz do Douro	Upper	H.F	1.97	38.6	L.F
		L.F	3.13	61.4	
	Mid	H.F	2.02	42.8	L.F
		L.F	2.7	57.2	
	Lower	H.F	1.99	48.2	L.F
		L.F	2.14	51.8	
Praia do Homem do Leme	Upper	H.F	1.95	49.9	L.F
		L.F	1.96	50.1	
	Mid	H.F	1.9	48.5	L.F
		L.F	2.02	51.5	
	Lower	H.F			
		L.F			

Sufficient heavy minerals obtained after first separation/no more sample available for second separation

Annex 4

Table of the particle roundness of the light mineral fraction and percentage composition in each zone of the samples collected.

Roundness	Memória			Homem Leme			Cabedelo			Lavadores		
	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower
very angular				10.7%								
angular									11.5%			9%
subangular	16.7%	23,5%		35.7%	11.3%	4.4%	4%	23%			5%	20%
subrounded	50%	47.1%	55.6%	53.6%	48.4%	73.5%	27%	67%	58%	88%	86%	71%
rounded	33.3%	29.4%	44.4%		40.3%	22.1%	69%	10%	19%	12%	9%	
well rounded									11.5%			

Annex 5

Sedimentological parameters obtained using GRADISTAT

SAMPLE STATISTICS

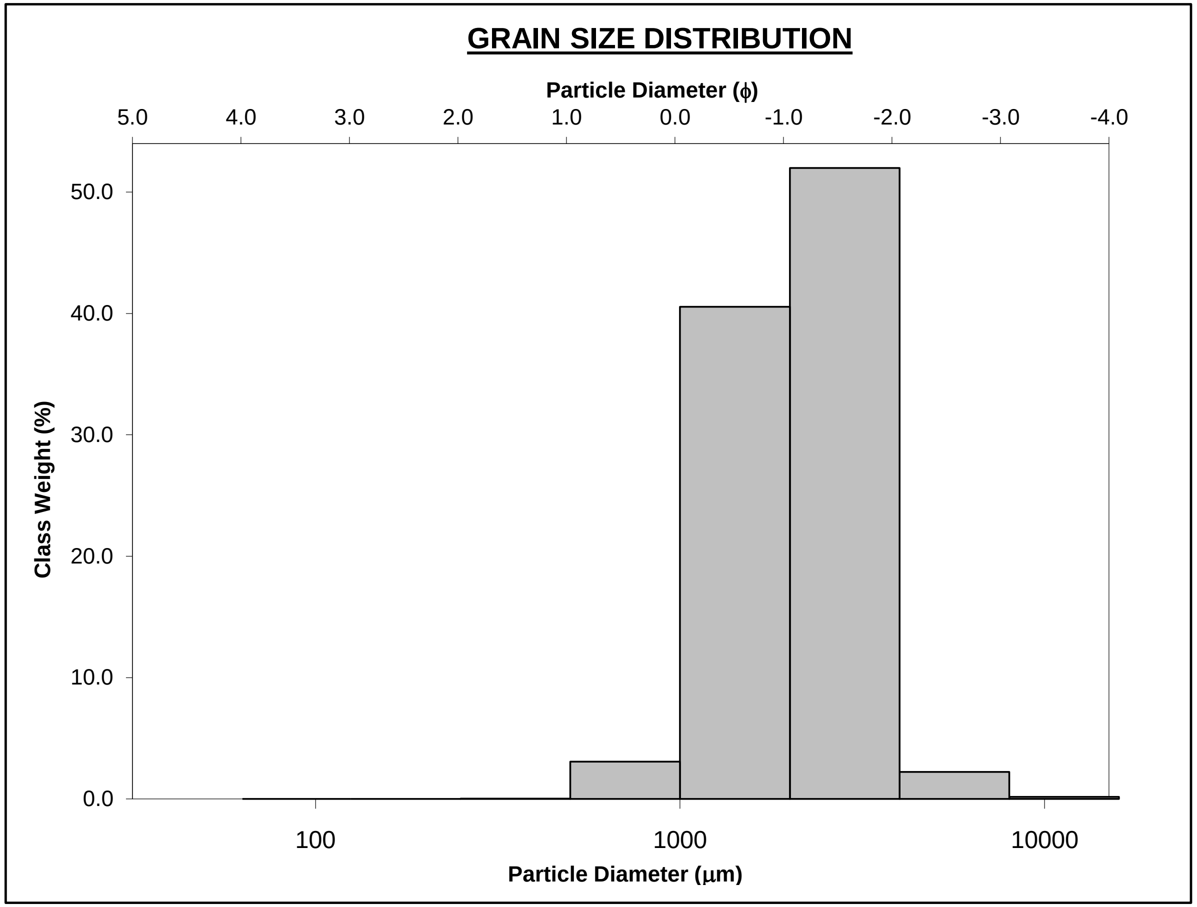
SAMPLE IDENTITY: Memória (higher zone) ANALYST & DATE: ,
SAMPLE TYPE: Unimodal, Moderately Well Sorted TEXTURAL GROUP: Sandy Gravel
SEDIMENT NAME: Sandy Very Fine Gravel

	μm	φ
MODE 1:	3000.0	-1.500
MODE 2:		
MODE 3:		
D_{10}:	1120.8	-1.858
MEDIAN or D_{50}:	2147.8	-1.103
D_{90}:	3623.8	-0.165
(D_{90} / D_{10}):	3.233	0.089
$(D_{90} - D_{10})$:	2503.0	1.693
(D_{75} / D_{25}):	2.067	0.335
$(D_{75} - D_{25})$:	1537.1	1.047

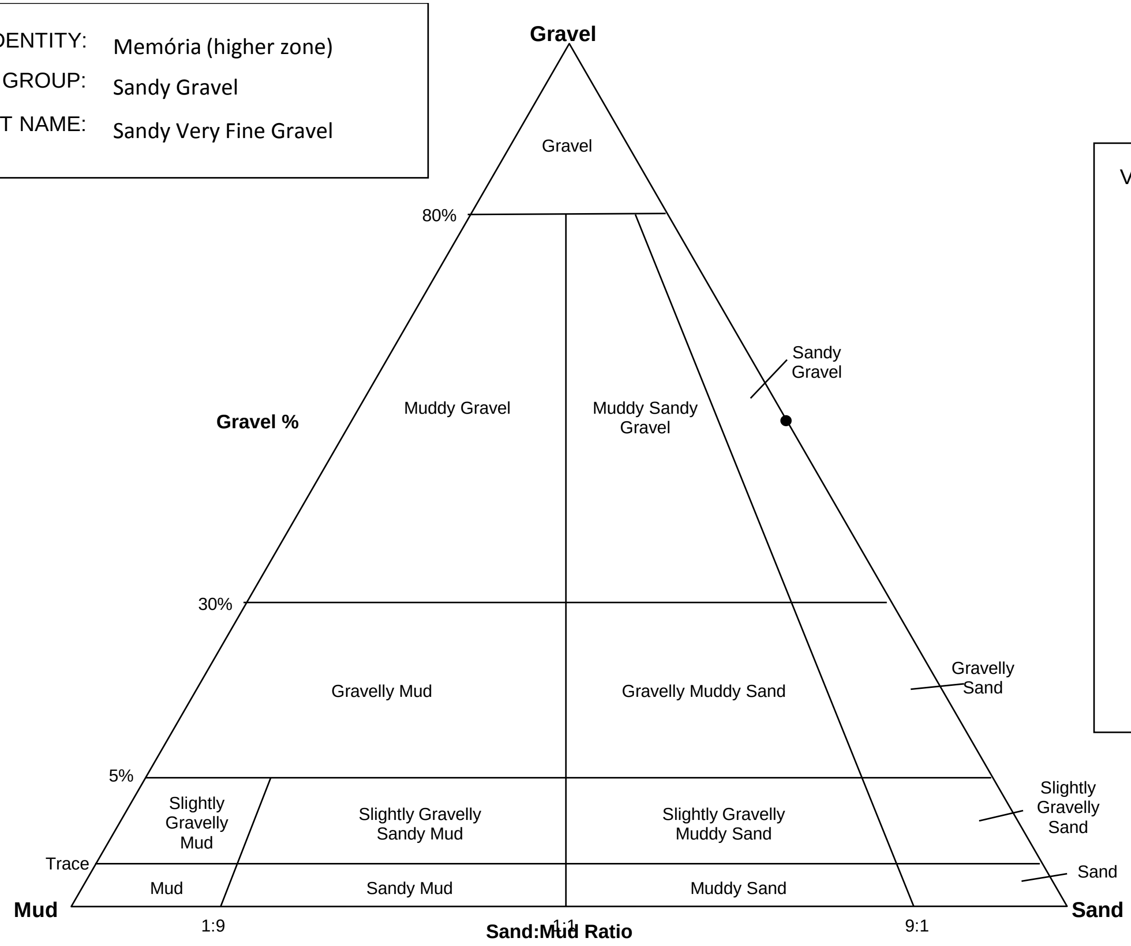
GRAIN SIZE DISTRIBUTION

GRAVEL:	55.5%	COARSE SAND:	3.1%
SAND:	44.5%	MEDIUM SAND:	0.0%
MUD:	0.0%	FINE SAND:	0.0%
		V FINE SAND:	0.0%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.2%	MEDIUM SILT:	0.0%
FINE GRAVEL:	2.3%	FINE SILT:	0.0%
V FINE GRAVEL:	53.0%	V FINE SILT:	0.0%
V COARSE SAND:	41.4%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	2391.4	2066.4	-1.047	2073.8	-1.052	Very Fine Gravel
SORTING (σ):	1034.1	1.533	0.616	1.567	0.648	Moderately Well Sorted
SKEWNESS (Sk):	2.078	-0.536	0.536	-0.108	0.108	Fine Skewed
KURTOSIS (K):	16.88	7.052	7.052	0.747	0.747	Platykurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0 4.0 3.0 2.0 1.0 0.0 -1.0 -2.0 -3.0 -4.0
Class Weight (%)
0.0 10.0 20.0 30.0 40.0 50.0
100 1000 10000
Particle Diameter (μm)

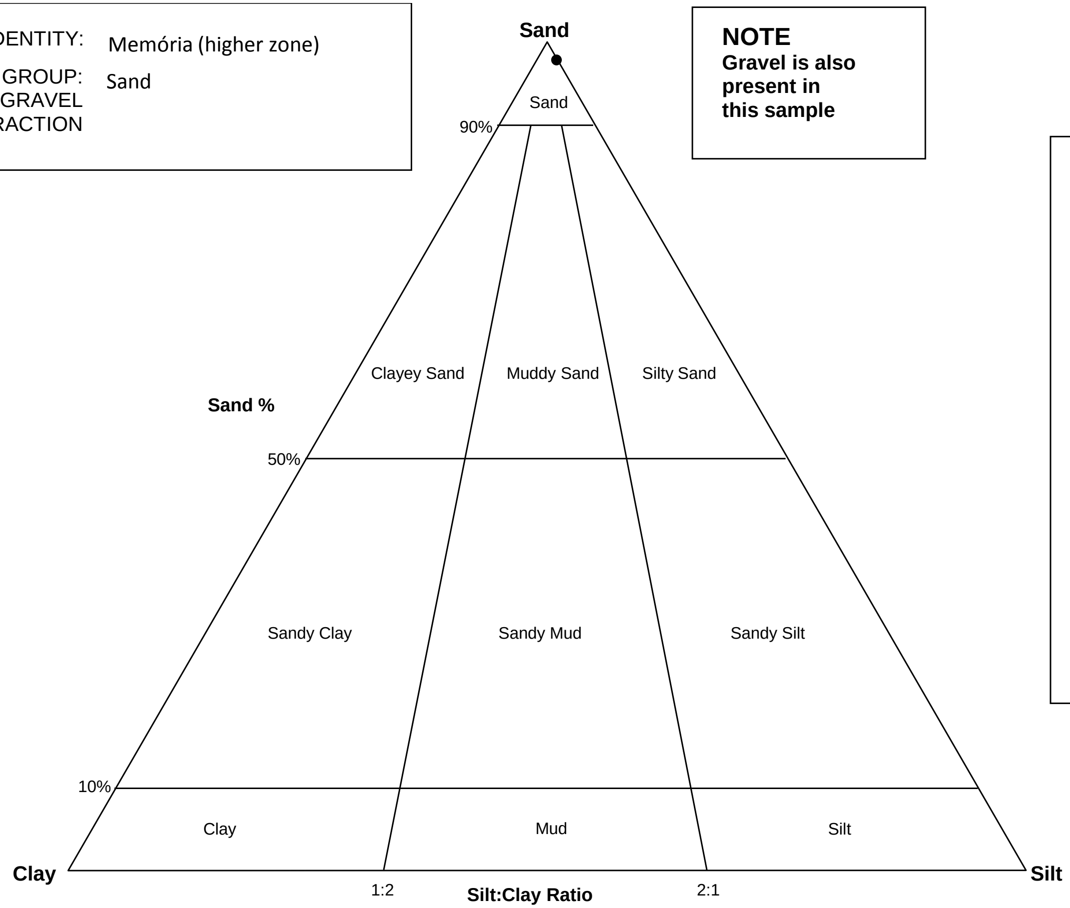
SAMPLE IDENTITY:	Memória (higher zone)
TEXTURAL GROUP:	Sandy Gravel
SEDIMENT NAME:	Sandy Very Fine Gravel



Gravel:	55.5 %
Sand:	44.5 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	0.2%
Fine Gravel:	2.3%
Very Fine Gravel:	53.0 %
Very Coarse Sand:	41.4 %
Coarse Sand:	3.1%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%

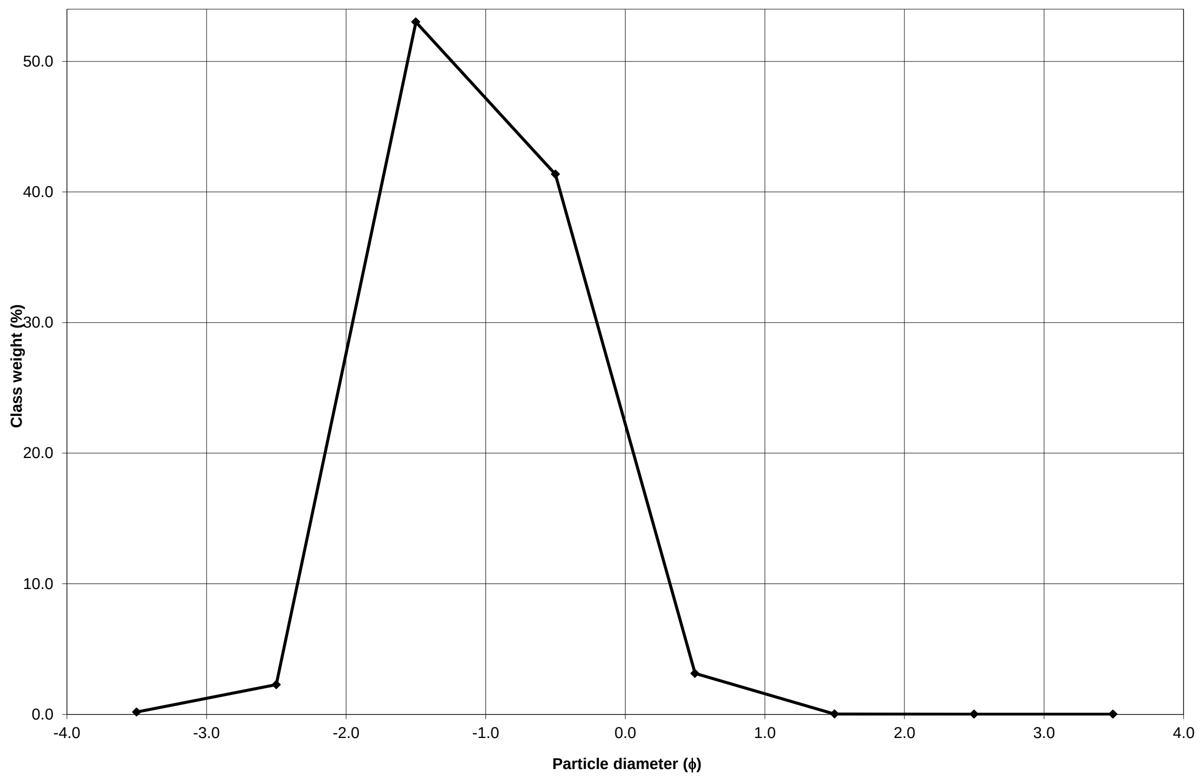
SAMPLE IDENTITY:	Memória (higher zone)
TEXTURAL GROUP: IGNORING GRAVEL FRACTION	Sand



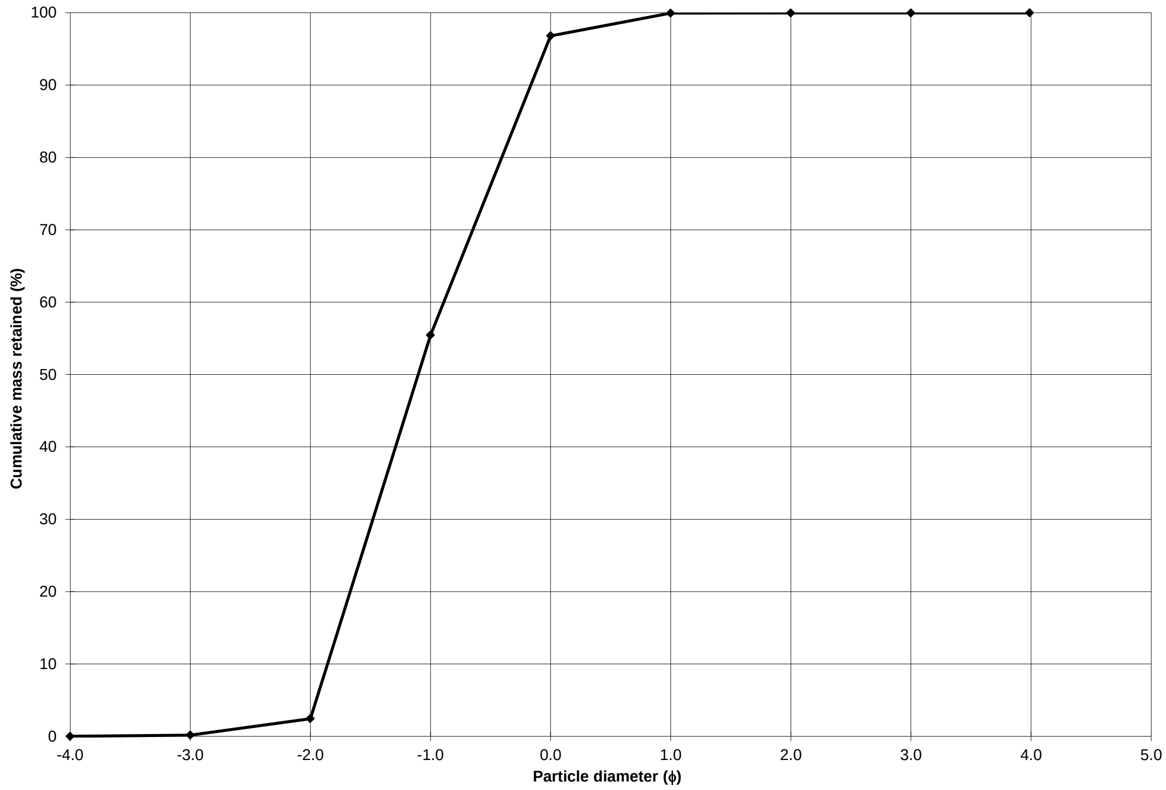
NOTE
Gravel is also present in this sample

Gravel:	55.5 %
Sand:	44.5 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	0.2%
Fine Gravel:	2.3%
Very Fine Gravel:	53.0 %
Very Coarse Sand:	41.4 %
Coarse Sand:	3.1%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



Cumulative (phi)

SAMPLE STATISTICS

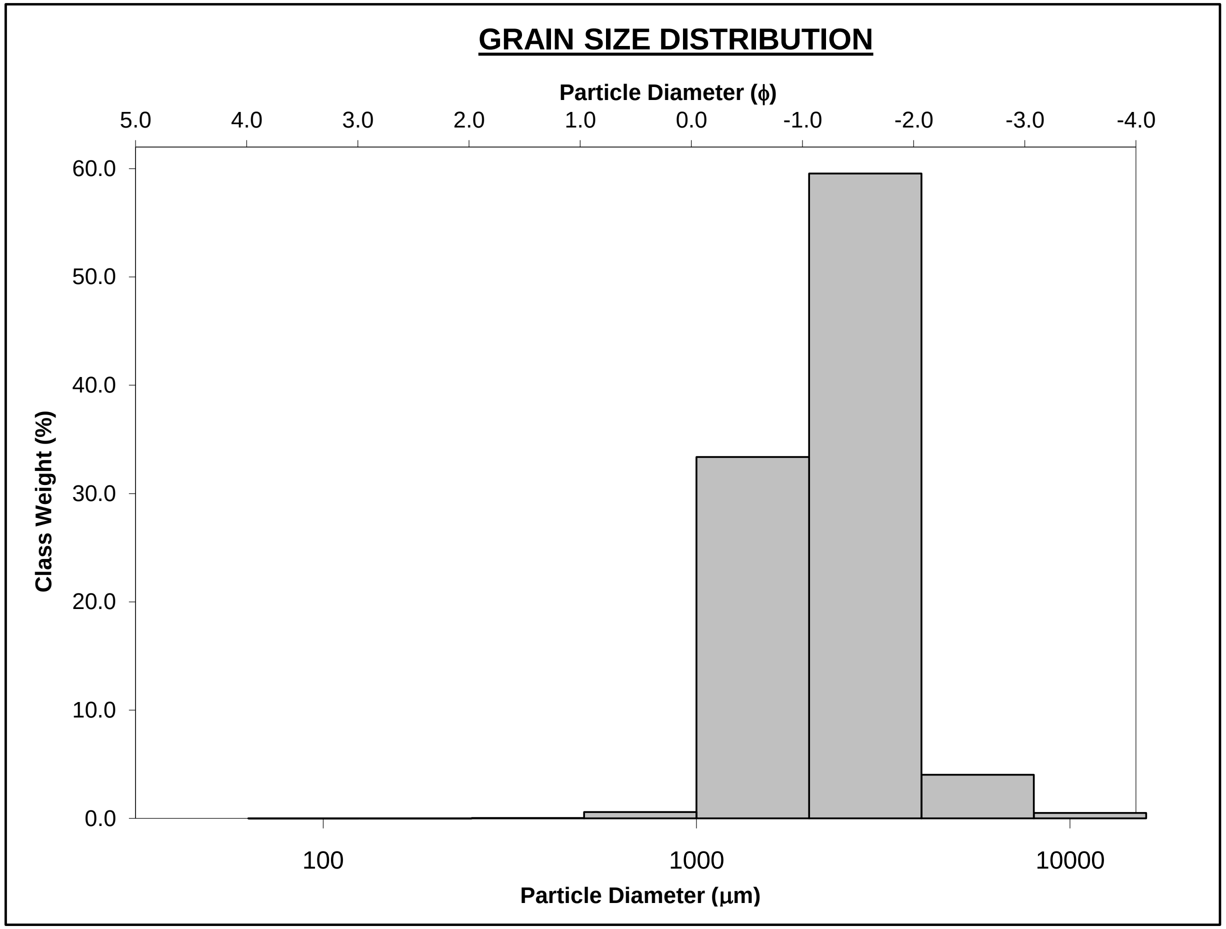
SAMPLE IDENTITY: Memória (mid zone) ANALYST & DATE: ,
SAMPLE TYPE: Unimodal, Moderately Well Sorted TEXTURAL GROUP: Sandy Gravel
SEDIMENT NAME: Sandy Very Fine Gravel

	μm	ϕ
MODE 1:	3000.0	-1.500
MODE 2:		
MODE 3:		
D_{10}:	1210.4	-1.912
MEDIAN or D_{50}:	2383.0	-1.253
D_{90}:	3762.1	-0.276
(D_{90} / D_{10}):	3.108	0.144
$(D_{90} - D_{10})$:	2551.7	1.636
(D_{75} / D_{25}):	1.929	0.430
$(D_{75} - D_{25})$:	1527.0	0.948

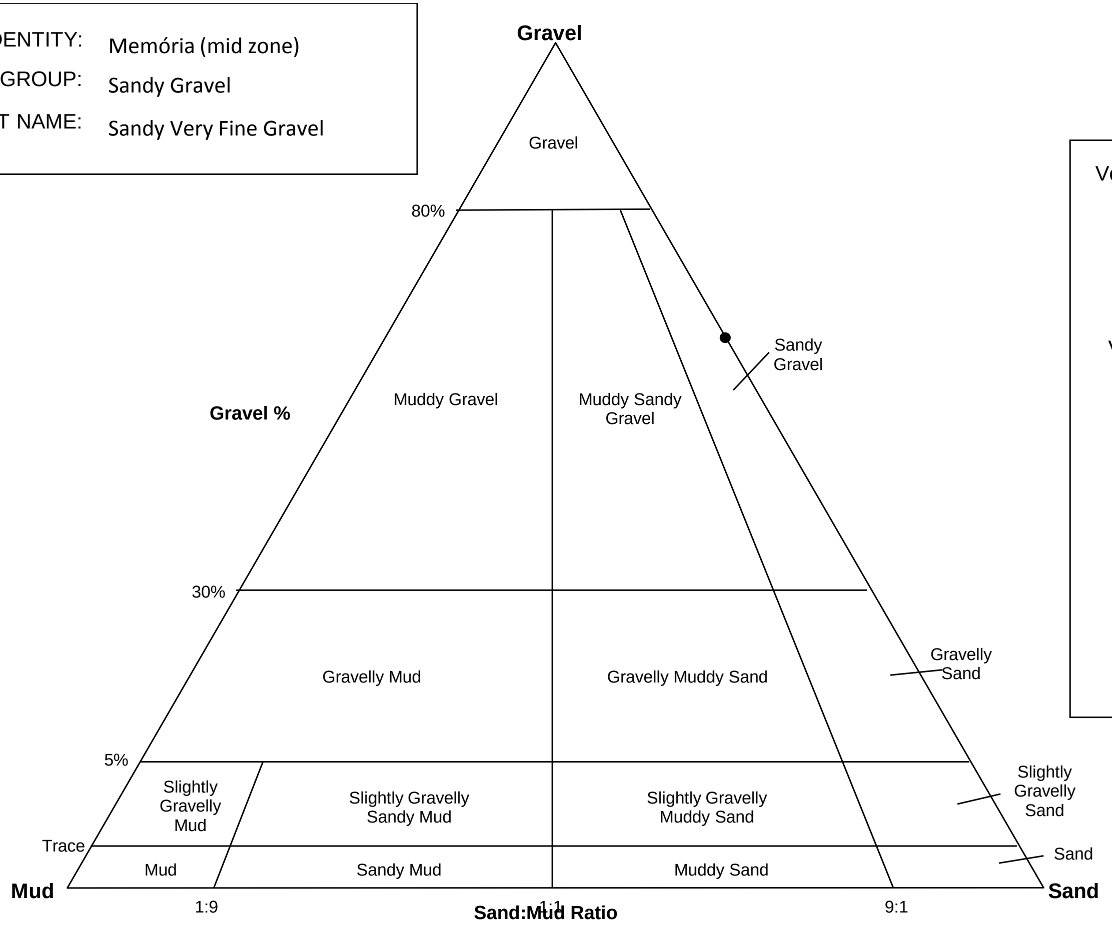
GRAIN SIZE DISTRIBUTION

GRAVEL:	65.3%	COARSE SAND:	0.6%
SAND:	34.7%	MEDIUM SAND:	0.0%
MUD:	0.0%	FINE SAND:	0.0%
		V FINE SAND:	0.0%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.5%	MEDIUM SILT:	0.0%
FINE GRAVEL:	4.1%	FINE SILT:	0.0%
V FINE GRAVEL:	60.7%	V FINE SILT:	0.0%
V COARSE SAND:	34.0%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	2645.8	2294.7	-1.198	2253.9	-1.172	Very Fine Gravel
SORTING (σ):	1211.3	1.497	0.582	1.540	0.623	Moderately Well Sorted
SKEWNESS (Sk):	2.993	0.067	-0.067	-0.191	0.191	Fine Skewed
KURTOSIS (K):	21.41	4.006	4.006	0.806	0.806	Platykurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Class Weight (%)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
100
1000
10000
Particle Diameter (μm)

SAMPLE IDENTITY:	Memória (mid zone)
TEXTURAL GROUP:	Sandy Gravel
SEDIMENT NAME:	Sandy Very Fine Gravel

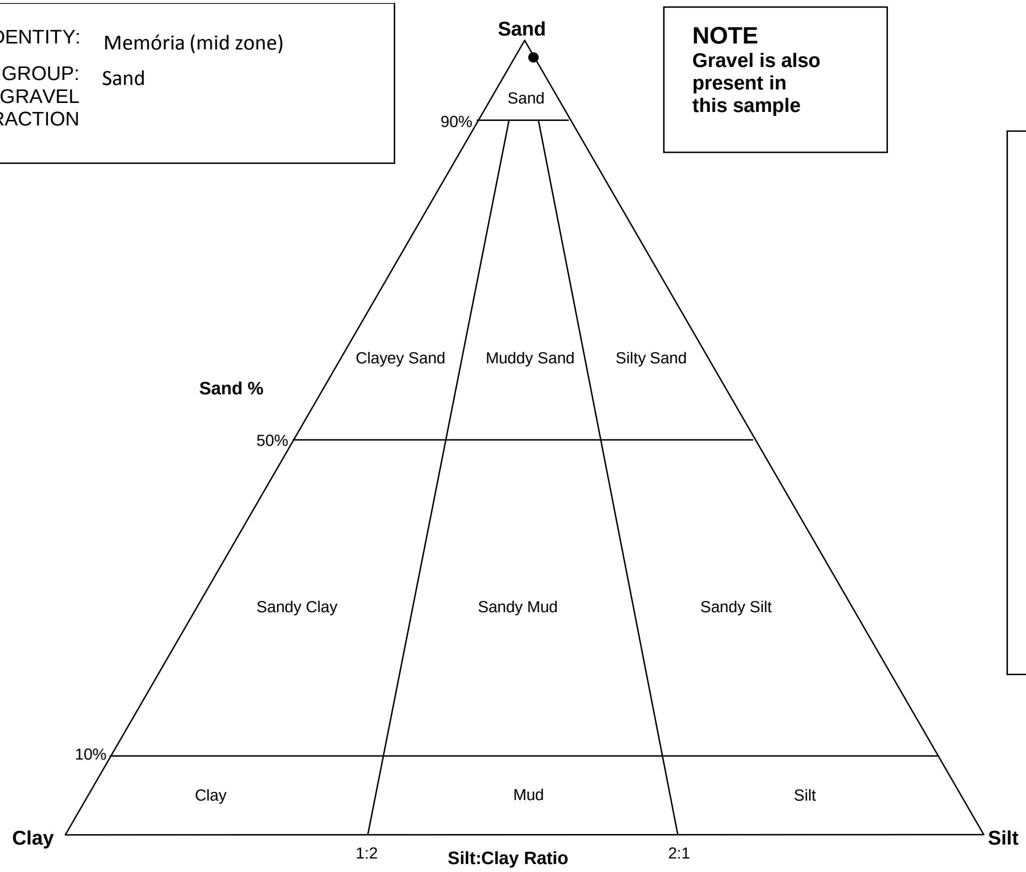


Gravel:	65.3 %
Sand:	34.7 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	0.5%
Fine Gravel:	4.1%
Very Fine Gravel:	60.7 %
Very Coarse Sand:	34.0 %
Coarse Sand:	0.6%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%

SAMPLE IDENTITY: Memória (mid zone)

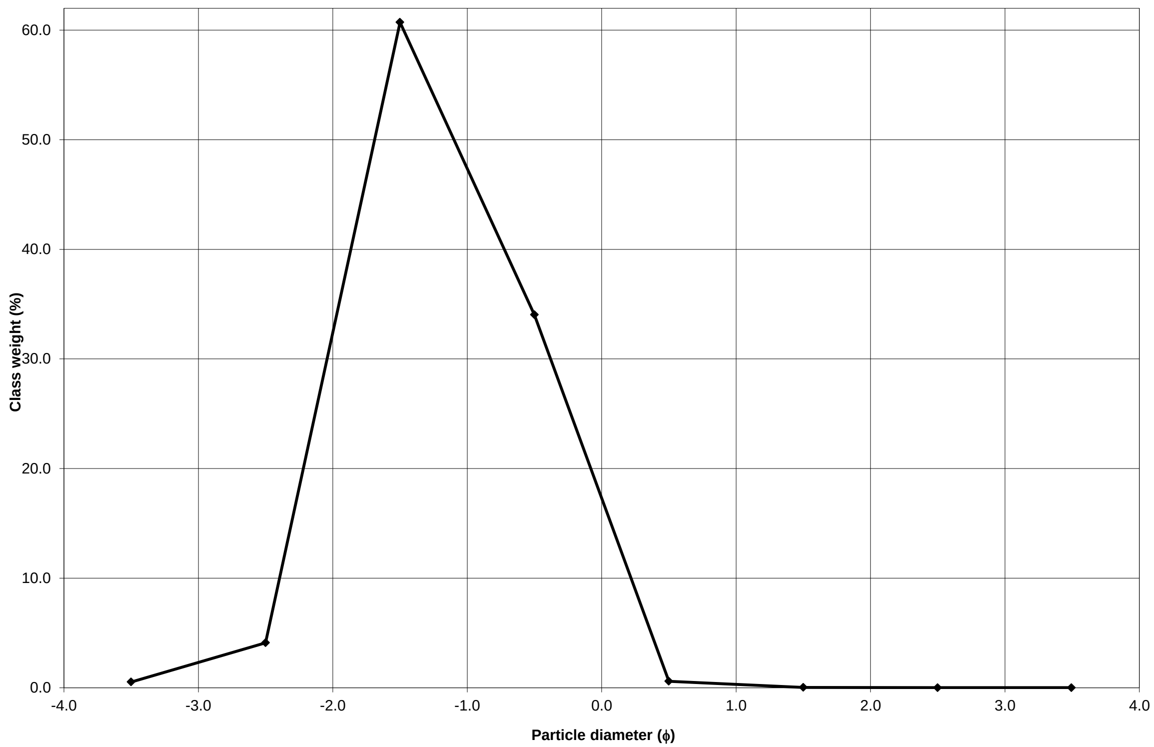
TEXTURAL GROUP: IGNORING GRAVEL FRACTION: Sand



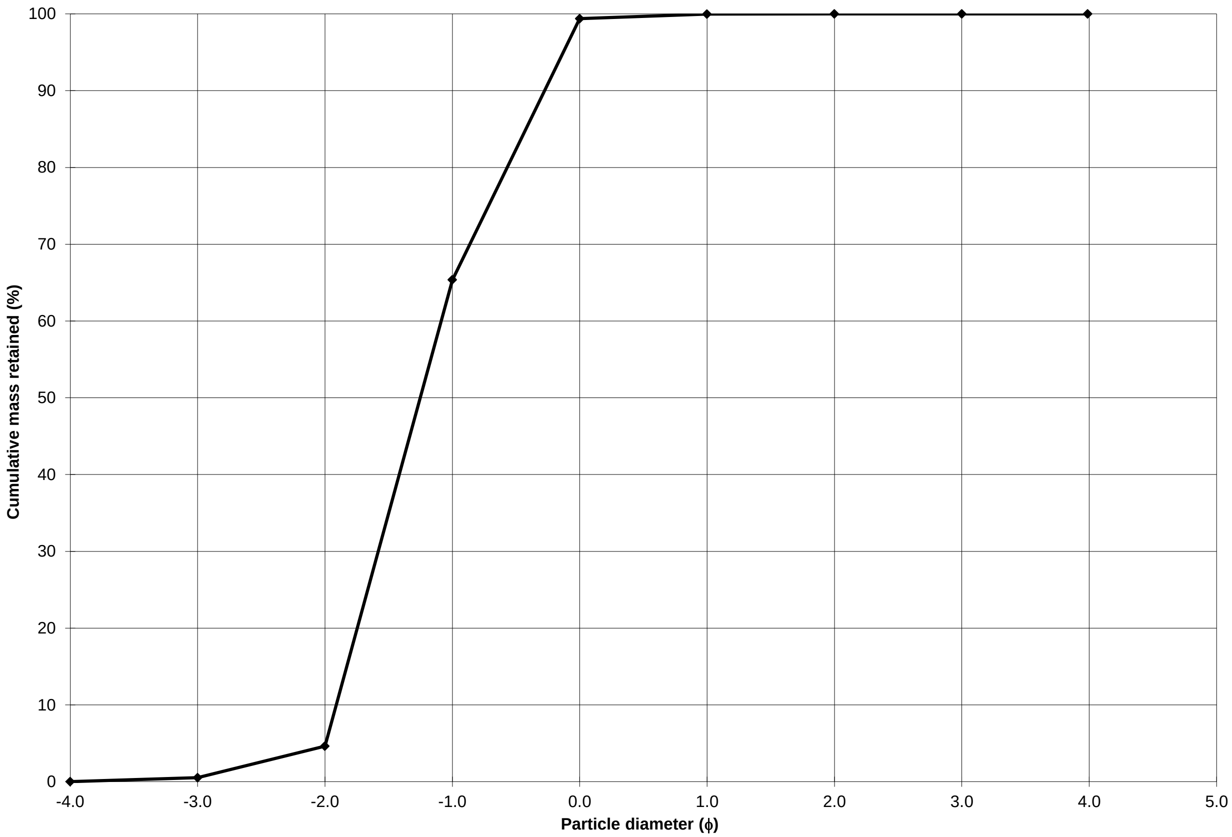
NOTE
Gravel is also present in this sample

Gravel:	65.3 %
Sand:	34.7 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	0.5%
Fine Gravel:	4.1%
Very Fine Gravel:	60.7 %
Very Coarse Sand:	34.0 %
Coarse Sand:	0.6%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



Cumulative (phi)

SAMPLE STATISTICS

SAMPLE IDENTITY: **Memória (lower zone)** ANALYST & DATE: ,

SAMPLE TYPE: Unimodal, Moderately Well Sorted TEXTURAL GROUP: Sandy Gravel

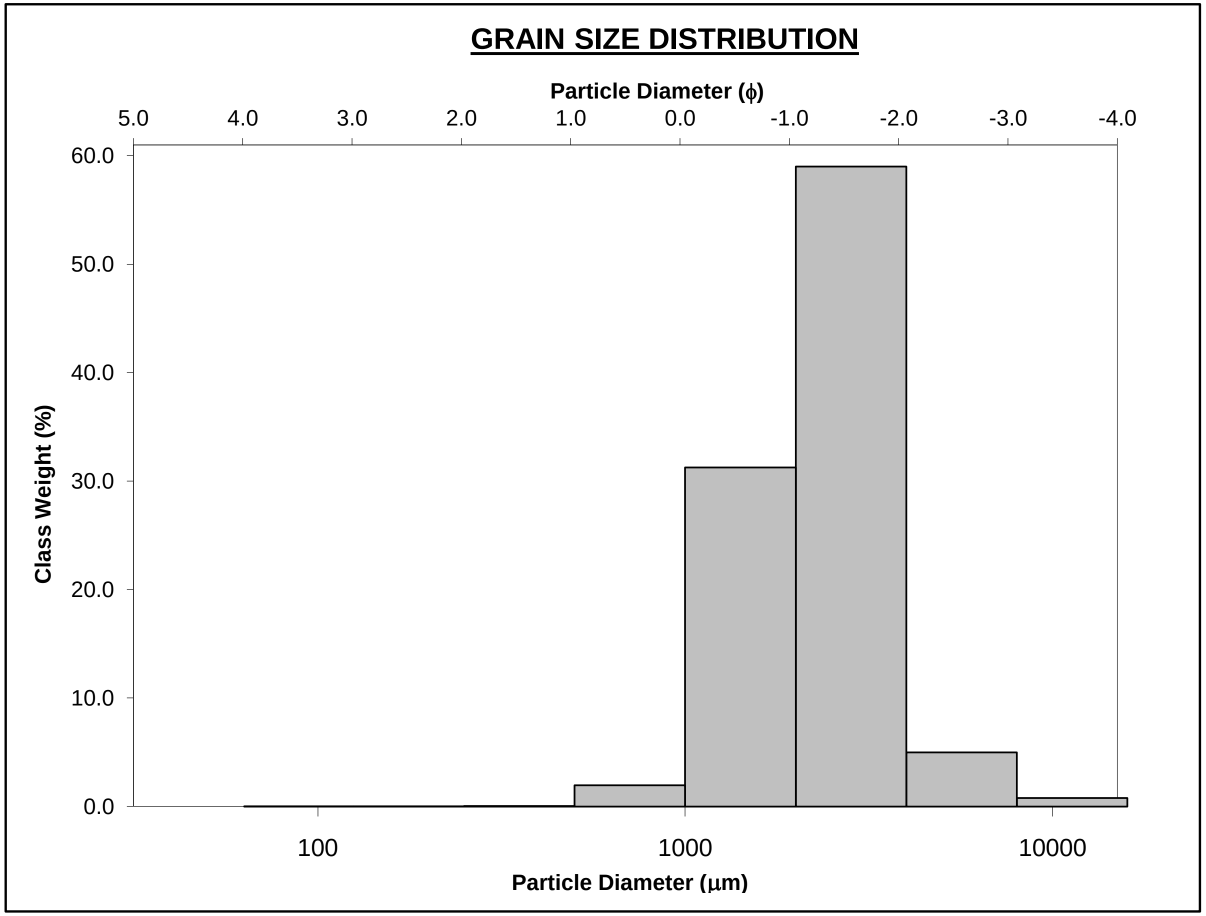
SEDIMENT NAME: Sandy Very Fine Gravel

	μm	ϕ
MODE 1:	3000.0	-1.500
MODE 2:		
MODE 3:		
D_{10}:	1188.1	-1.931
MEDIAN or D_{50}:	2406.3	-1.267
D_{90}:	3814.2	-0.249
(D_{90} / D_{10}):	3.210	0.129
$(D_{90} - D_{10})$:	2626.0	1.683
(D_{75} / D_{25}):	1.949	0.428
$(D_{75} - D_{25})$:	1562.6	0.963

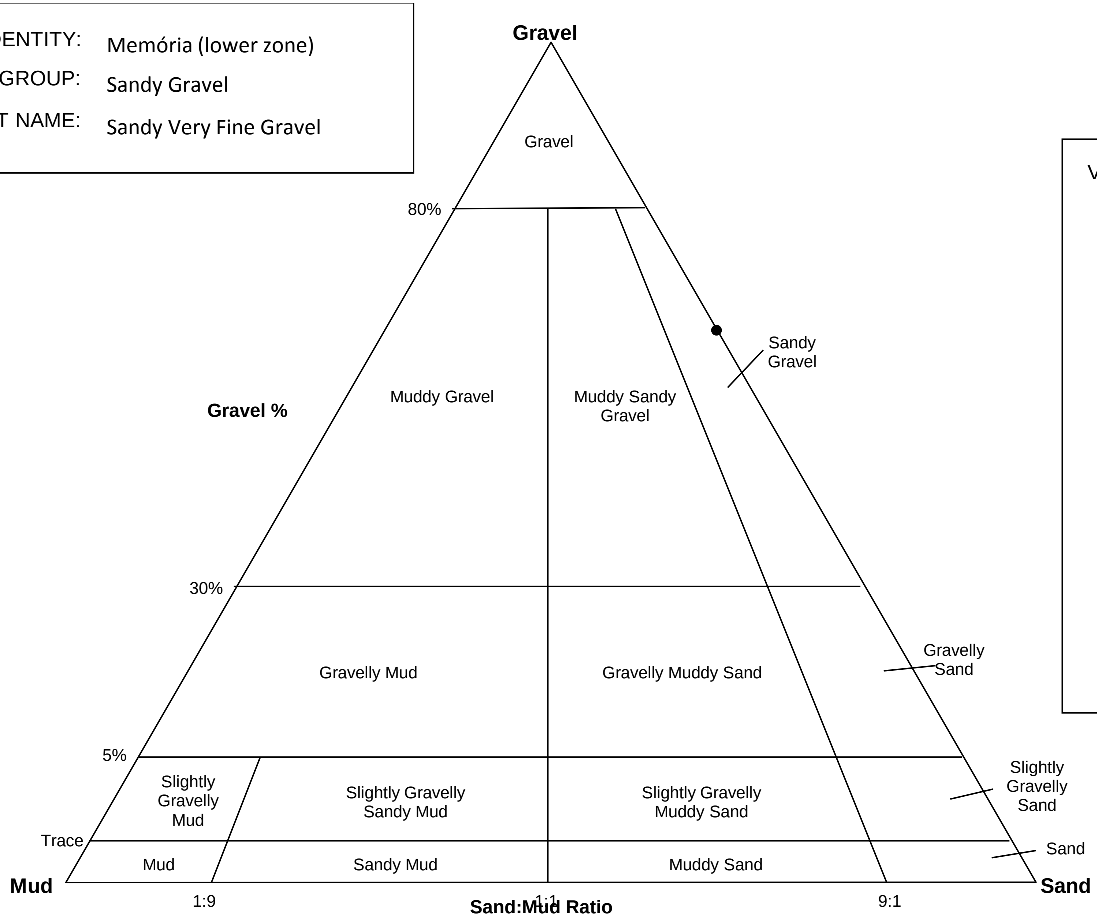
GRAIN SIZE DISTRIBUTION

GRAVEL:	66.1%	COARSE SAND:	2.0%
SAND:	33.9%	MEDIUM SAND:	0.1%
MUD:	0.0%	FINE SAND:	0.0%
		V FINE SAND:	0.0%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.8%	MEDIUM SILT:	0.0%
FINE GRAVEL:	5.1%	FINE SILT:	0.0%
V FINE GRAVEL:	60.2%	V FINE SILT:	0.0%
V COARSE SAND:	31.9%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	2698.3	2305.8	-1.205	2263.4	-1.179	Very Fine Gravel
SORTING (σ):	1351.7	1.554	0.636	1.584	0.664	Moderately Well Sorted
SKEWNESS (Sk):	3.024	-0.109	0.109	-0.160	0.160	Fine Skewed
KURTOSIS (K):	19.74	4.972	4.972	0.885	0.885	Platykurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0 4.0 3.0 2.0 1.0 0.0 -1.0 -2.0 -3.0 -4.0
Class Weight (%)
60.0 50.0 40.0 30.0 20.0 10.0 0.0
100 1000 10000
Particle Diameter (μm)

SAMPLE IDENTITY:	Memória (lower zone)
TEXTURAL GROUP:	Sandy Gravel
SEDIMENT NAME:	Sandy Very Fine Gravel

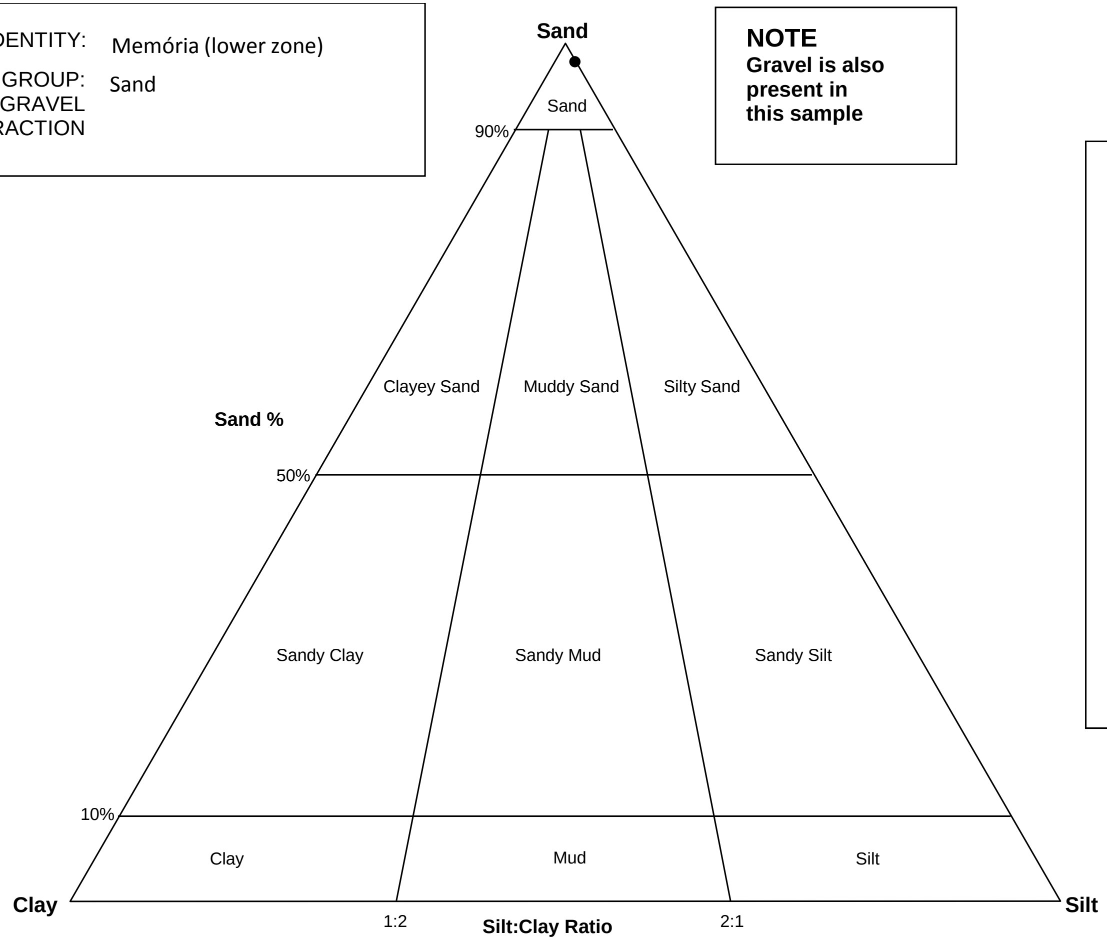


Gravel:	66.1%
Sand:	33.9%
Mud:	0.0%

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	0.8%
Fine Gravel:	5.1%
Very Fine Gravel:	60.2%
Very Coarse Sand:	31.9%
Coarse Sand:	2.0%
Medium Sand:	0.1%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%

SAMPLE IDENTITY: Memória (lower zone)

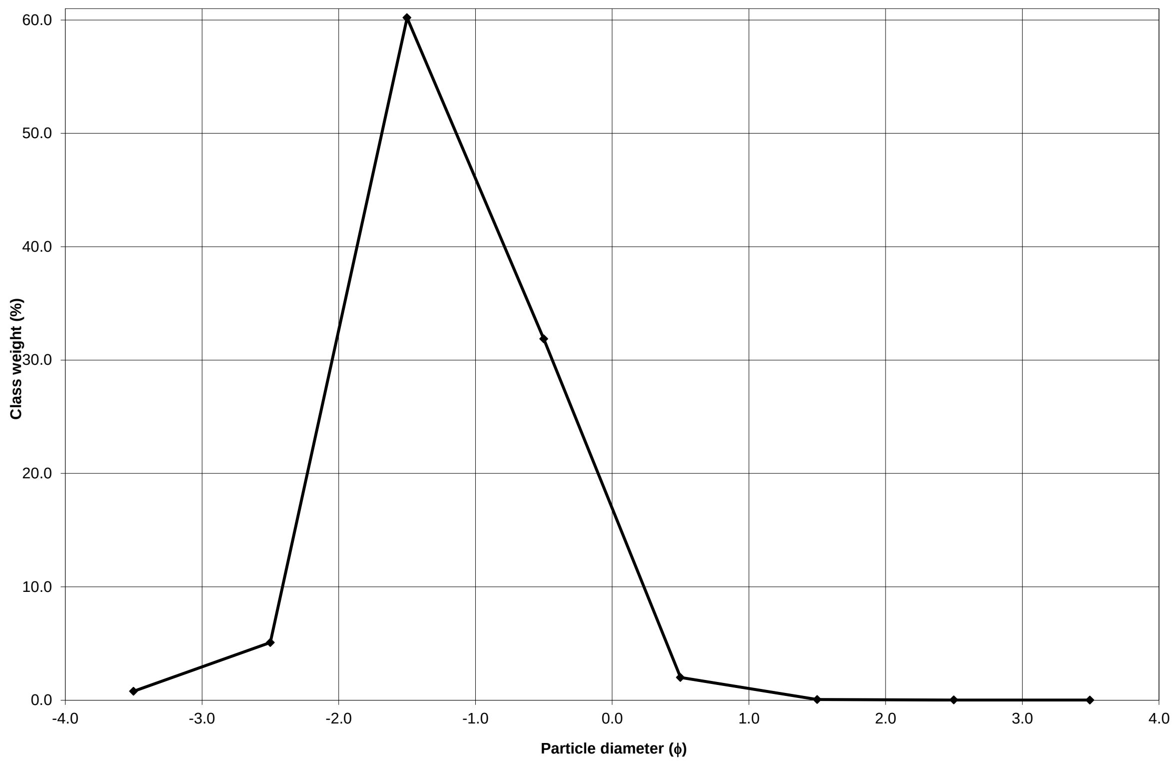
TEXTURAL GROUP: IGNORING GRAVEL FRACTION: Sand



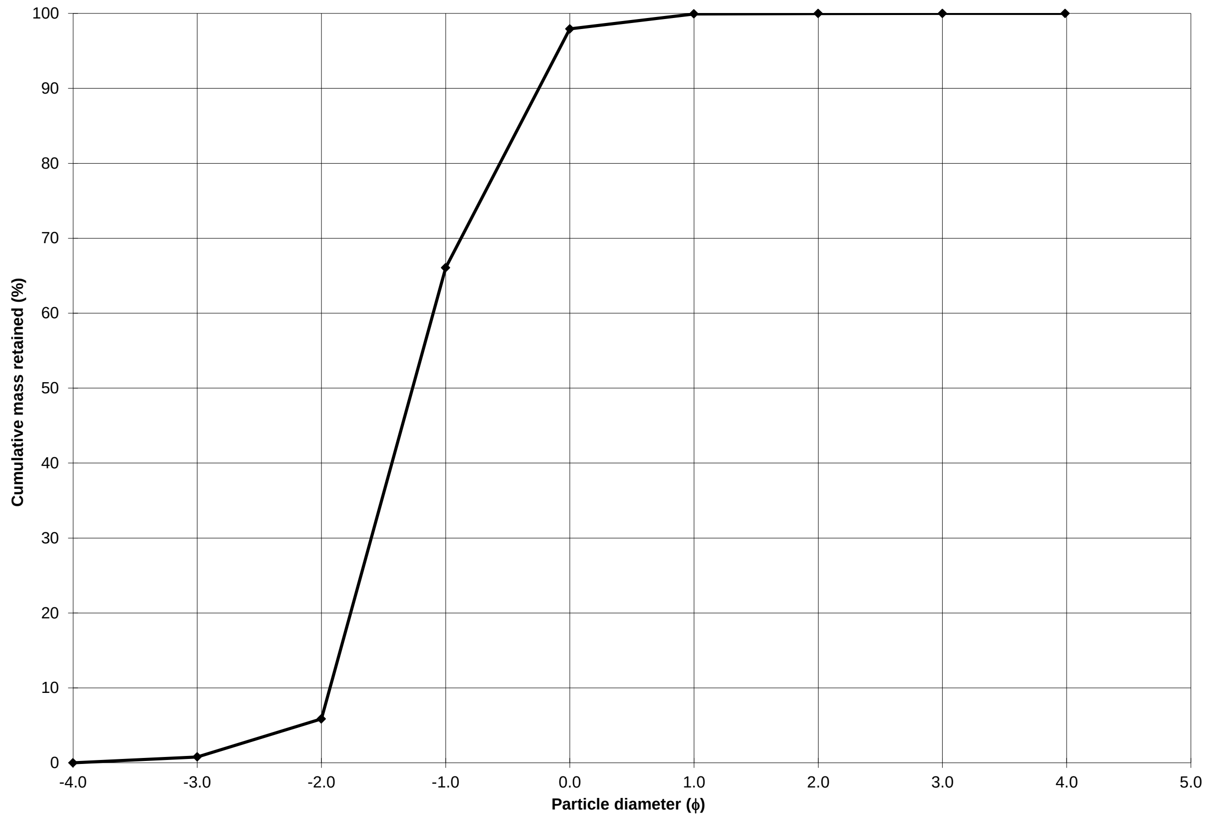
NOTE
Gravel is also present in this sample

Gravel:	66.1 %
Sand:	33.9 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	0.8%
Fine Gravel:	5.1%
Very Fine Gravel:	60.2 %
Very Coarse Sand:	31.9 %
Coarse Sand:	2.0%
Medium Sand:	0.1%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



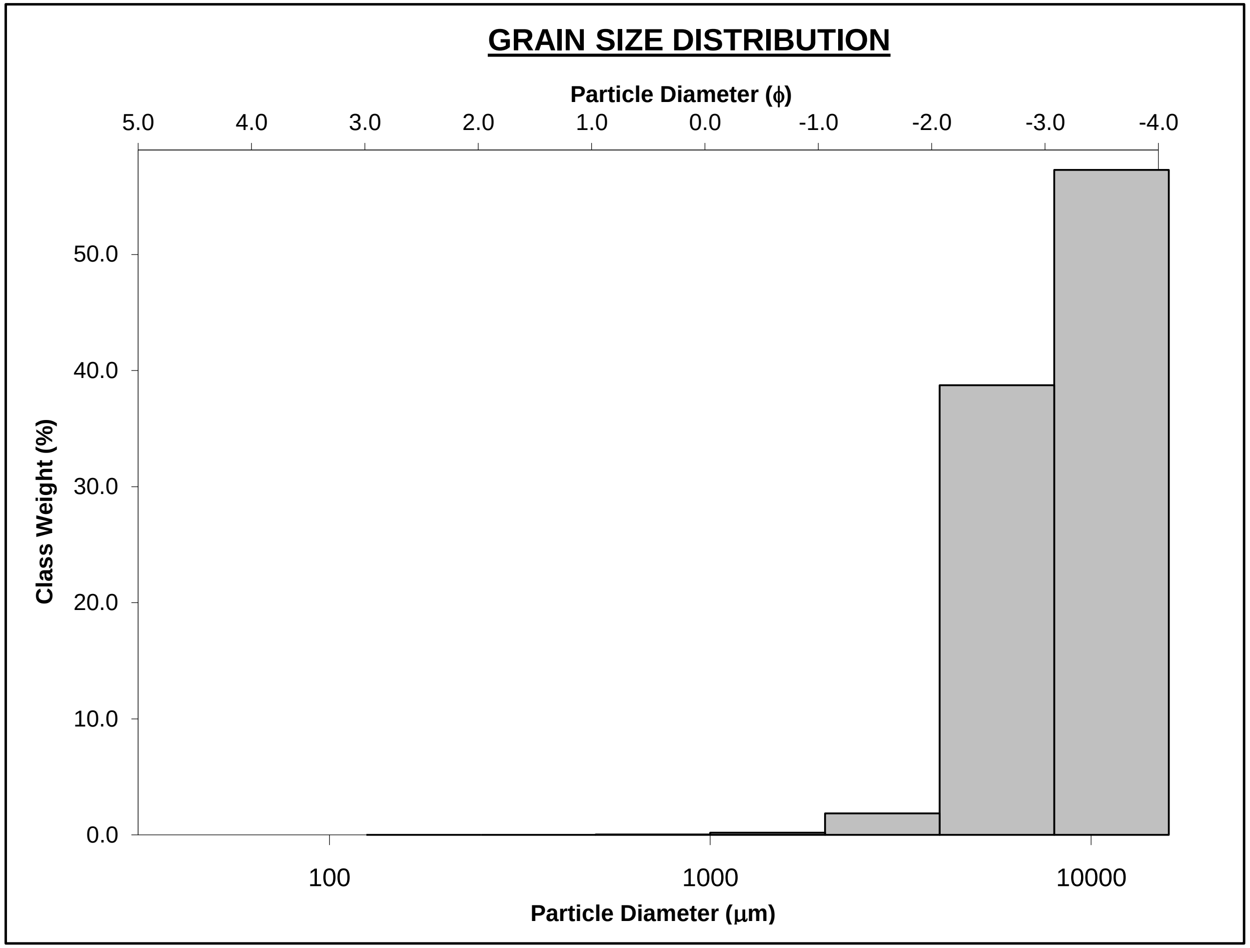
Cumulative (phi)

SAMPLE STATISTICS

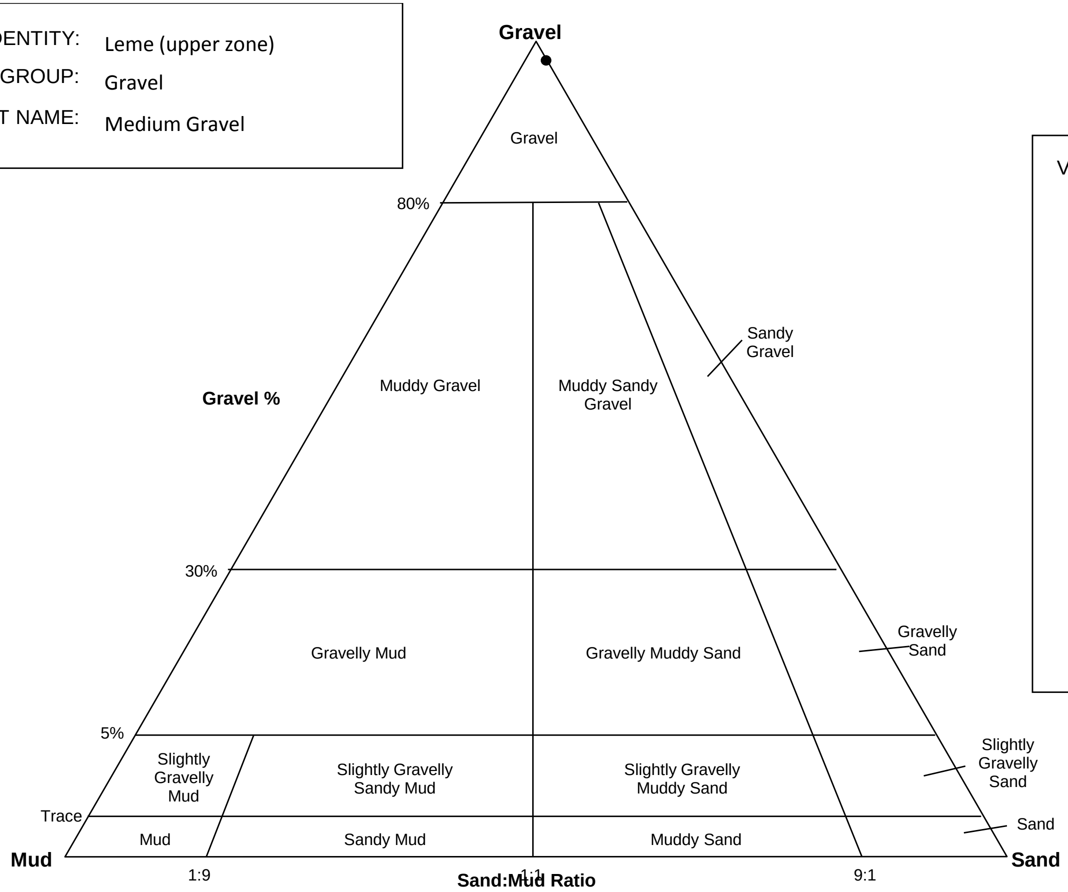
SAMPLE IDENTITY:	Leme (upper zone)	ANALYST & DATE:	,
SAMPLE TYPE:	Unimodal, Moderately Well Sorted	TEXTURAL GROUP:	Gravel
SEDIMENT NAME:	Medium Gravel		

	μm	ϕ	GRAIN SIZE DISTRIBUTION			
MODE 1:	12000.0	-3.500	GRAVEL:	99.8%	COARSE SAND:	0.0%
MODE 2:			SAND:	0.2%	MEDIUM SAND:	0.0%
MODE 3:			MUD:	0.0%	FINE SAND:	0.0%
D_{10}:	4643.8	-3.923			V FINE SAND:	0.0%
MEDIAN or D_{50}:	9164.5	-3.196	V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
D_{90}:	15164.6	-2.215	COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
(D_{90} / D_{10}):	3.266	0.565	MEDIUM GRAVEL:	60.8%	MEDIUM SILT:	0.0%
$(D_{90} - D_{10})$:	10520.8	1.707	FINE GRAVEL:	37.2%	FINE SILT:	0.0%
(D_{75} / D_{25}):	2.045	0.717	V FINE GRAVEL:	1.8%	V FINE SILT:	0.0%
$(D_{75} - D_{25})$:	6414.5	1.032	V COARSE SAND:	0.2%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	8895.8	4967.6	-2.885	8746.7	-3.129	Medium Gravel
SORTING (σ):	3701.9	8.436	0.889	1.486	0.572	Moderately Well Sorted
SKEWNESS (Sk):	-0.739	-3.619	1.948	-0.365	0.365	Very Fine Skewed
KURTOSIS (K):	2.476	14.58	6.969	0.557	0.557	Very Platykurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Class Weight (%)
50.0
40.0
30.0
20.0
10.0
0.0
100
1000
10000
Particle Diameter (µm)

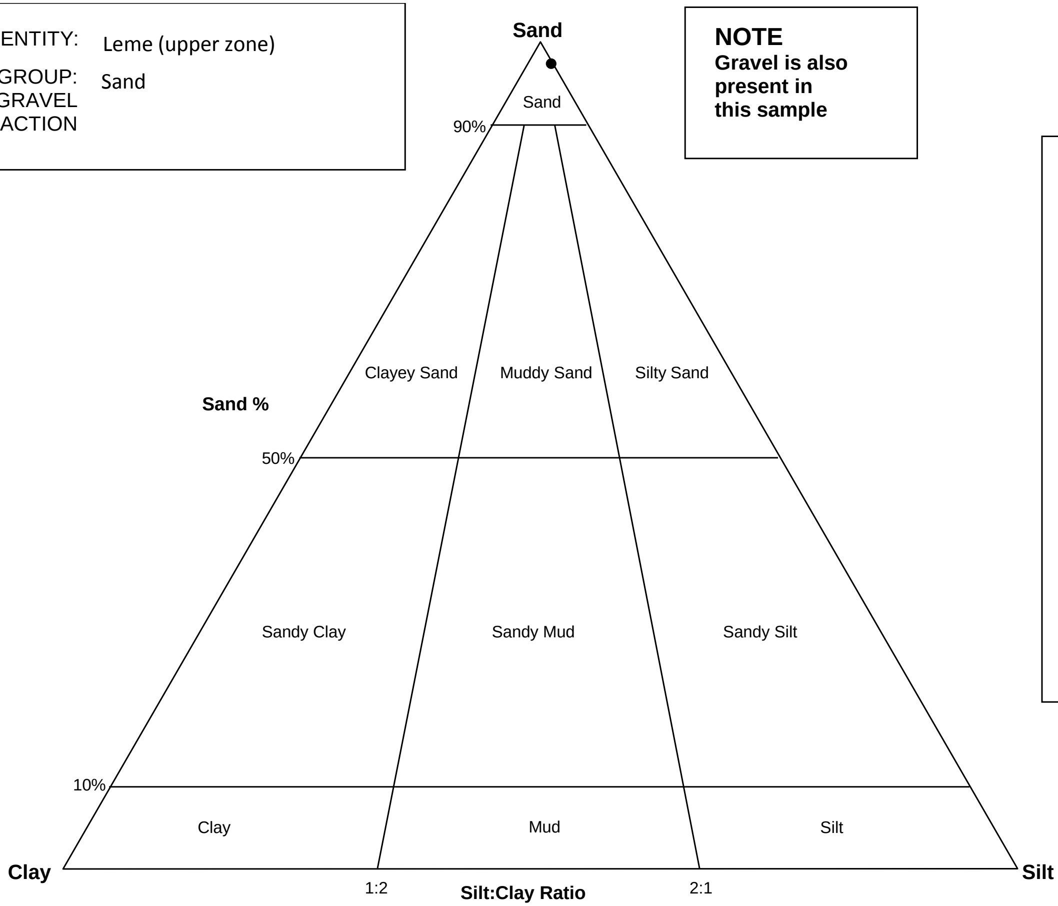
SAMPLE IDENTITY:	Leme (upper zone)
TEXTURAL GROUP:	Gravel
SEDIMENT NAME:	Medium Gravel



Gravel:	99.8%
Sand:	0.2%
Mud:	0.0%

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	60.8%
Fine Gravel:	37.2%
Very Fine Gravel:	1.8%
Very Coarse Sand:	0.2%
Coarse Sand:	0.0%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%

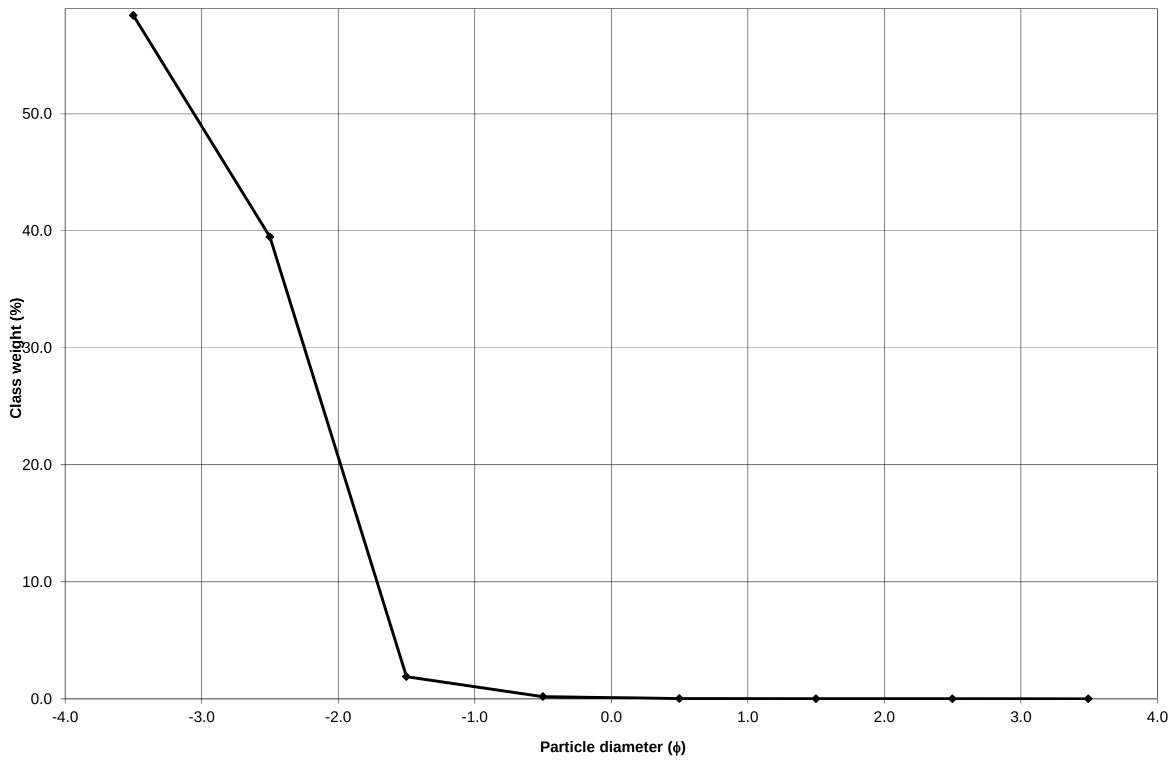
SAMPLE IDENTITY: Leme (upper zone)
TEXTURAL GROUP: IGNORING GRAVEL FRACTION: Sand



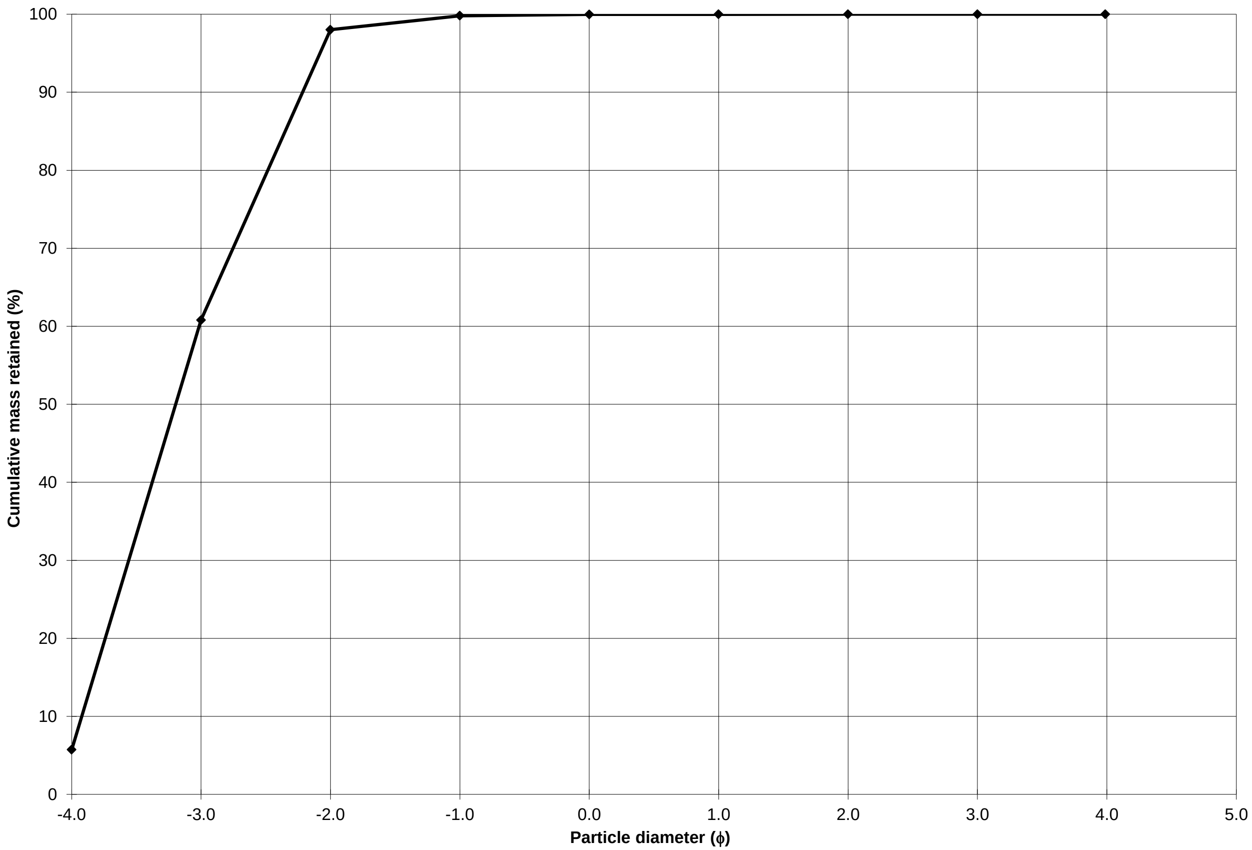
NOTE
Gravel is also present in this sample

Gravel:	99.8%
Sand:	0.2%
Mud:	0.0%

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	60.8%
Fine Gravel:	37.2%
Very Fine Gravel:	1.8%
Very Coarse Sand:	0.2%
Coarse Sand:	0.0%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



Cumulative (phi)

SAMPLE STATISTICS

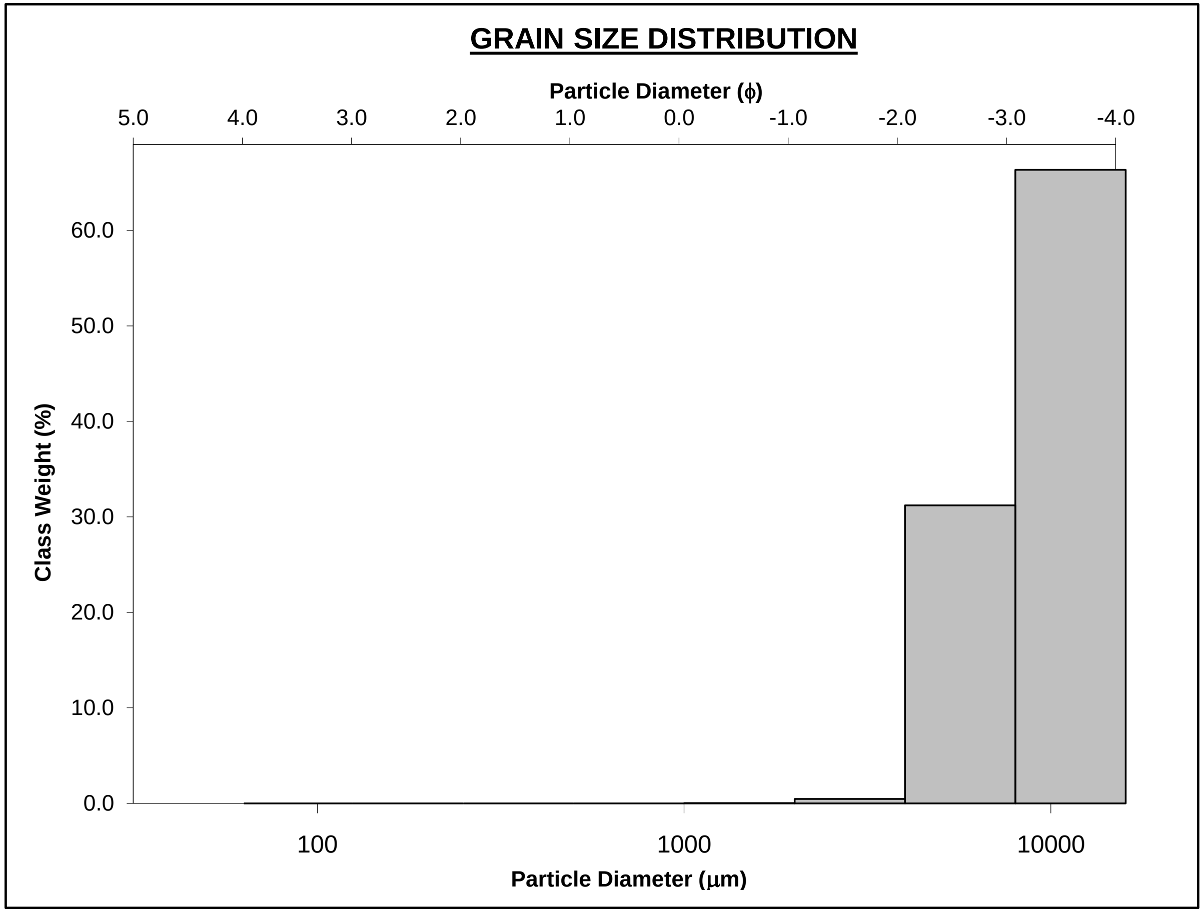
SAMPLE IDENTITY: Leme (mid zone) ANALYST & DATE: ,
SAMPLE TYPE: Unimodal, Moderately Well Sorted TEXTURAL GROUP: Gravel
SEDIMENT NAME: Medium Gravel

	μm	φ
MODE 1:	12000.0	-3.500
MODE 2:		
MODE 3:		
D_{10}:	4973.2	-3.922
MEDIAN or D_{50}:	9847.2	-3.300
D_{90}:	15160.4	-2.314
(D_{90} / D_{10}):	3.048	0.590
$(D_{90} - D_{10})$:	10187.2	1.608
(D_{75} / D_{25}):	1.839	0.762
$(D_{75} - D_{25})$:	5881.9	0.879

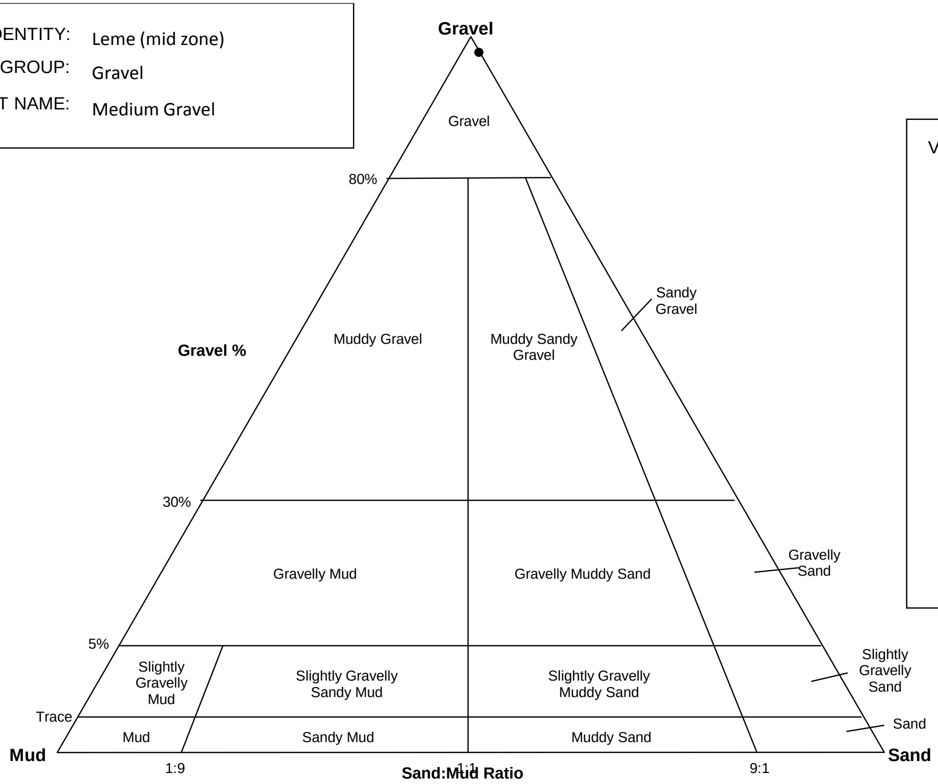
GRAIN SIZE DISTRIBUTION

GRAVEL:	99.9%	COARSE SAND:	0.0%
SAND:	0.0%	MEDIUM SAND:	0.0%
MUD:	0.0%	FINE SAND:	0.0%
		V FINE SAND:	0.0%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	69.3%	MEDIUM SILT:	0.0%
FINE GRAVEL:	30.2%	FINE SILT:	0.0%
V FINE GRAVEL:	0.4%	V FINE SILT:	0.0%
V COARSE SAND:	0.0%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	9538.9	5704.9	-3.011	9277.4	-3.214	Medium Gravel
SORTING (σ):	3530.4	7.486	0.843	1.525	0.609	Moderately Well Sorted
SKEWNESS (Sk):	-1.111	-3.947	2.416	-0.221	0.221	Fine Skewed
KURTOSIS (K):	3.197	17.07	9.930	0.862	0.862	Platykurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Class Weight (%)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
100
1000
10000
Particle Diameter (μm)

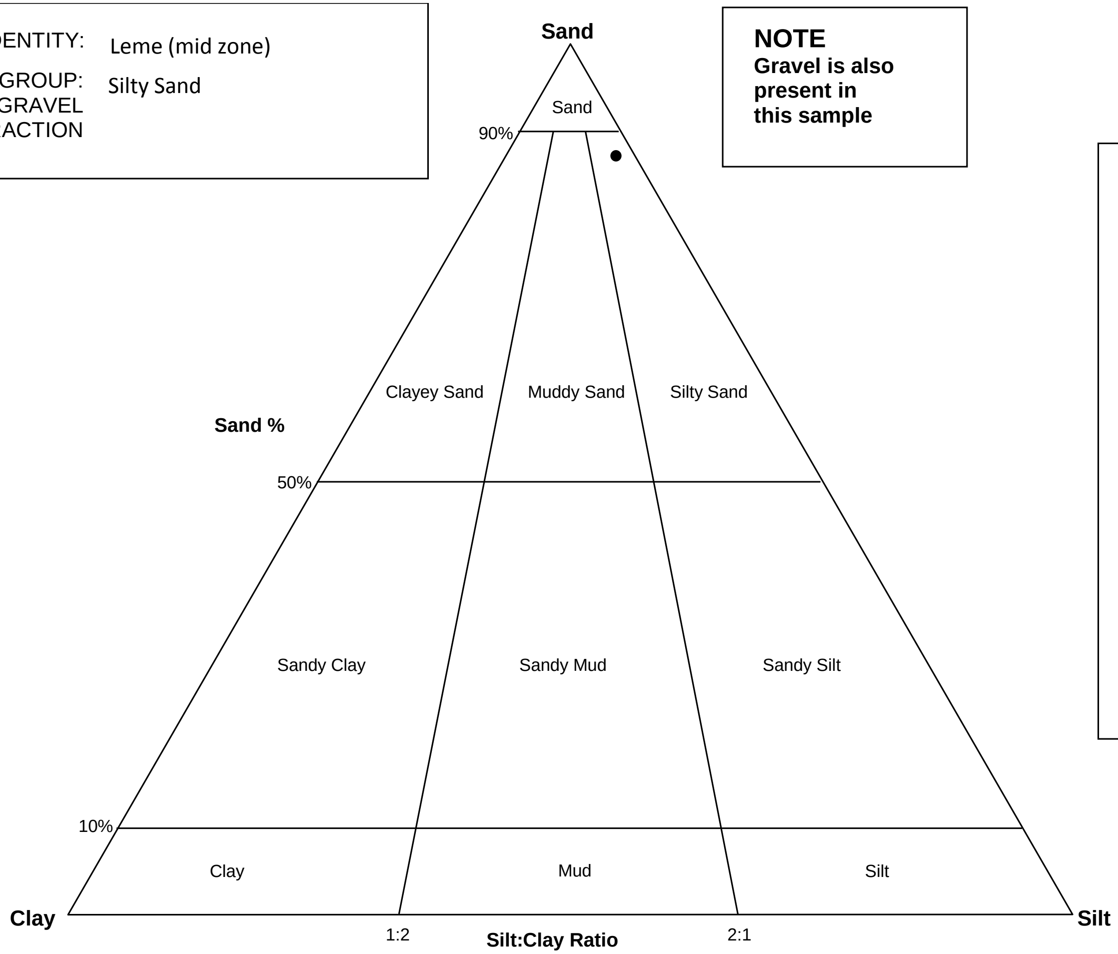
SAMPLE IDENTITY:	Leme (mid zone)
TEXTURAL GROUP:	Gravel
SEDIMENT NAME:	Medium Gravel



Gravel:	99.9%
Sand:	0.0%
Mud:	0.0%

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	69.3%
Fine Gravel:	30.2%
Very Fine Gravel:	0.4%
Very Coarse Sand:	0.0%
Coarse Sand:	0.0%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%

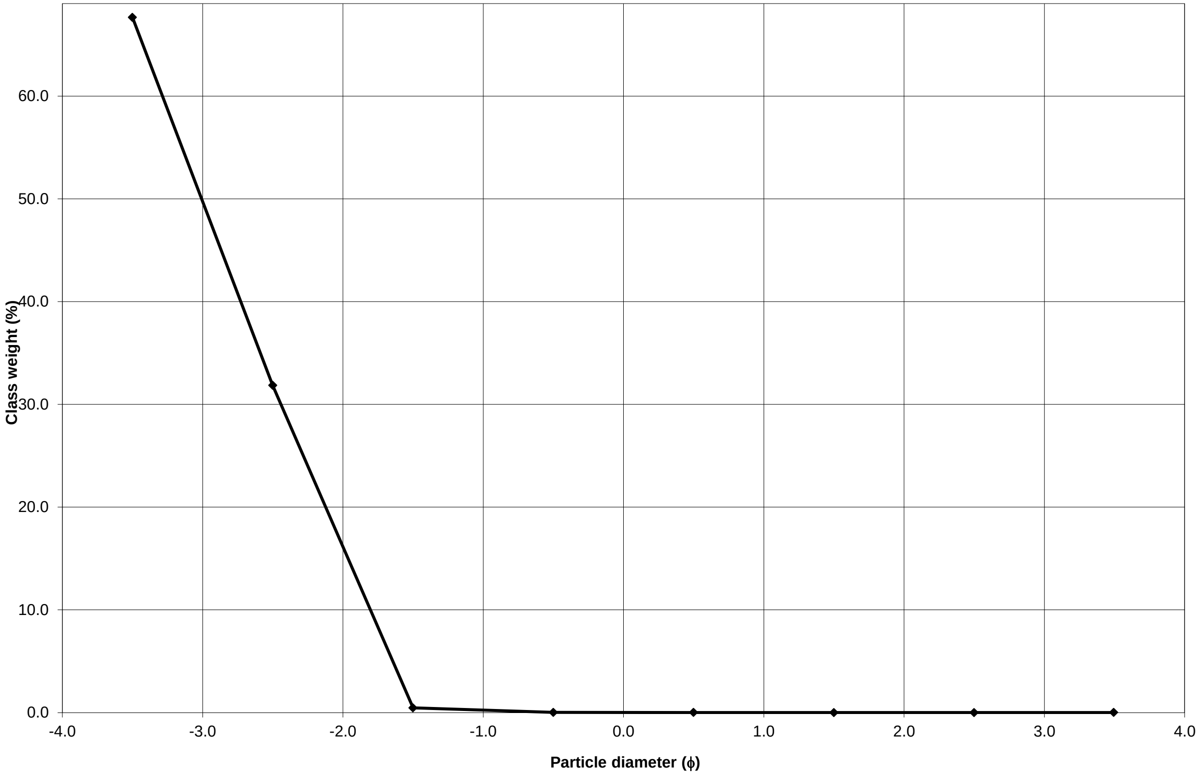
SAMPLE IDENTITY:	Leme (mid zone)
TEXTURAL GROUP: IGNORING GRAVEL FRACTION	Silty Sand



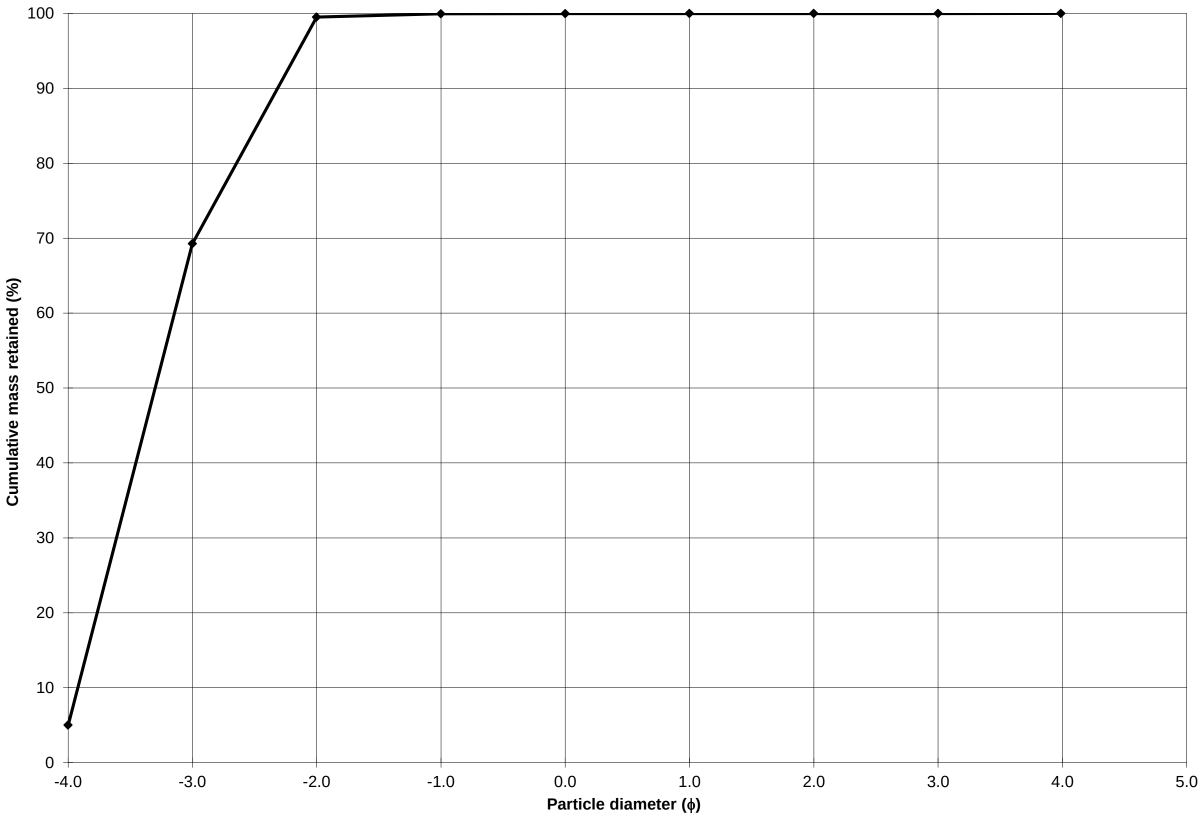
NOTE
Gravel is also present in this sample

Gravel:	99.9 %
Sand:	0.0%
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	69.3 %
Fine Gravel:	30.2 %
Very Fine Gravel:	0.4%
Very Coarse Sand:	0.0%
Coarse Sand:	0.0%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



Cumulative (phi)

SAMPLE STATISTICS

SAMPLE IDENTITY: **Leme (lower zone)** ANALYST & DATE: ,

SAMPLE TYPE: Unimodal, Moderately Sorted TEXTURAL GROUP: Gravel

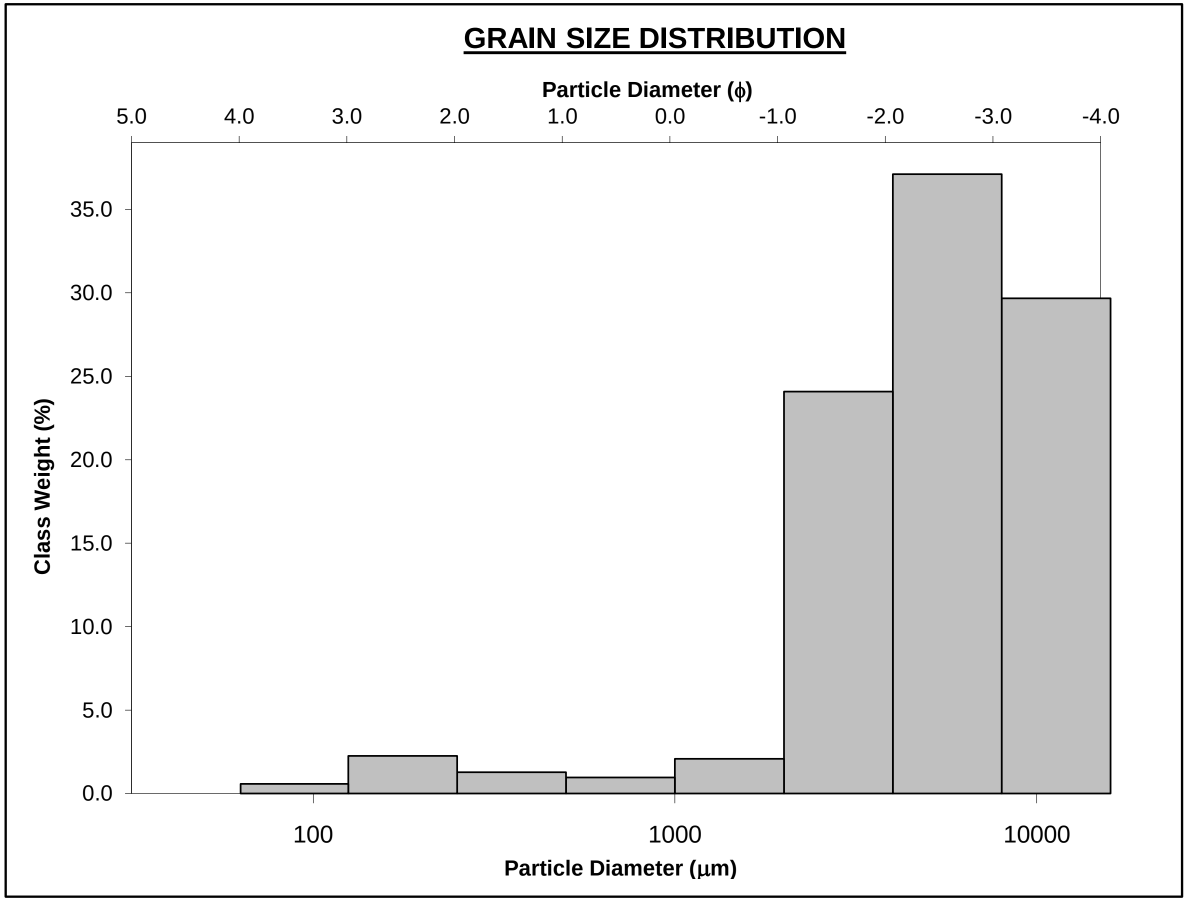
SEDIMENT NAME: Medium Gravel

	μm	φ
MODE 1:	6000.0	-2.500
MODE 2:		
MODE 3:		
D_{10}:	2205.8	-4.051
MEDIAN or D_{50}:	6220.4	-2.637
D_{90}:	16574.6	-1.141
(D_{90} / D_{10}):	7.514	0.282
$(D_{90} - D_{10})$:	14368.8	2.910
(D_{75} / D_{25}):	3.134	0.526
$(D_{75} - D_{25})$:	7596.3	1.648

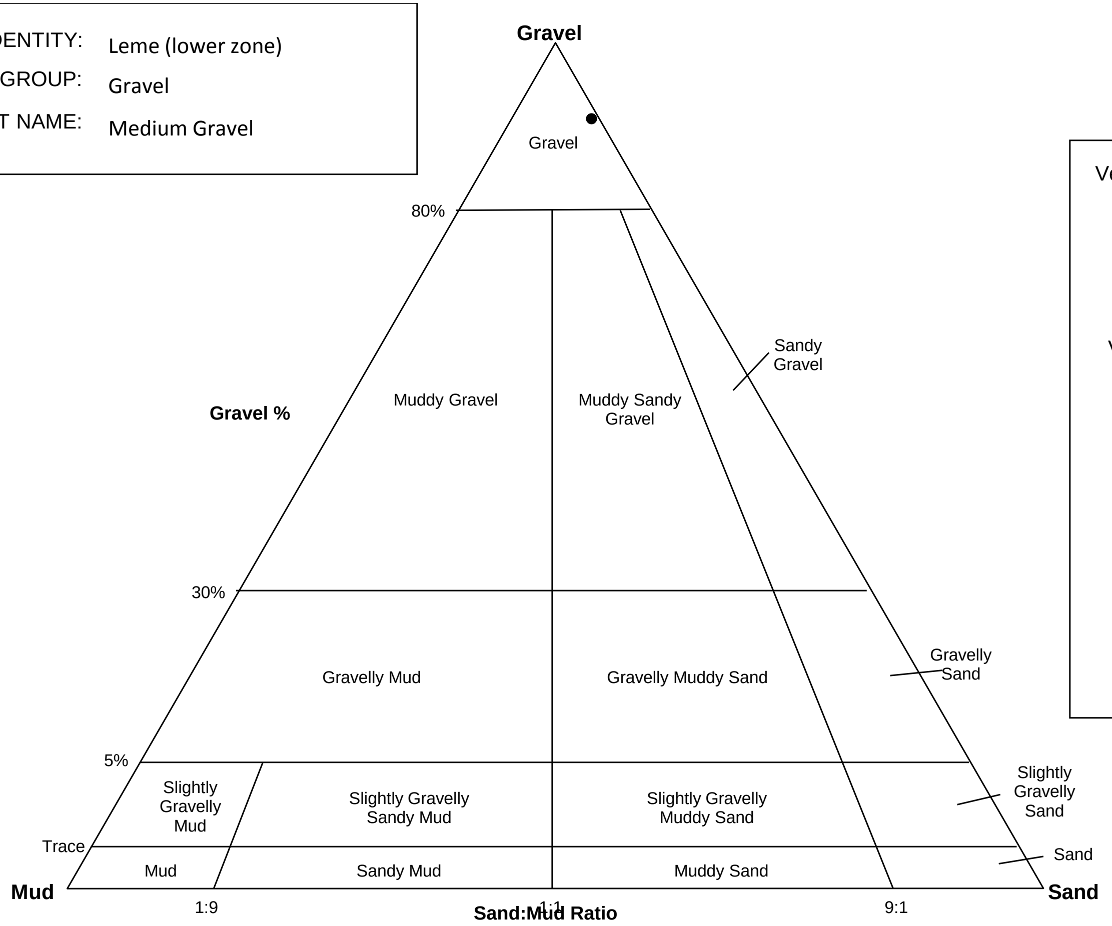
GRAIN SIZE DISTRIBUTION

GRAVEL:	93.1%	COARSE SAND:	0.9%
SAND:	6.5%	MEDIUM SAND:	1.2%
MUD:	0.5%	FINE SAND:	2.0%
		V FINE SAND:	0.5%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.1%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.1%
MEDIUM GRAVEL:	37.8%	MEDIUM SILT:	0.1%
FINE GRAVEL:	33.5%	FINE SILT:	0.1%
V FINE GRAVEL:	21.7%	V FINE SILT:	0.1%
V COARSE SAND:	1.9%	CLAY:	0.1%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	5918.2	1845.0	-1.987	6161.9	-2.623	Fine Gravel
SORTING (σ):	4194.6	16.74	1.538	1.843	0.882	Moderately Sorted
SKEWNESS (Sk):	0.288	-2.066	1.828	-0.954	0.954	Very Fine Skewed
KURTOSIS (K):	1.860	5.754	8.633	0.463	0.463	Very Platykurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Class Weight (%)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
100
1000
10000
Particle Diameter (µm)

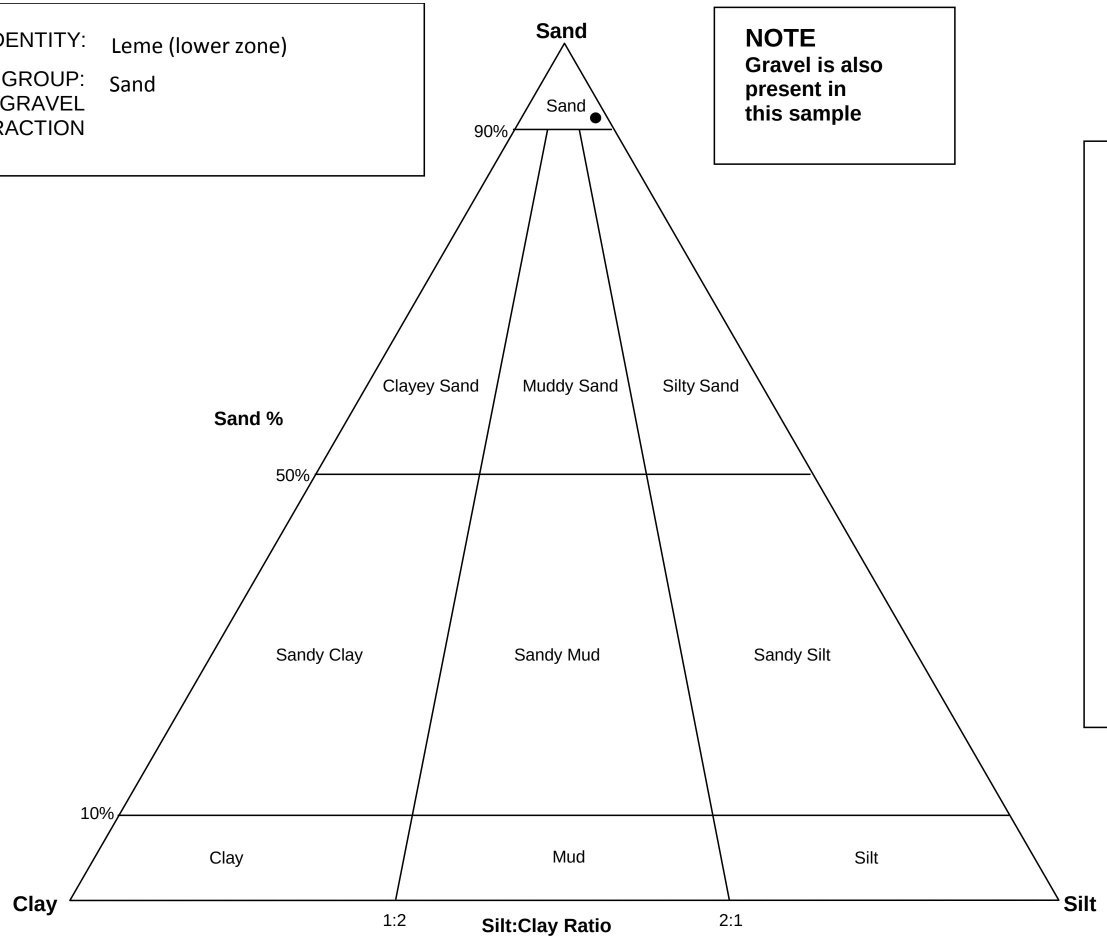
SAMPLE IDENTITY:	Leme (lower zone)
TEXTURAL GROUP:	Gravel
SEDIMENT NAME:	Medium Gravel



Gravel:	93.1 %
Sand:	6.5%
Mud:	0.5 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	37.8 %
Fine Gravel:	33.5 %
Very Fine Gravel:	21.7 %
Very Coarse Sand:	1.9%
Coarse Sand:	0.9%
Medium Sand:	1.2%
Fine Sand:	2.0%
Very Fine Sand:	0.5%
Very Coarse Silt:	0.1%
Coarse Silt:	0.1%
Medium Silt:	0.1%
Fine Silt:	0.1%
Very Fine Silt:	0.1%
Clay:	0.1%

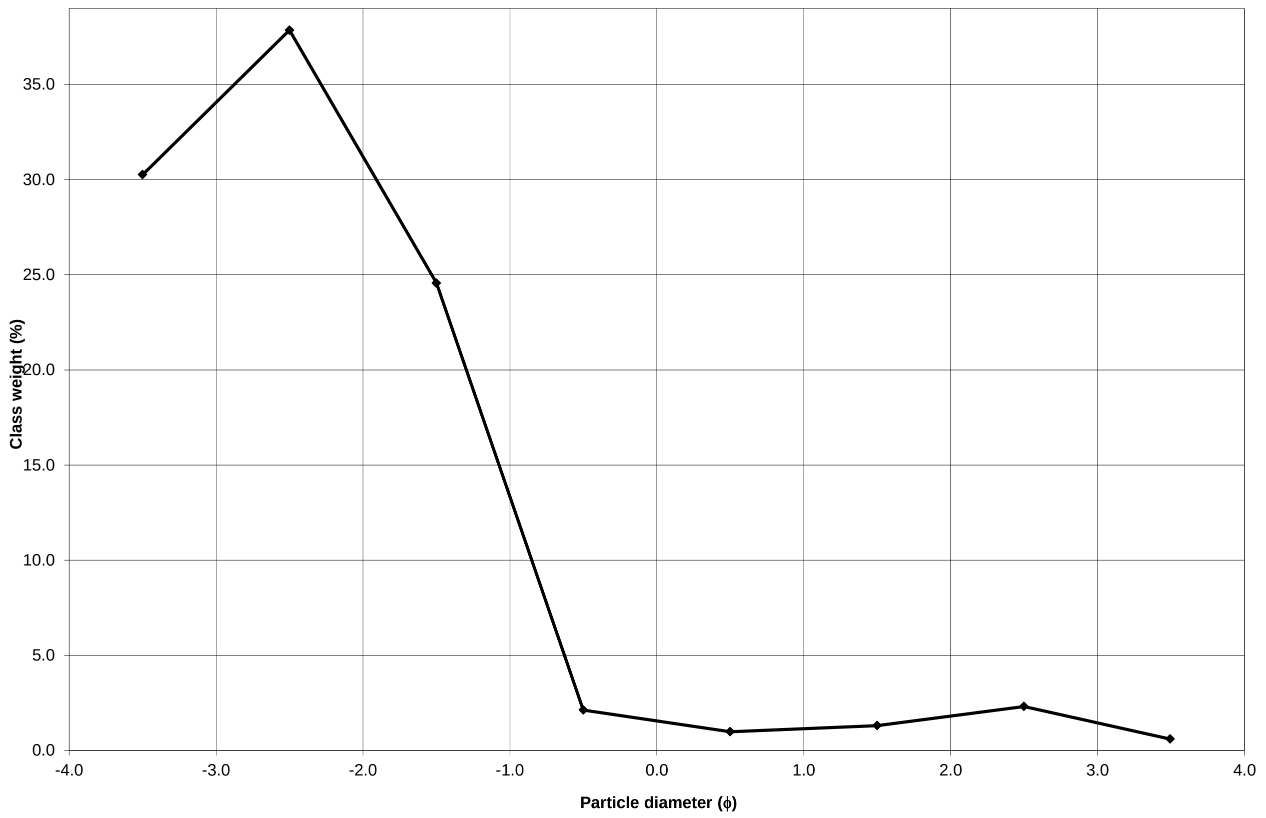
SAMPLE IDENTITY:	Leme (lower zone)
TEXTURAL GROUP: IGNORING GRAVEL FRACTION	Sand



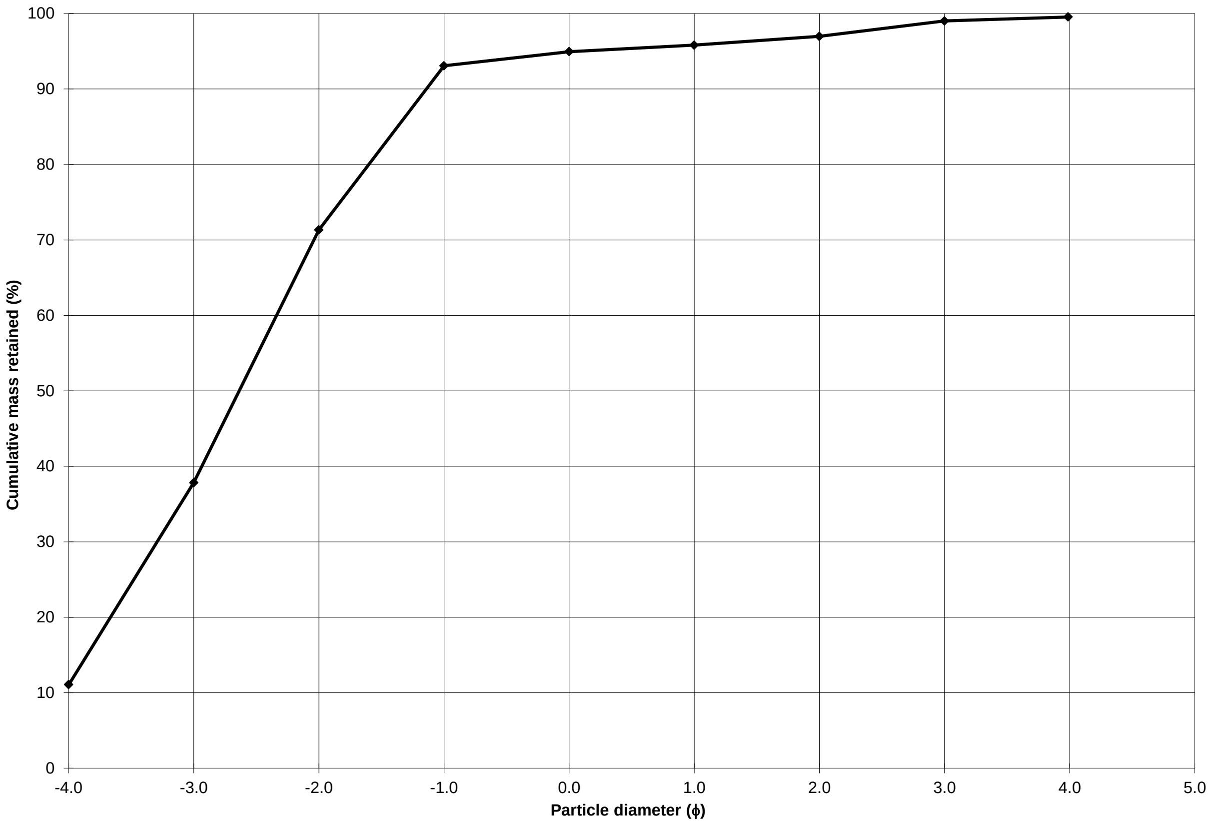
NOTE
Gravel is also present in this sample

Gravel:	93.1 %
Sand:	6.5%
Mud:	0.5 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	37.8 %
Fine Gravel:	33.5 %
Very Fine Gravel:	21.7 %
Very Coarse Sand:	1.9%
Coarse Sand:	0.9%
Medium Sand:	1.2%
Fine Sand:	2.0%
Very Fine Sand:	0.5%
Very Coarse Silt:	0.1%
Coarse Silt:	0.1%
Medium Silt:	0.1%
Fine Silt:	0.1%
Very Fine Silt:	0.1%
Clay:	0.1%



Distribution (phi)



Cumulative (phi)

SAMPLE STATISTICS

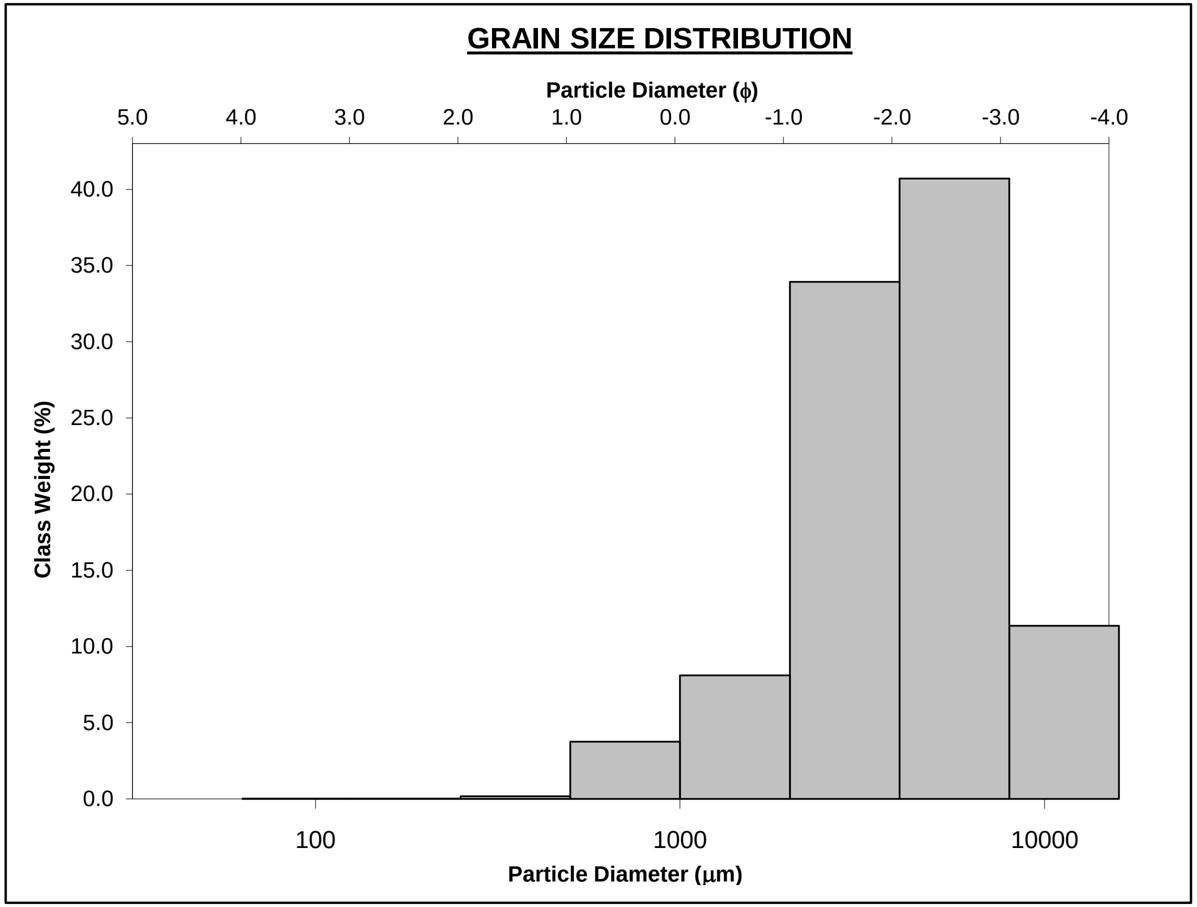
SAMPLE IDENTITY: Cabedelo (upper zone) ANALYST & DATE: ,
SAMPLE TYPE: Unimodal, Moderately Sorted TEXTURAL GROUP: Gravel
SEDIMENT NAME: Fine Gravel

	μm	ϕ
MODE 1:	6000.0	-2.500
MODE 2:		
MODE 3:		
D_{10}:	1654.6	-3.193
MEDIAN or D_{50}:	4237.1	-2.083
D_{90}:	9147.9	-0.726
(D_{90} / D_{10}):	5.529	0.227
(D_{90} - D_{10}):	7493.4	2.467
(D_{75} / D_{25}):	2.494	0.510
(D_{75} - D_{25}):	3865.4	1.318

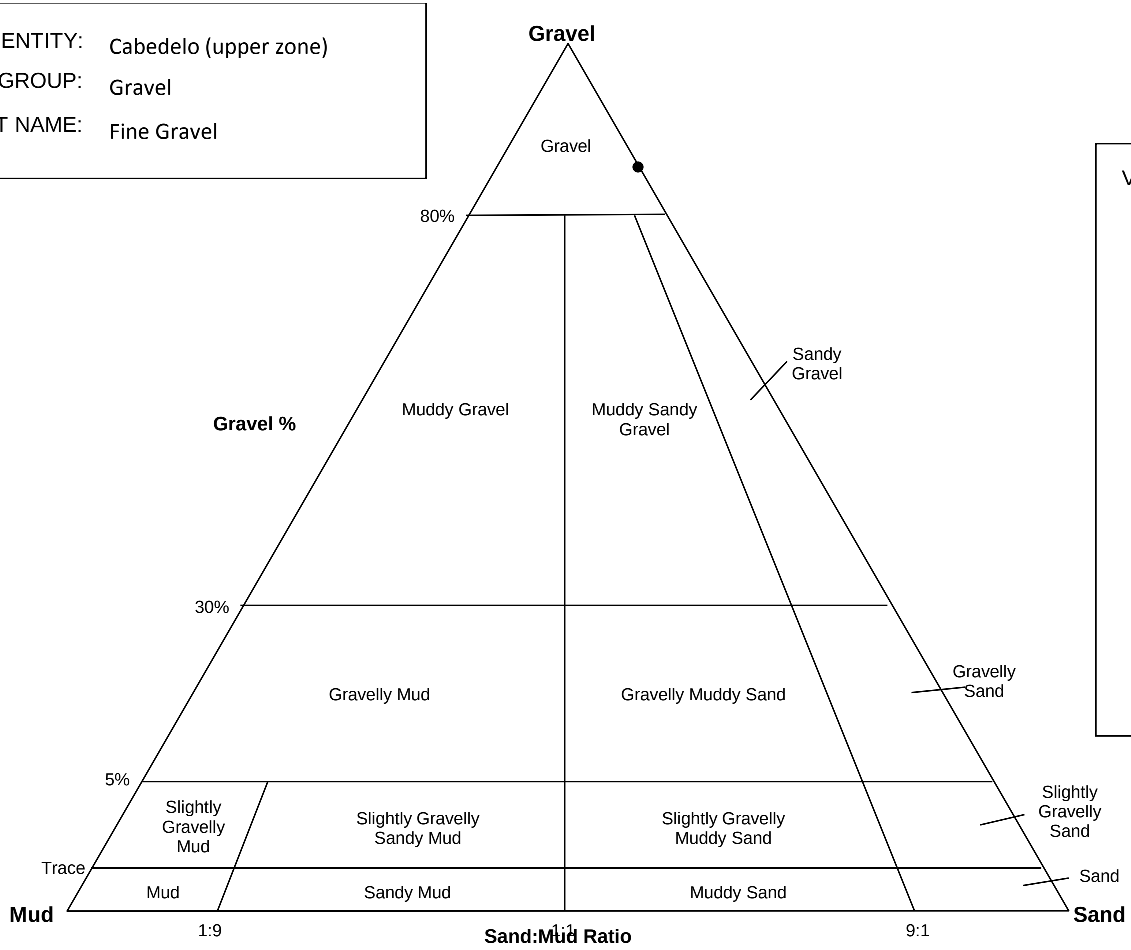
GRAIN SIZE DISTRIBUTION

GRAVEL:	87.8%	COARSE SAND:	3.8%
SAND:	12.2%	MEDIUM SAND:	0.2%
MUD:	0.0%	FINE SAND:	0.0%
		V FINE SAND:	0.0%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	12.2%	MEDIUM SILT:	0.0%
FINE GRAVEL:	41.2%	FINE SILT:	0.0%
V FINE GRAVEL:	34.3%	V FINE SILT:	0.0%
V COARSE SAND:	8.2%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	5034.9	3713.4	-1.964	4094.3	-2.034	Fine Gravel
SORTING (σ):	3057.1	2.623	0.972	1.975	0.982	Moderately Sorted
SKEWNESS (Sk):	1.000	-4.620	0.758	-0.101	0.101	Fine Skewed
KURTOSIS (K):	3.532	39.05	4.825	1.091	1.091	Mesokurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Class Weight (%)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
100
1000
10000
Particle Diameter (μm)

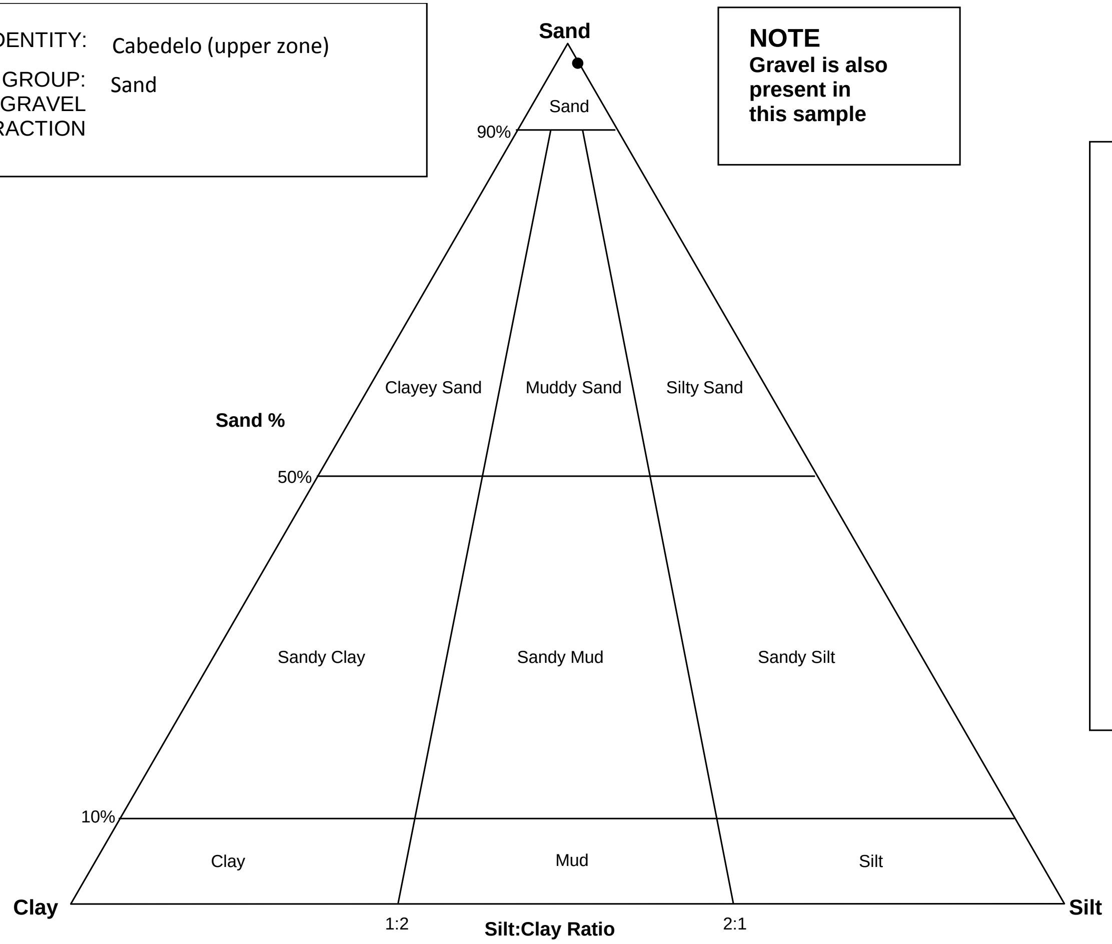
SAMPLE IDENTITY:	Cabedelo (upper zone)
TEXTURAL GROUP:	Gravel
SEDIMENT NAME:	Fine Gravel



Gravel:	87.8 %
Sand:	12.2 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	12.2 %
Fine Gravel:	41.2 %
Very Fine Gravel:	34.3 %
Very Coarse Sand:	8.2%
Coarse Sand:	3.8%
Medium Sand:	0.2%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%

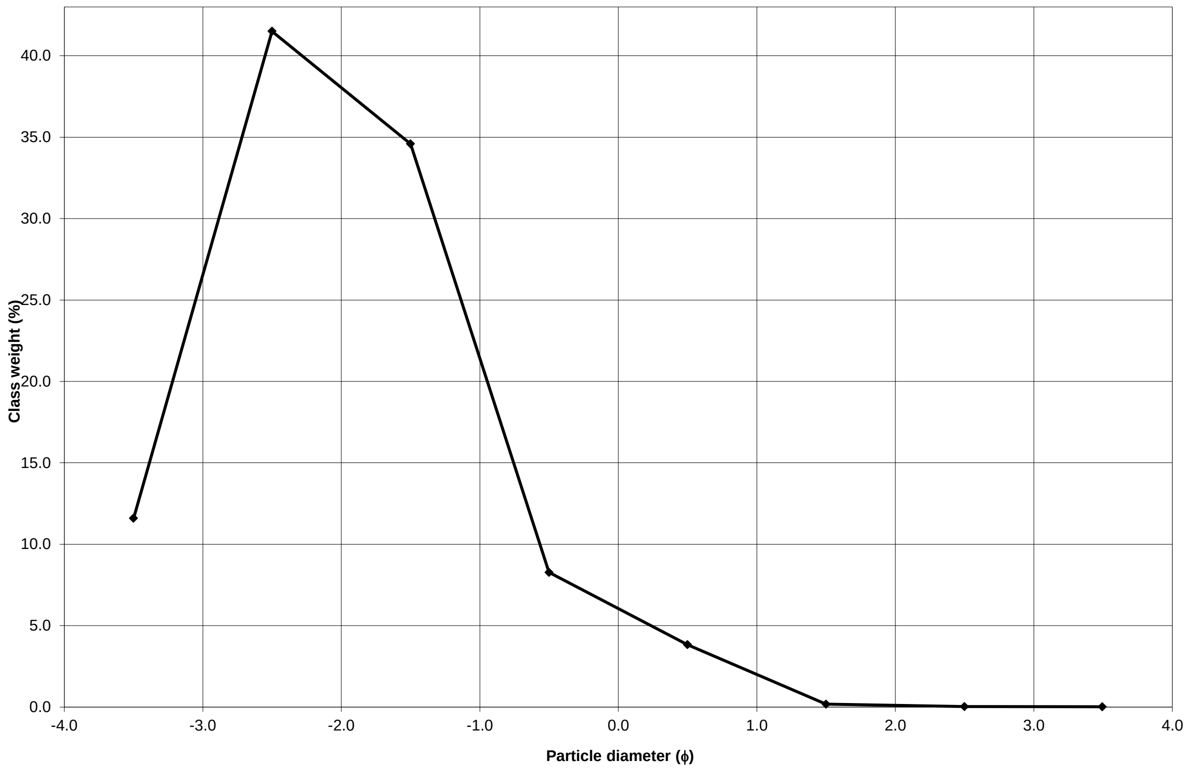
SAMPLE IDENTITY: Cabedelo (upper zone)
TEXTURAL GROUP: Sand
IGNORING GRAVEL FRACTION



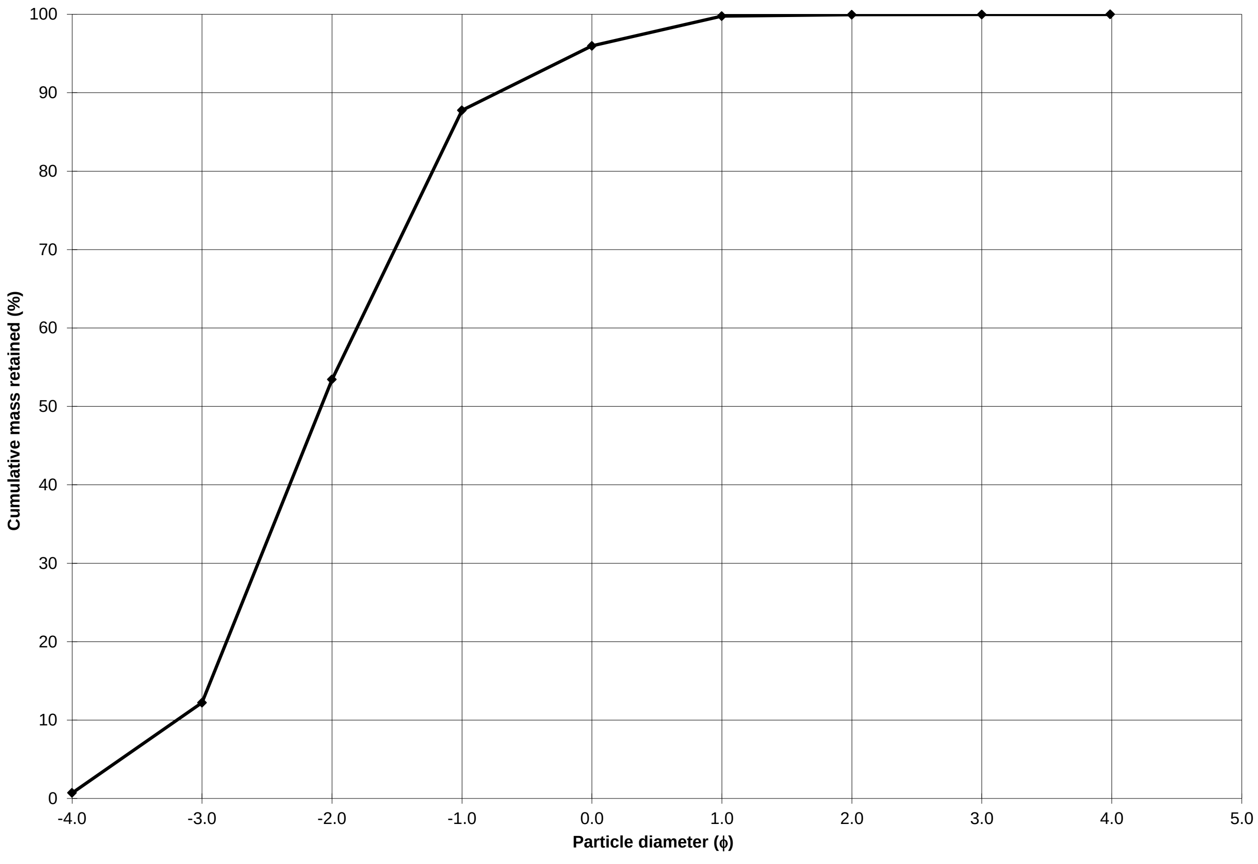
NOTE
Gravel is also present in this sample

Gravel:	87.8 %
Sand:	12.2 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	12.2 %
Fine Gravel:	41.2 %
Very Fine Gravel:	34.3 %
Very Coarse Sand:	8.2%
Coarse Sand:	3.8%
Medium Sand:	0.2%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



Cumulative (phi)

SAMPLE STATISTICS

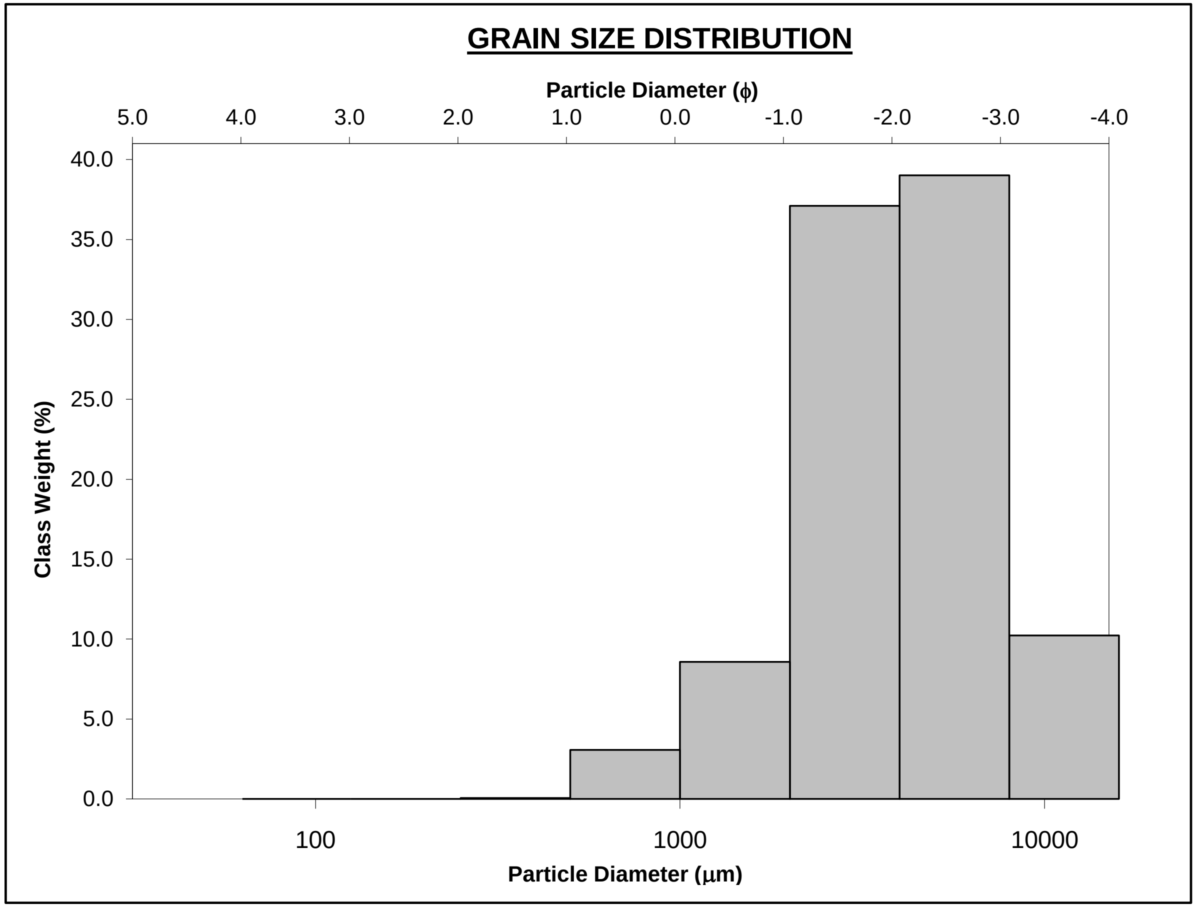
SAMPLE IDENTITY: Cabedelo (mid zone) ANALYST & DATE: ,
SAMPLE TYPE: Unimodal, Moderately Sorted TEXTURAL GROUP: Gravel
SEDIMENT NAME: Fine Gravel

	μm	φ
MODE 1:	6000.0	-2.500
MODE 2:		
MODE 3:		
D_{10}:	1726.2	-3.128
MEDIAN or D_{50}:	4050.2	-2.018
D_{90}:	8742.2	-0.788
(D_{90} / D_{10}):	5.064	0.252
(D_{90} - D_{10}):	7016.0	2.340
(D_{75} / D_{25}):	2.465	0.509
(D_{75} - D_{25}):	3737.0	1.301

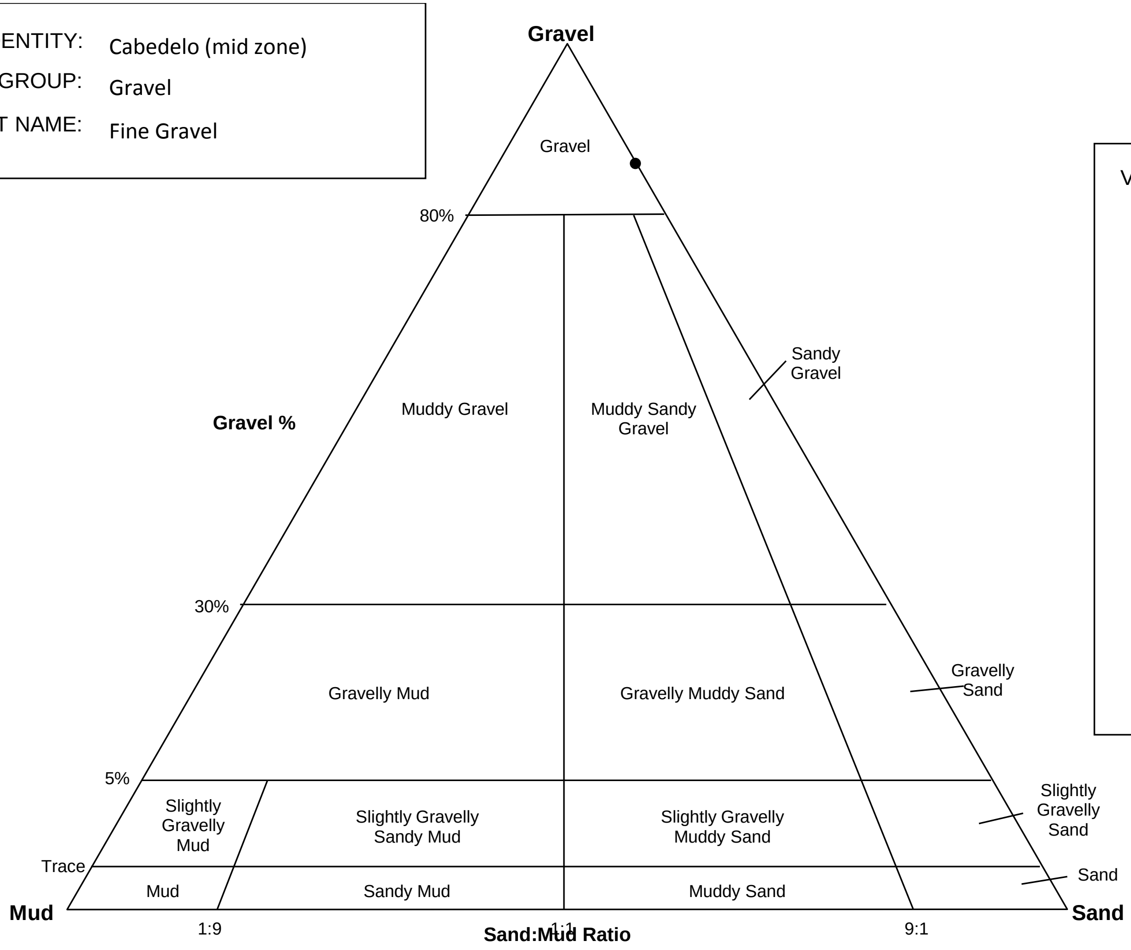
GRAIN SIZE DISTRIBUTION

GRAVEL:	88.2%	COARSE SAND:	3.1%
SAND:	11.8%	MEDIUM SAND:	0.1%
MUD:	0.0%	FINE SAND:	0.0%
		V FINE SAND:	0.0%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	11.3%	MEDIUM SILT:	0.0%
FINE GRAVEL:	39.4%	FINE SILT:	0.0%
V FINE GRAVEL:	37.5%	V FINE SILT:	0.0%
V COARSE SAND:	8.7%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	4880.0	3568.3	-1.934	4009.5	-2.003	Fine Gravel
SORTING (σ):	2970.9	2.810	0.931	1.942	0.958	Moderately Sorted
SKEWNESS (Sk):	1.091	-4.952	0.558	-0.044	0.044	Symmetrical
KURTOSIS (K):	3.814	39.46	4.123	1.071	1.071	Mesokurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Class Weight (%)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
100
1000
10000
Particle Diameter (μm)

SAMPLE IDENTITY: Cabedelo (mid zone)
TEXTURAL GROUP: Gravel
SEDIMENT NAME: Fine Gravel

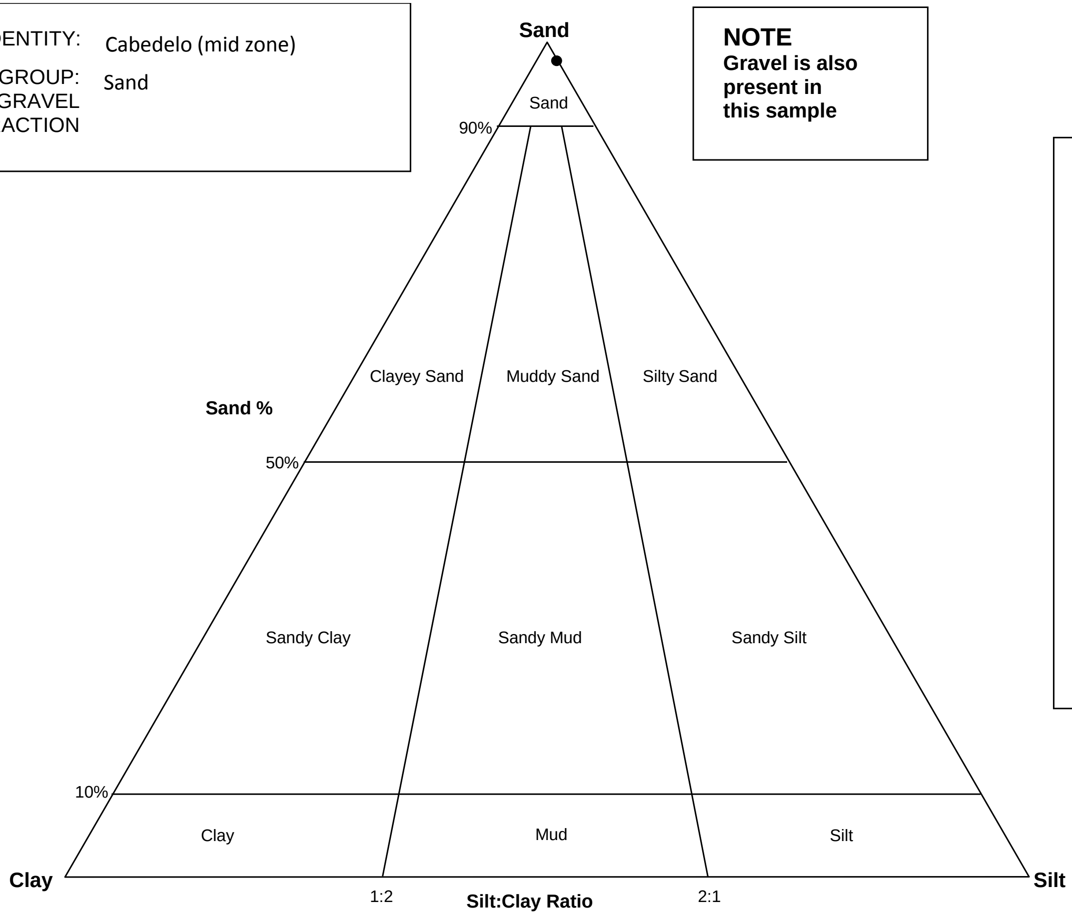


Gravel:	88.2 %
Sand:	11.8 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	11.3 %
Fine Gravel:	39.4 %
Very Fine Gravel:	37.5 %
Very Coarse Sand:	8.7%
Coarse Sand:	3.1%
Medium Sand:	0.1%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%

SAMPLE IDENTITY: Cabedelo (mid zone)

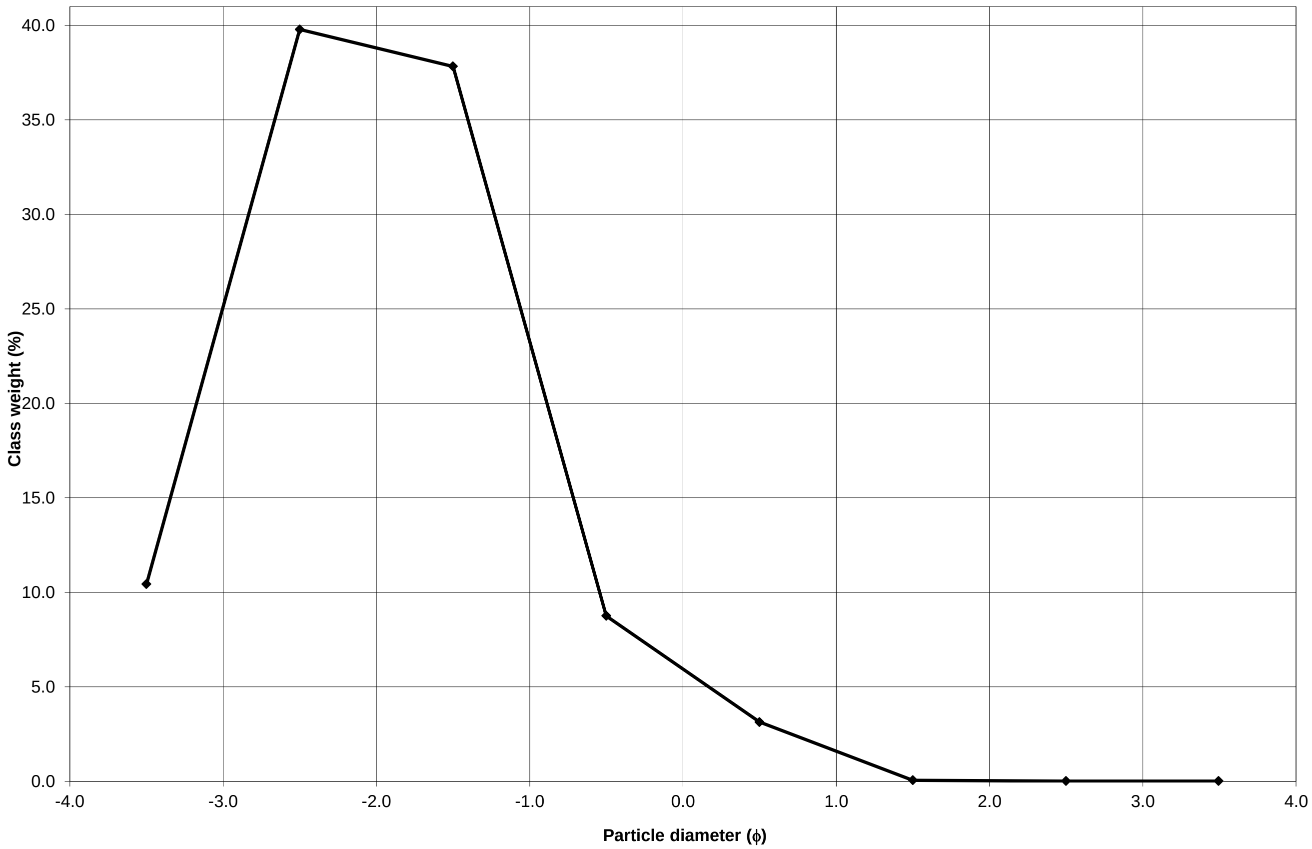
TEXTURAL GROUP: IGNORING GRAVEL FRACTION: Sand



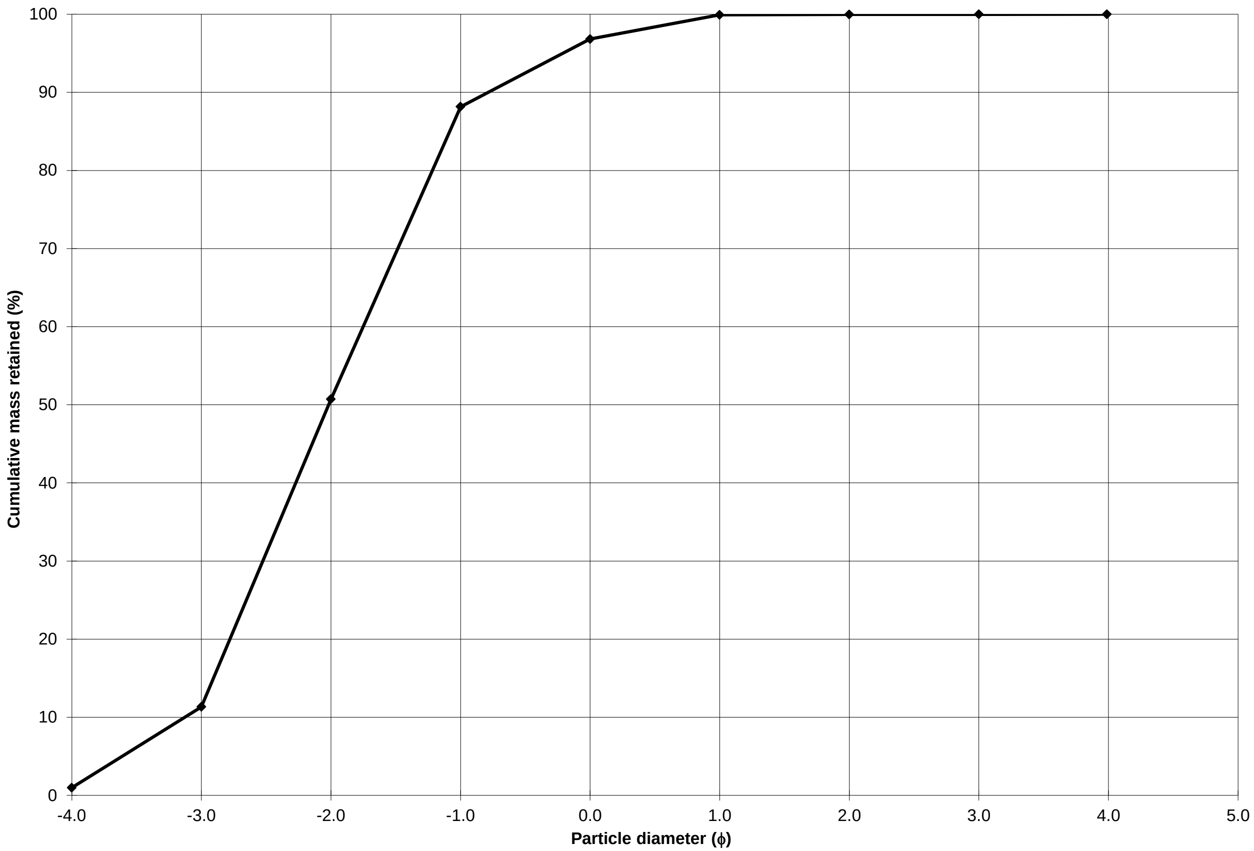
NOTE
Gravel is also present in this sample

Gravel:	88.2 %
Sand:	11.8 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	11.3 %
Fine Gravel:	39.4 %
Very Fine Gravel:	37.5 %
Very Coarse Sand:	8.7%
Coarse Sand:	3.1%
Medium Sand:	0.1%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



Cumulative (phi)

SAMPLE STATISTICS

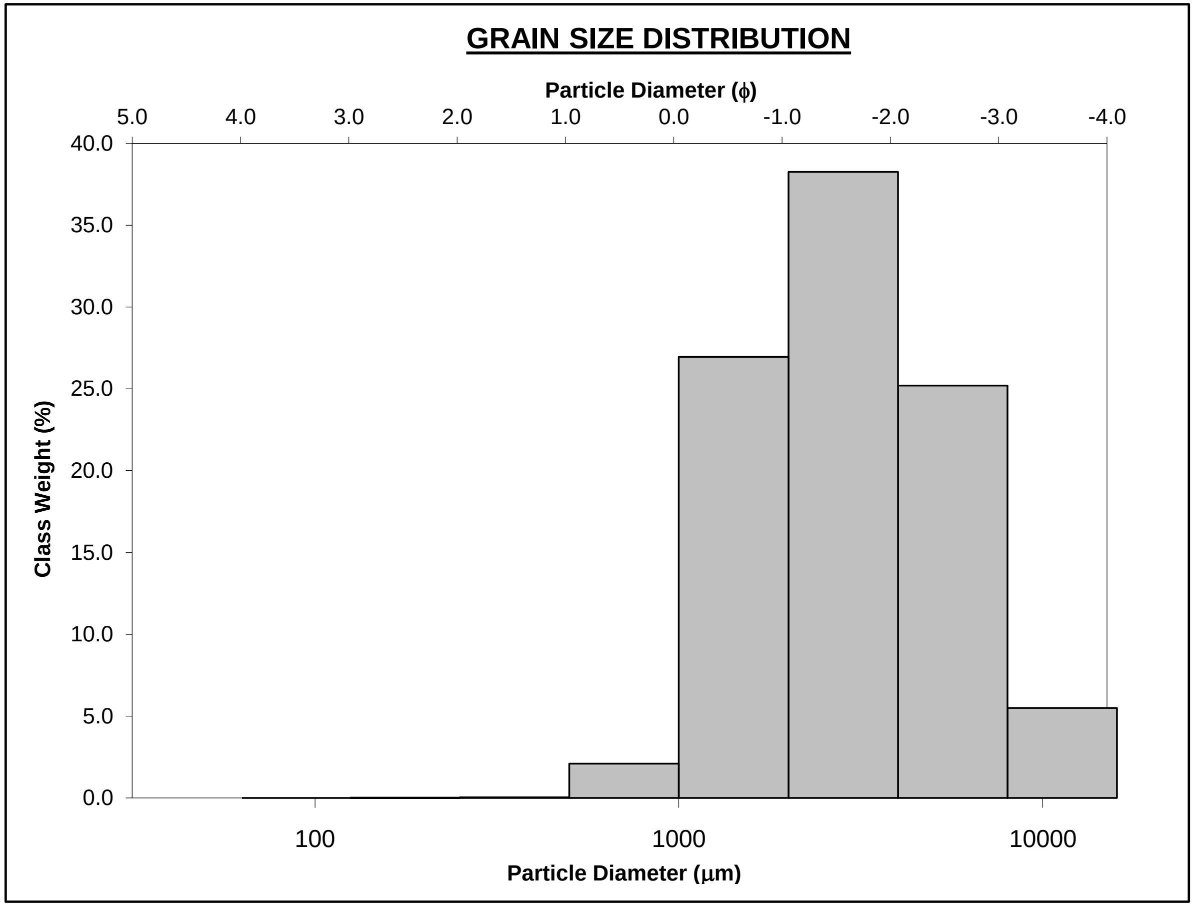
SAMPLE IDENTITY: Cabedelo (lower zone) ANALYST & DATE: ,
SAMPLE TYPE: Unimodal, Moderately Sorted TEXTURAL GROUP: Sandy Gravel
SEDIMENT NAME: Sandy Very Fine Gravel

	μm	φ
MODE 1:	3000.0	-1.500
MODE 2:		
MODE 3:		
D_{10}:	1217.2	-2.829
MEDIAN or D_{50}:	2869.3	-1.521
D_{90}:	7106.8	-0.284
(D_{90} / D_{10}):	5.839	0.100
$(D_{90} - D_{10})$:	5889.6	2.546
(D_{75} / D_{25}):	2.669	0.369
$(D_{75} - D_{25})$:	2965.0	1.416

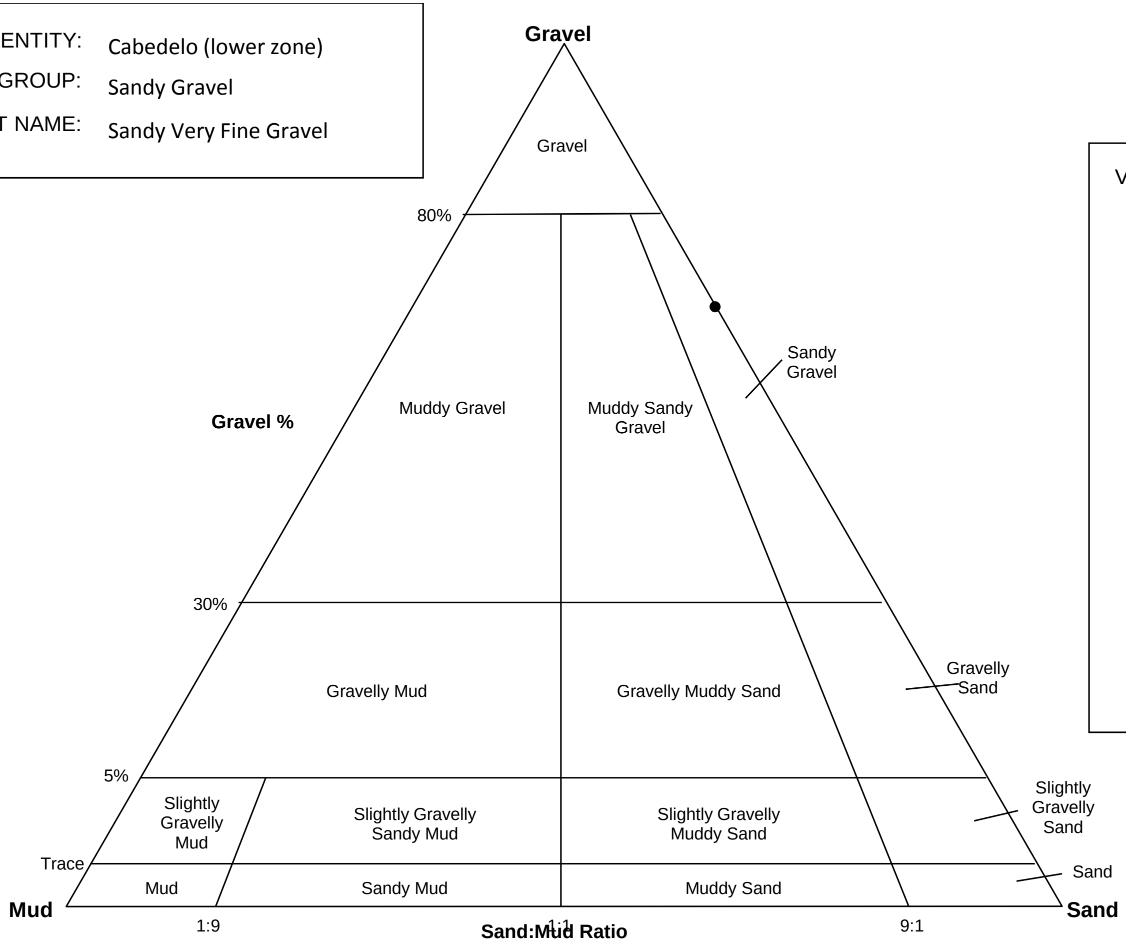
GRAIN SIZE DISTRIBUTION

GRAVEL:	70.3%	COARSE SAND:	2.1%
SAND:	29.7%	MEDIUM SAND:	0.0%
MUD:	0.0%	FINE SAND:	0.0%
		V FINE SAND:	0.0%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	5.6%	MEDIUM SILT:	0.0%
FINE GRAVEL:	25.7%	FINE SILT:	0.0%
V FINE GRAVEL:	39.0%	V FINE SILT:	0.0%
V COARSE SAND:	27.5%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	3813.6	2925.1	-1.548	2906.8	-1.539	Very Fine Gravel
SORTING (σ):	2632.0	1.899	0.925	1.971	0.979	Moderately Sorted
SKEWNESS (Sk):	1.602	0.034	-0.034	0.042	-0.042	Symmetrical
KURTOSIS (K):	5.583	3.467	3.467	0.870	0.870	Platykurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Class Weight (%)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
100
1000
10000
Particle Diameter (μm)

SAMPLE IDENTITY:	Cabedelo (lower zone)
TEXTURAL GROUP:	Sandy Gravel
SEDIMENT NAME:	Sandy Very Fine Gravel

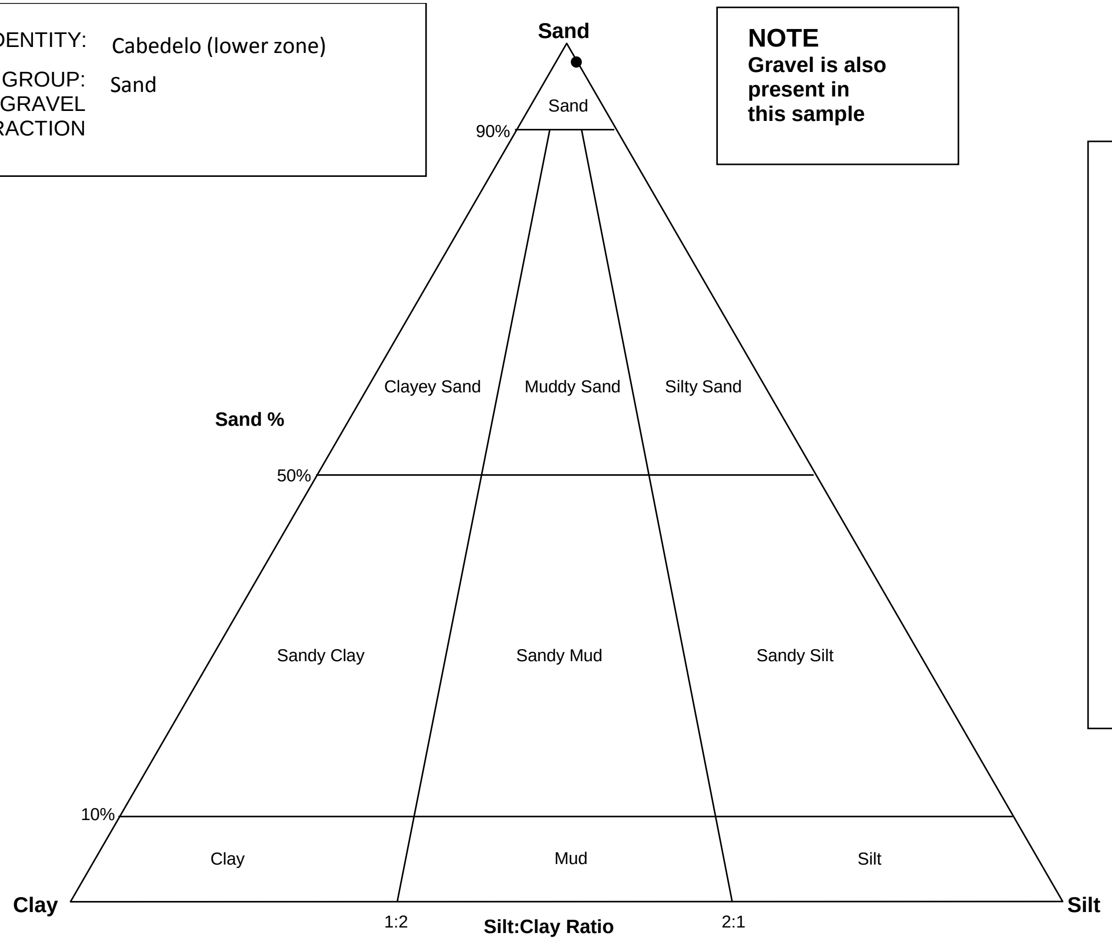


Gravel:	70.3 %
Sand:	29.7 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	5.6%
Fine Gravel:	25.7 %
Very Fine Gravel:	39.0 %
Very Coarse Sand:	27.5 %
Coarse Sand:	2.1%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%

SAMPLE IDENTITY: Cabedelo (lower zone)

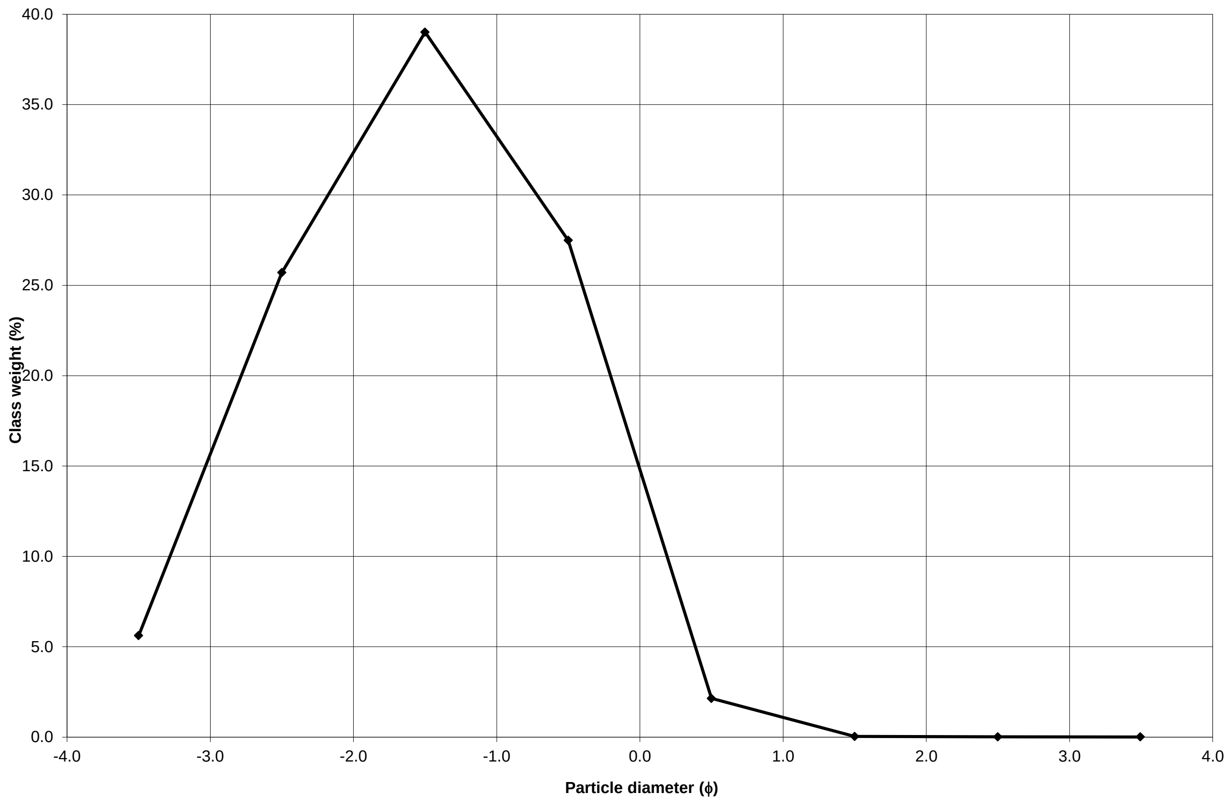
TEXTURAL GROUP: IGNORING GRAVEL FRACTION: Sand



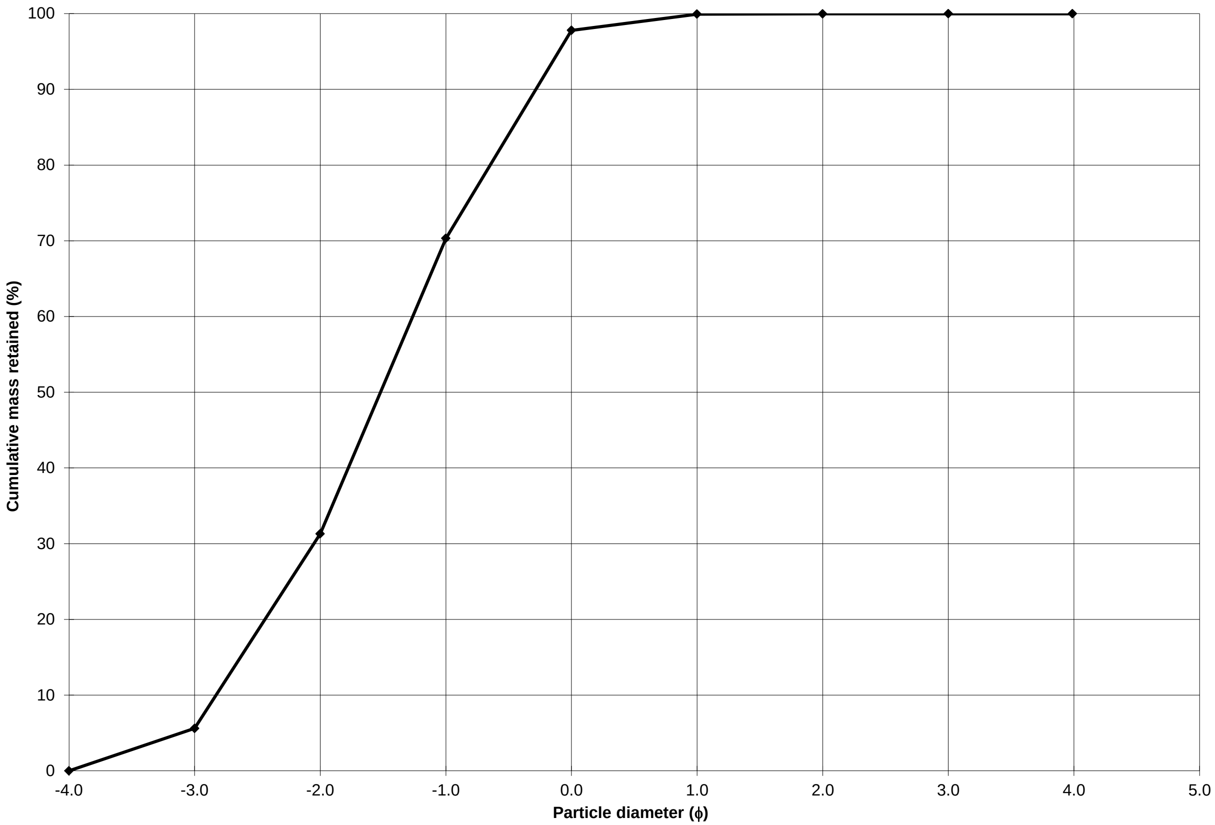
NOTE
Gravel is also present in this sample

Gravel:	70.3 %
Sand:	29.7 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	5.6%
Fine Gravel:	25.7 %
Very Fine Gravel:	39.0 %
Very Coarse Sand:	27.5 %
Coarse Sand:	2.1%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



Cumulative (phi)

SAMPLE STATISTICS

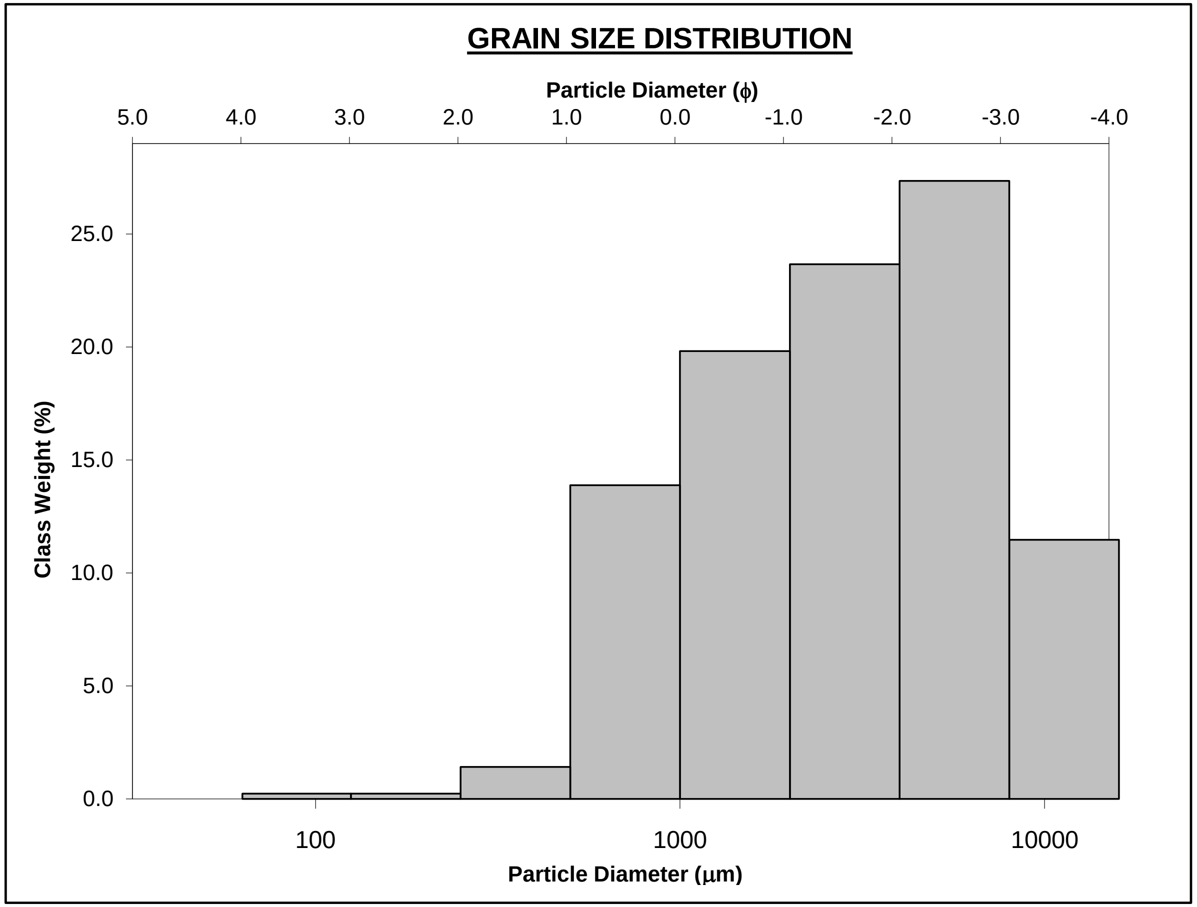
SAMPLE IDENTITY: Lavadores (upper zone)
ANALYST & DATE: ,
SAMPLE TYPE: Unimodal, Poorly Sorted
TEXTURAL GROUP: Sandy Gravel
SEDIMENT NAME: Sandy Fine Gravel

	μm	φ
MODE 1:	6000.0	-2.500
MODE 2:		
MODE 3:		
D_{10}:	763.8	-3.631
MEDIAN or D_{50}:	3244.1	-1.698
D_{90}:	12386.6	0.389
(D_{90} / D_{10}):	16.22	-0.107
$(D_{90} - D_{10})$:	11622.8	4.019
(D_{75} / D_{25}):	4.516	0.192
$(D_{75} - D_{25})$:	5032.4	2.175

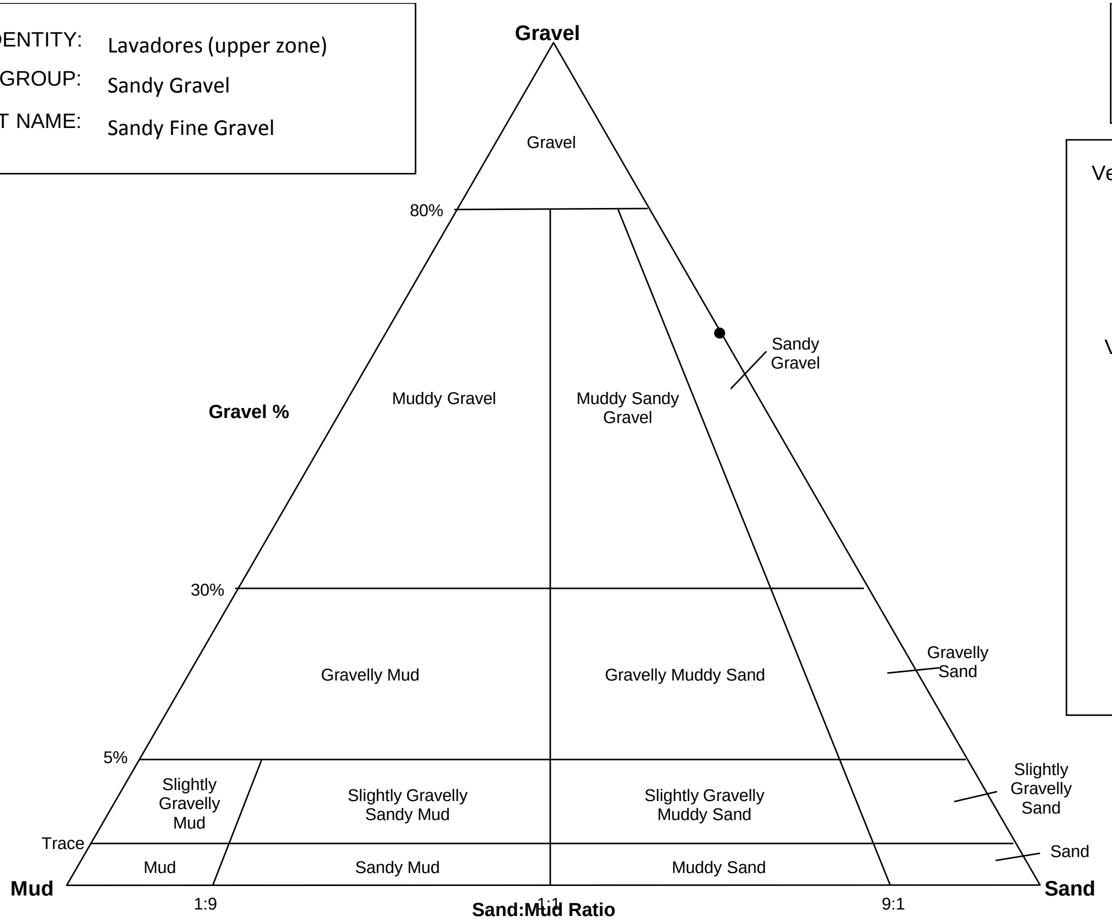
GRAIN SIZE DISTRIBUTION

GRAVEL:	65.8%	COARSE SAND:	13.3%
SAND:	34.1%	MEDIUM SAND:	1.4%
MUD:	0.1%	FINE SAND:	0.2%
		V FINE SAND:	0.2%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	16.9%	MEDIUM SILT:	0.0%
FINE GRAVEL:	26.2%	FINE SILT:	0.0%
V FINE GRAVEL:	22.7%	V FINE SILT:	0.0%
V COARSE SAND:	19.0%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	3963.2	1715.7	-1.371	3049.9	-1.609	Very Fine Gravel
SORTING (σ):	3479.9	7.973	1.342	2.614	1.386	Poorly Sorted
SKEWNESS (Sk):	1.121	-2.643	0.327	-0.140	0.140	Fine Skewed
KURTOSIS (K):	3.428	9.990	3.221	0.779	0.779	Platykurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Class Weight (%)
25.0
20.0
15.0
10.0
5.0
0.0
100
1000
10000
Particle Diameter (μm)

SAMPLE IDENTITY:	Lavadores (upper zone)
TEXTURAL GROUP:	Sandy Gravel
SEDIMENT NAME:	Sandy Fine Gravel

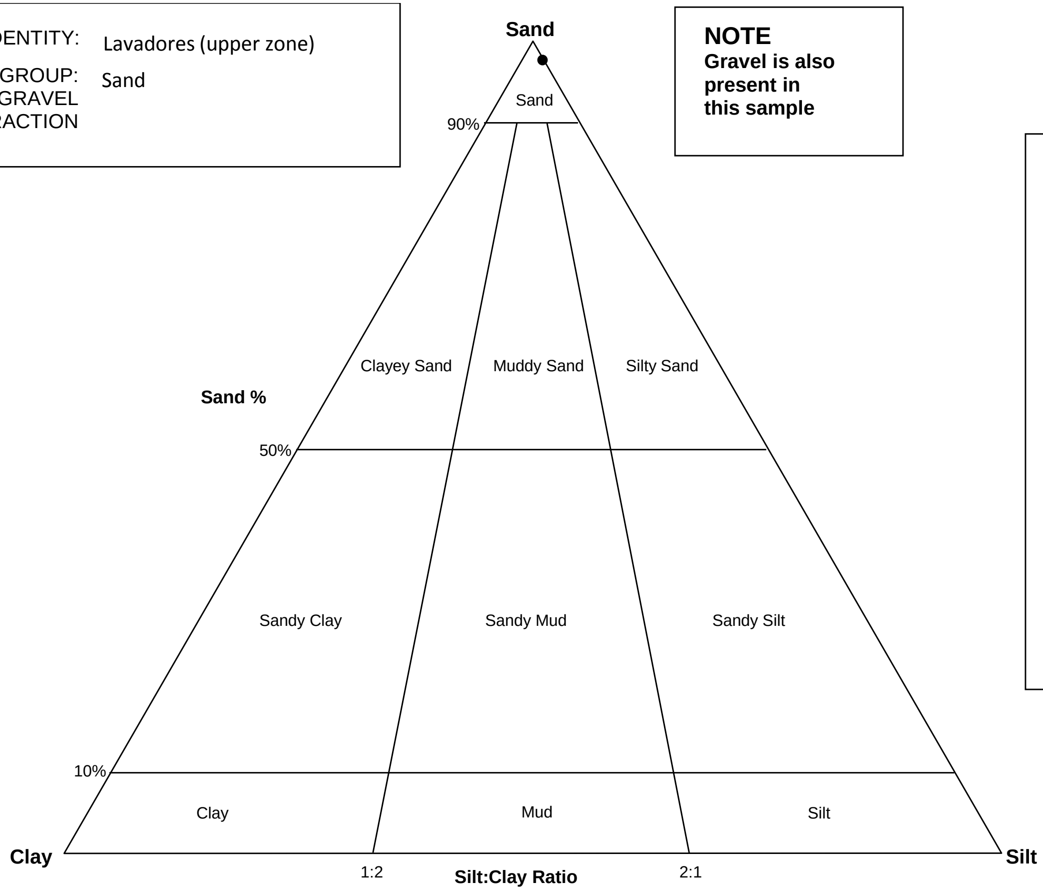


Gravel:	65.8%
Sand:	34.1%
Mud:	0.1%

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	16.9%
Fine Gravel:	26.2%
Very Fine Gravel:	22.7%
Very Coarse Sand:	19.0%
Coarse Sand:	13.3%
Medium Sand:	1.4%
Fine Sand:	0.2%
Very Fine Sand:	0.2%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%

SAMPLE IDENTITY: Lavadores (upper zone)

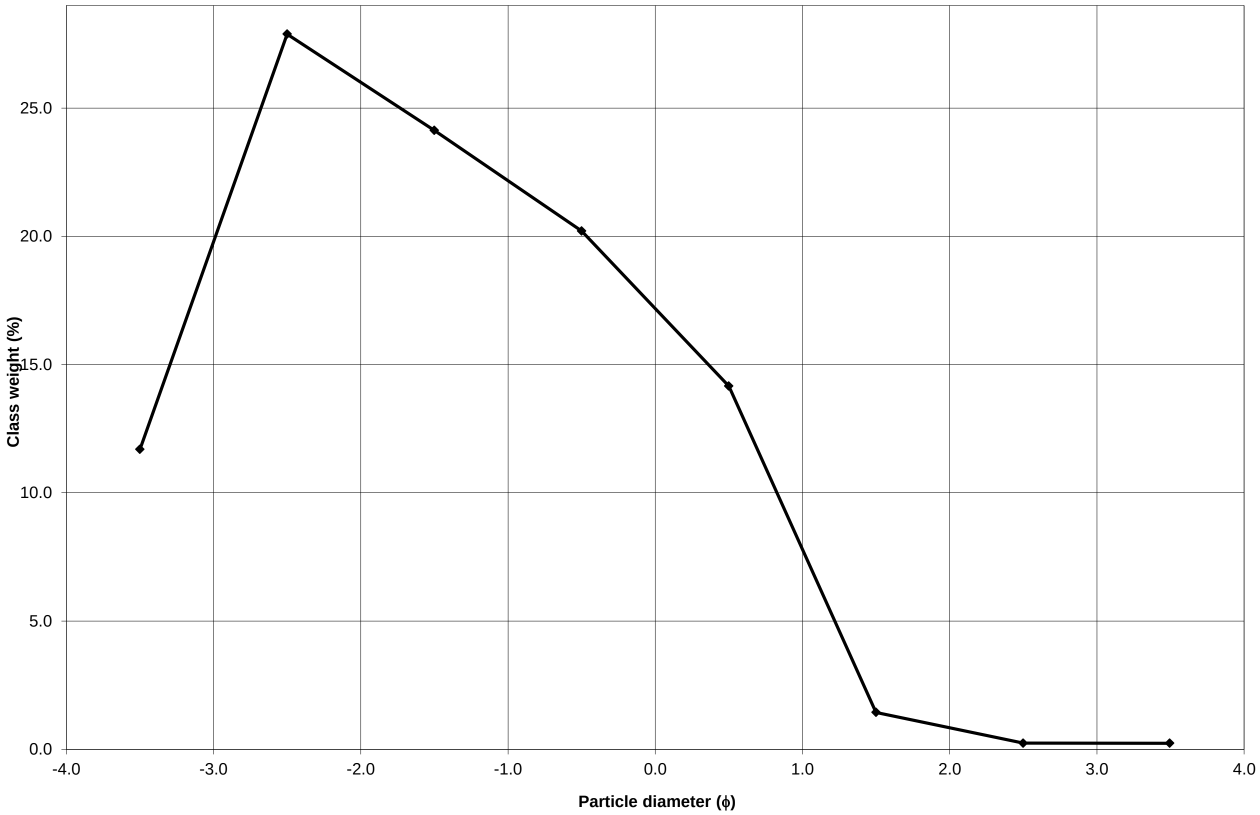
TEXTURAL GROUP: IGNORING GRAVEL FRACTION: Sand



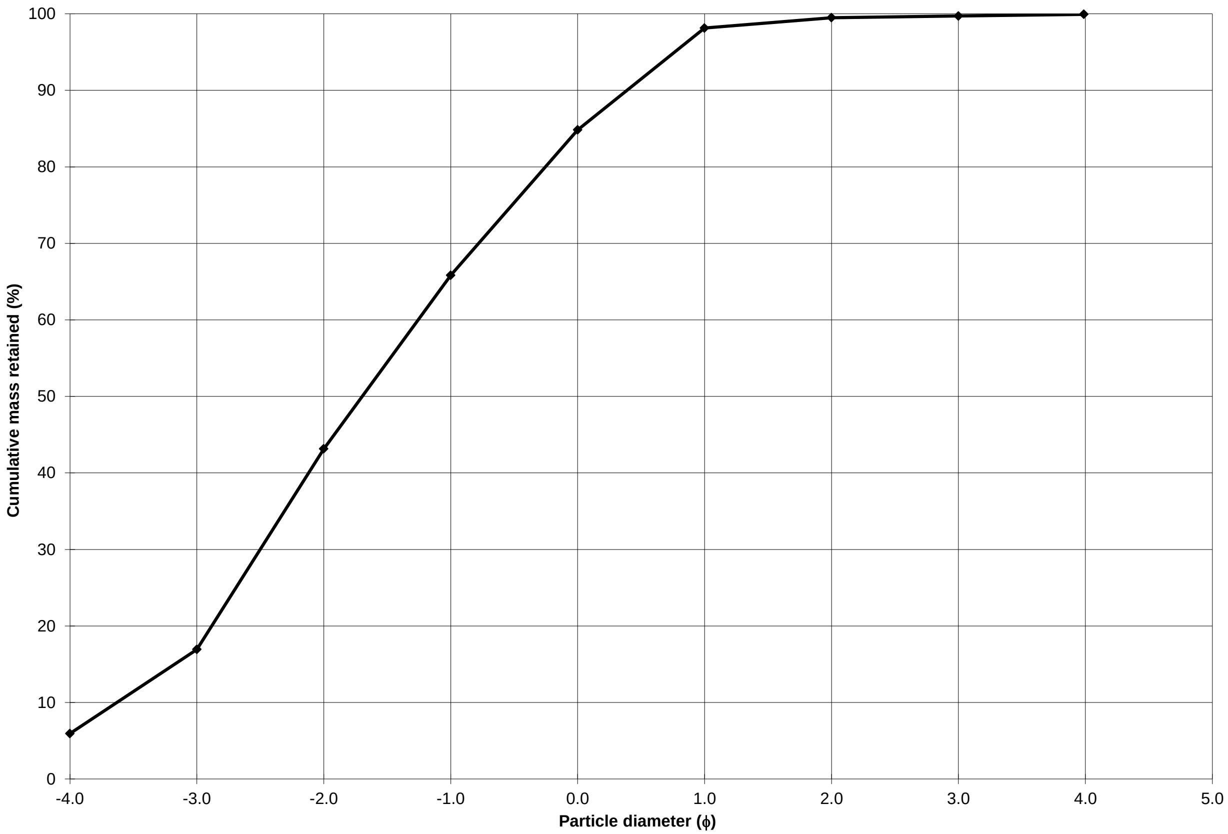
NOTE
Gravel is also present in this sample

Gravel:	65.8 %
Sand:	34.1 %
Mud:	0.1 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	16.9 %
Fine Gravel:	26.2 %
Very Fine Gravel:	22.7 %
Very Coarse Sand:	19.0 %
Coarse Sand:	13.3 %
Medium Sand:	1.4%
Fine Sand:	0.2%
Very Fine Sand:	0.2%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



Cumulative (phi)

SAMPLE STATISTICS

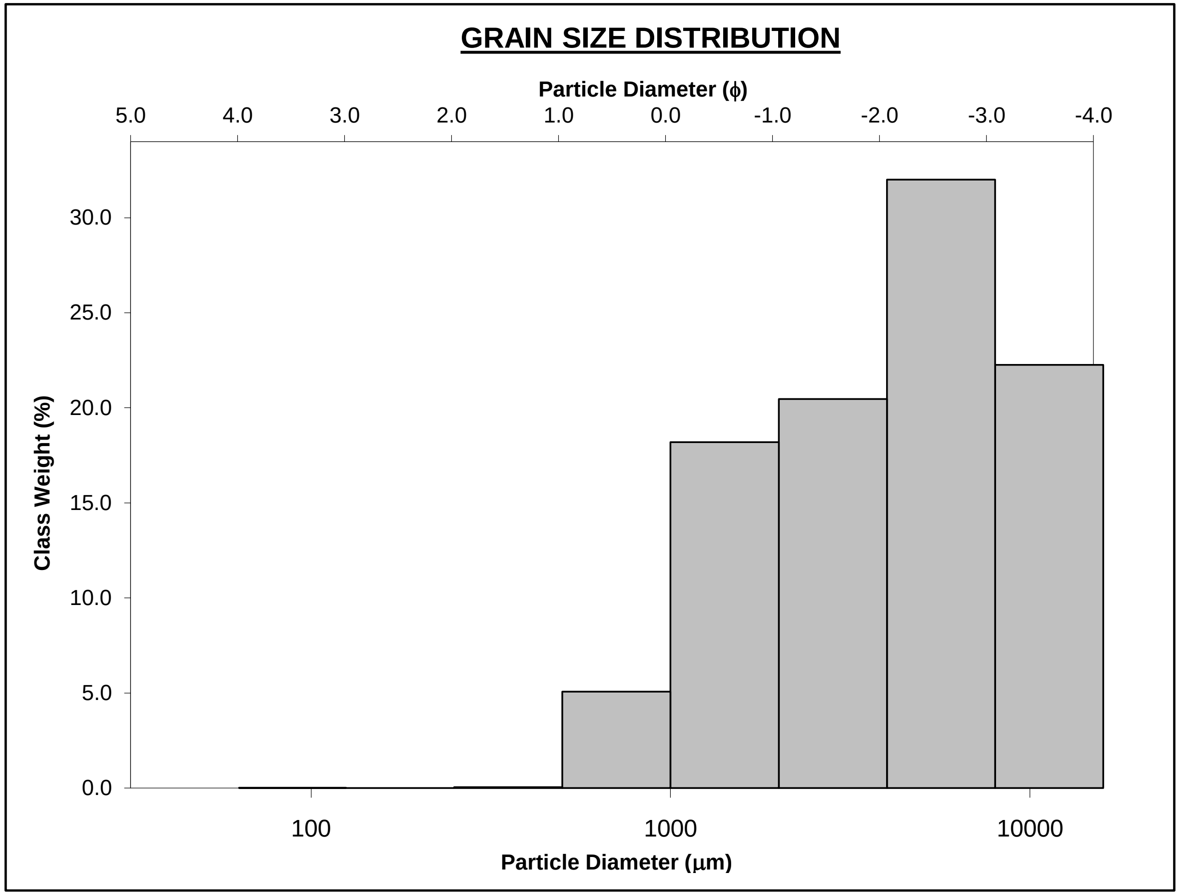
SAMPLE IDENTITY: Lavadores (mid zone) ANALYST & DATE: ,
SAMPLE TYPE: Unimodal, Poorly Sorted TEXTURAL GROUP: Sandy Gravel
SEDIMENT NAME: Sandy Fine Gravel

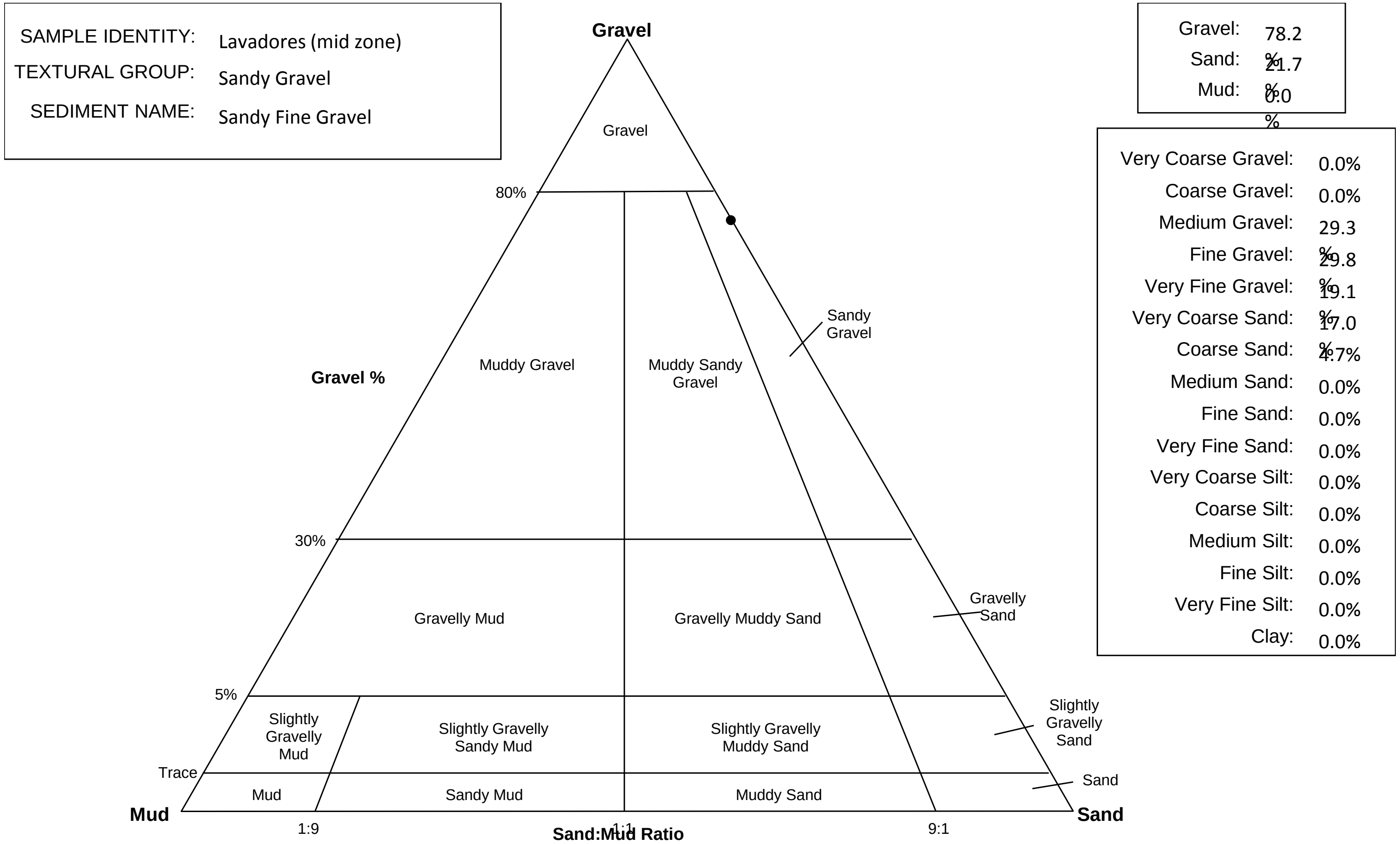
	μm	φ
MODE 1:	6000.0	-2.500
MODE 2:		
MODE 3:		
D_{10}:	1236.6	-3.932
MEDIAN or D_{50}:	4948.4	-2.307
D_{90}:	15258.2	-0.306
(D_{90} / D_{10}):	12.34	0.078
$(D_{90} - D_{10})$:	14021.6	3.625
(D_{75} / D_{25}):	4.110	0.364
$(D_{75} - D_{25})$:	6995.7	2.039

GRAIN SIZE DISTRIBUTION

GRAVEL:	78.2%	COARSE SAND:	4.7%
SAND:	21.7%	MEDIUM SAND:	0.0%
MUD:	0.0%	FINE SAND:	0.0%
		V FINE SAND:	0.0%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	29.3%	MEDIUM SILT:	0.0%
FINE GRAVEL:	29.8%	FINE SILT:	0.0%
V FINE GRAVEL:	19.1%	V FINE SILT:	0.0%
V COARSE SAND:	17.0%	CLAY:	0.0%

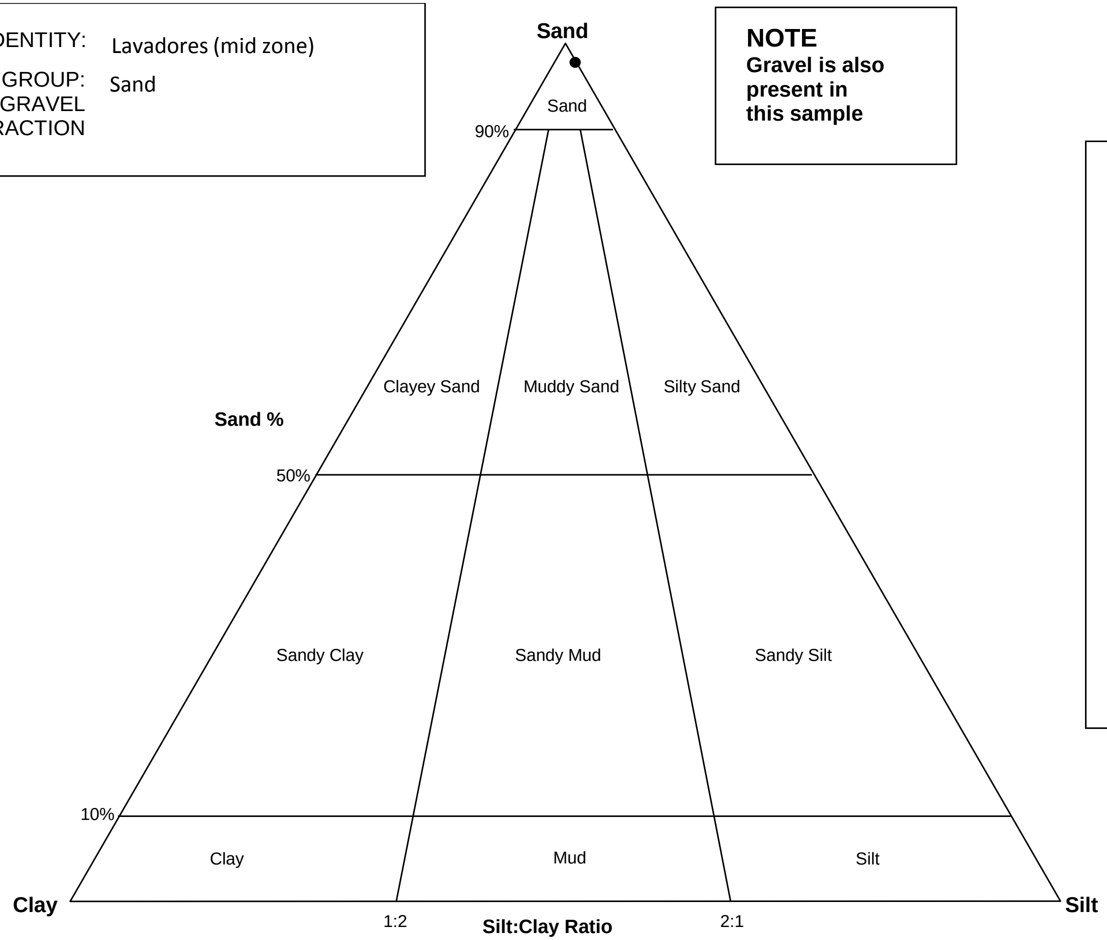
	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	5142.1	1948.1	-1.817	4604.8	-2.203	Fine Gravel
SORTING (σ):	4037.7	11.59	1.264	2.139	1.097	Poorly Sorted
SKEWNESS (Sk):	0.627	-2.439	0.278	-0.542	0.542	Very Fine Skewed
KURTOSIS (K):	2.148	7.908	2.232	0.466	0.466	Very Platykurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Class Weight (%)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
100
1000
10000
Particle Diameter (μm)


SAMPLE IDENTITY: Lavadores (mid zone)
TEXTURAL GROUP: Sandy Gravel
SEDIMENT NAME: Sandy Fine Gravel
Gravel
Gravel
80%
Muddy Gravel
Muddy Sandy Gravel
Sandy Gravel
Gravel %
30%
Gravelly Mud
Gravelly Muddy Sand
Gravelly Sand
5%
Slightly Gravelly Mud
Slightly Gravelly Sandy Mud
Slightly Gravelly Muddy Sand
Slightly Gravelly Sand
Trace
Mud
Sandy Mud
Muddy Sand
Sand
Mud
Sand
1:9
1:1
9:1
Sand:Mud Ratio
Gravel: 78.2 %
Sand: 21.7 %
Mud: 0.0 %
Very Coarse Gravel: 0.0%
Coarse Gravel: 0.0%
Medium Gravel: 29.3 %
Fine Gravel: 29.8 %
Very Fine Gravel: 19.1 %
Very Coarse Sand: 17.0 %
Coarse Sand: 4.7%
Medium Sand: 0.0%
Fine Sand: 0.0%
Very Fine Sand: 0.0%
Very Coarse Silt: 0.0%
Coarse Silt: 0.0%
Medium Silt: 0.0%
Fine Silt: 0.0%
Very Fine Silt: 0.0%
Clay: 0.0%

SAMPLE IDENTITY: Lavadores (mid zone)

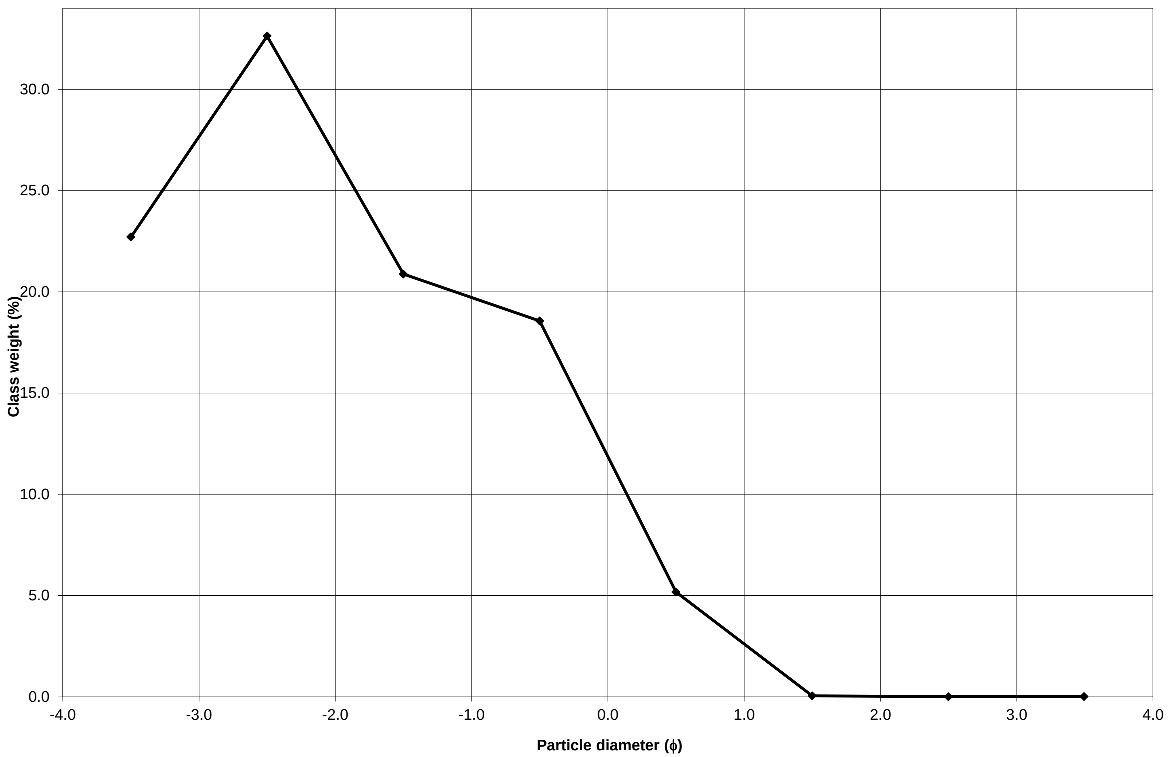
TEXTURAL GROUP: IGNORING GRAVEL FRACTION: Sand



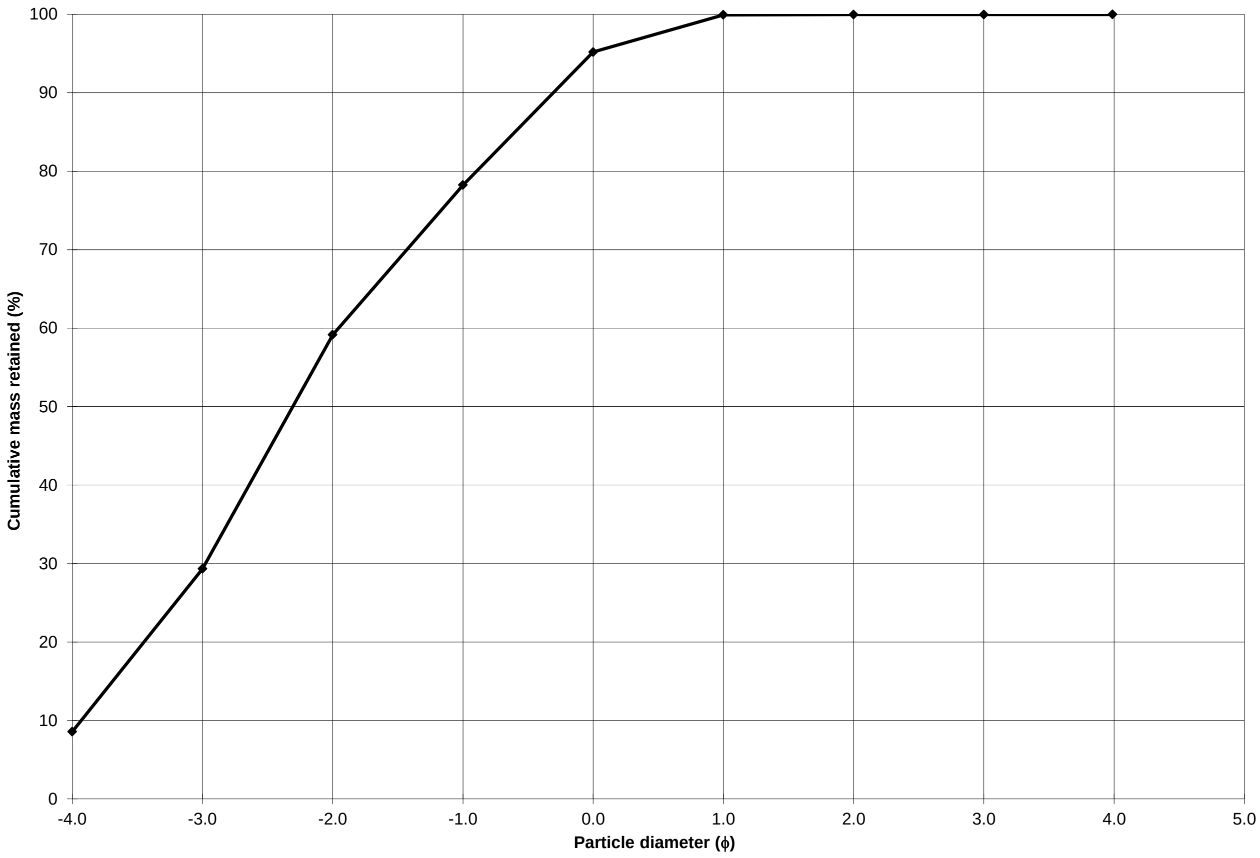
NOTE
Gravel is also present in this sample

Gravel:	78.2 %
Sand:	21.7 %
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	29.3 %
Fine Gravel:	29.8 %
Very Fine Gravel:	19.1 %
Very Coarse Sand:	17.0 %
Coarse Sand:	4.7%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



Cumulative (phi)

SAMPLE STATISTICS

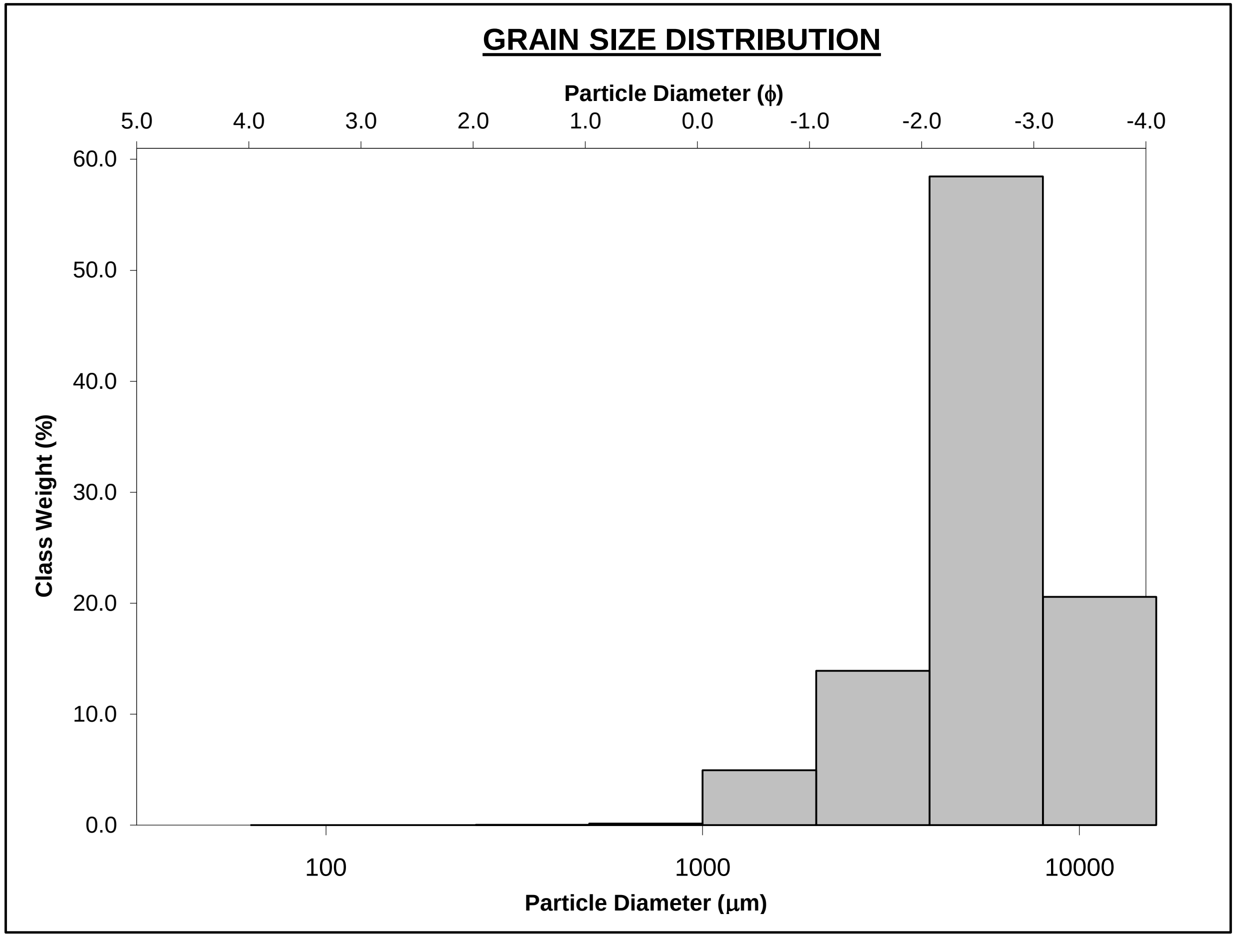
SAMPLE IDENTITY:	Lavadores (lower zone)	ANALYST & DATE:	,
SAMPLE TYPE:	Unimodal, Moderately Sorted	TEXTURAL GROUP:	Gravel
SEDIMENT NAME:	Fine Gravel		

	μm	ϕ
MODE 1:	6000.0	-2.500
MODE 2:		
MODE 3:		
D_{10}:	2534.6	-3.563
MEDIAN or D_{50}:	5738.4	-2.521
D_{90}:	11816.6	-1.342
(D_{90} / D_{10}):	4.662	0.377
$(D_{90} - D_{10})$:	9282.0	2.221
(D_{75} / D_{25}):	1.798	0.712
$(D_{75} - D_{25})$:	3416.3	0.847

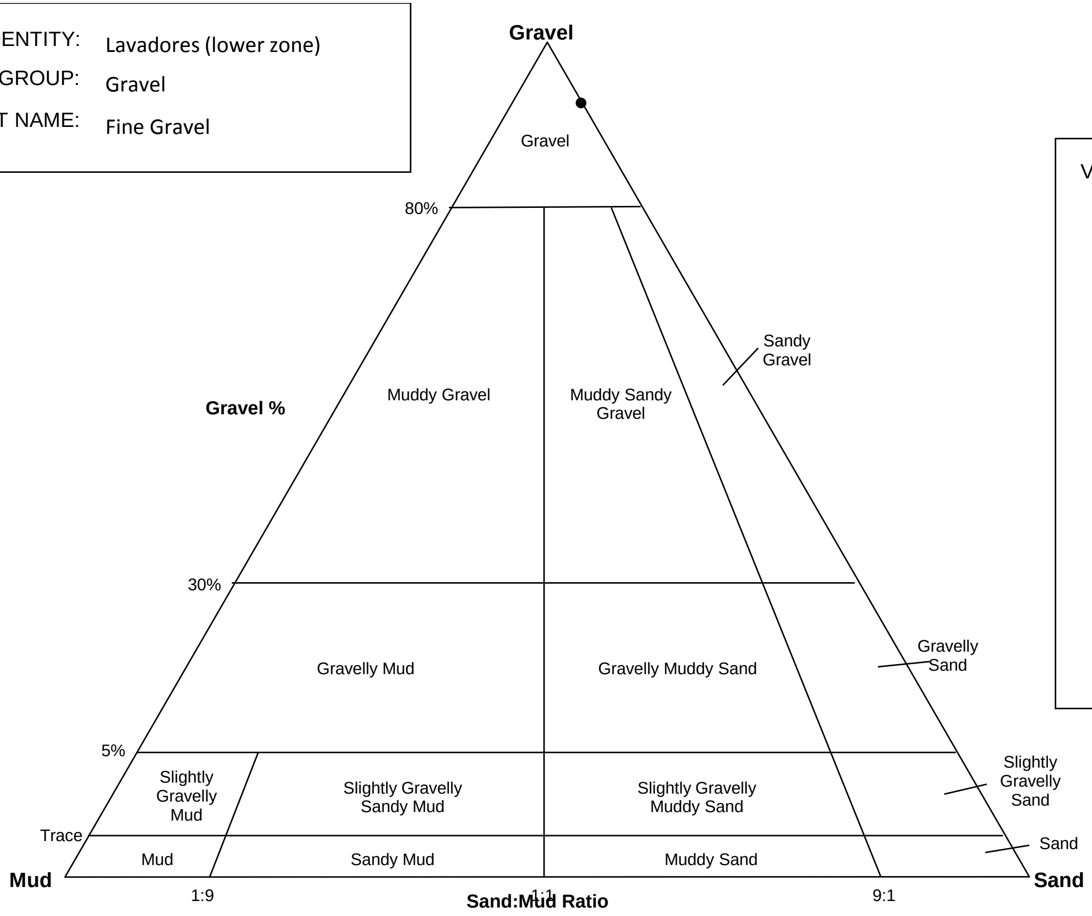
GRAIN SIZE DISTRIBUTION

GRAVEL:	94.8%	COARSE SAND:	0.1%
SAND:	5.2%	MEDIUM SAND:	0.0%
MUD:	0.0%	FINE SAND:	0.0%
		V FINE SAND:	0.0%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	21.7%	MEDIUM SILT:	0.0%
FINE GRAVEL:	59.1%	FINE SILT:	0.0%
V FINE GRAVEL:	14.1%	V FINE SILT:	0.0%
V COARSE SAND:	5.0%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	6534.5	5081.3	-2.436	5740.1	-2.521	Fine Gravel
SORTING (σ):	3140.0	2.656	0.802	1.750	0.807	Moderately Sorted
SKEWNESS (Sk):	0.590	-6.210	1.213	-0.048	0.048	Symmetrical
KURTOSIS (K):	2.661	53.97	8.386	1.376	1.376	Leptokurtic


GRAIN SIZE DISTRIBUTION
Particle Diameter (ϕ)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Class Weight (%)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
100
1000
10000
Particle Diameter (µm)

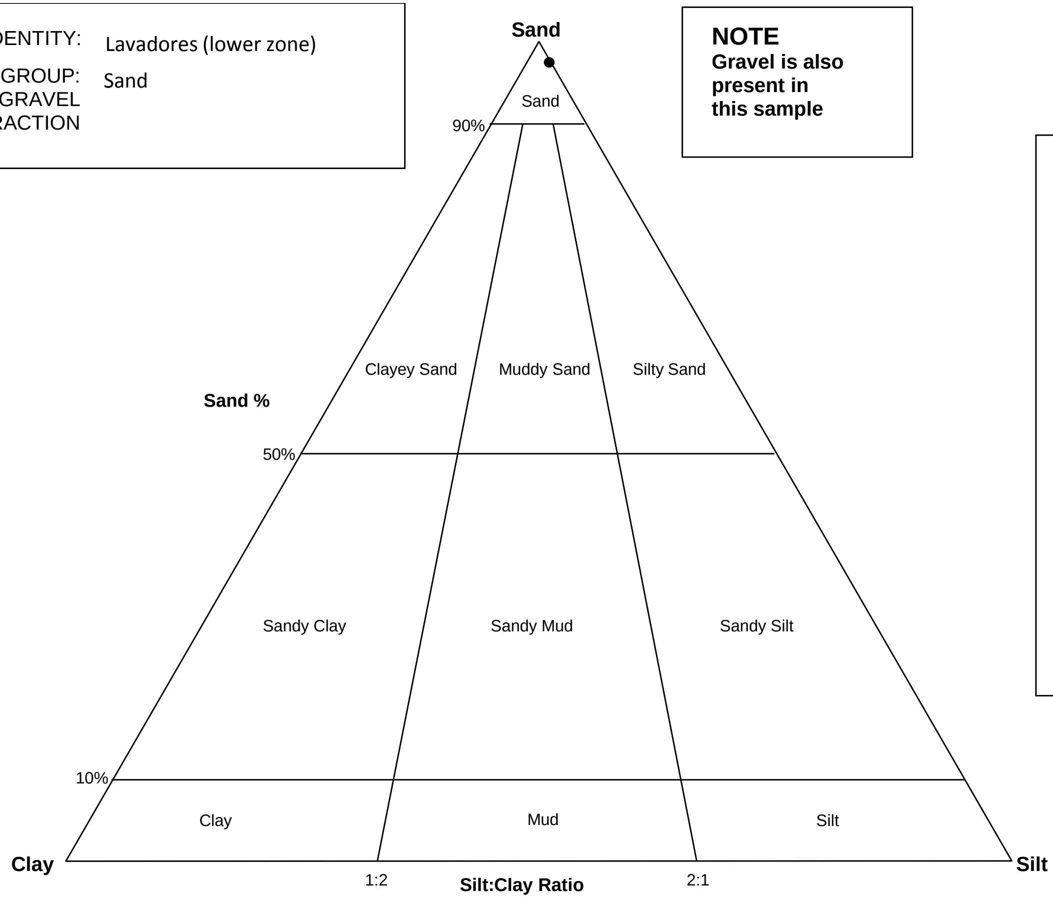
SAMPLE IDENTITY:	Lavadores (lower zone)
TEXTURAL GROUP:	Gravel
SEDIMENT NAME:	Fine Gravel



Gravel:	94.8 %
Sand:	5.2%
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	21.7 %
Fine Gravel:	59.1 %
Very Fine Gravel:	14.1 %
Very Coarse Sand:	5.0%
Coarse Sand:	0.1%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%

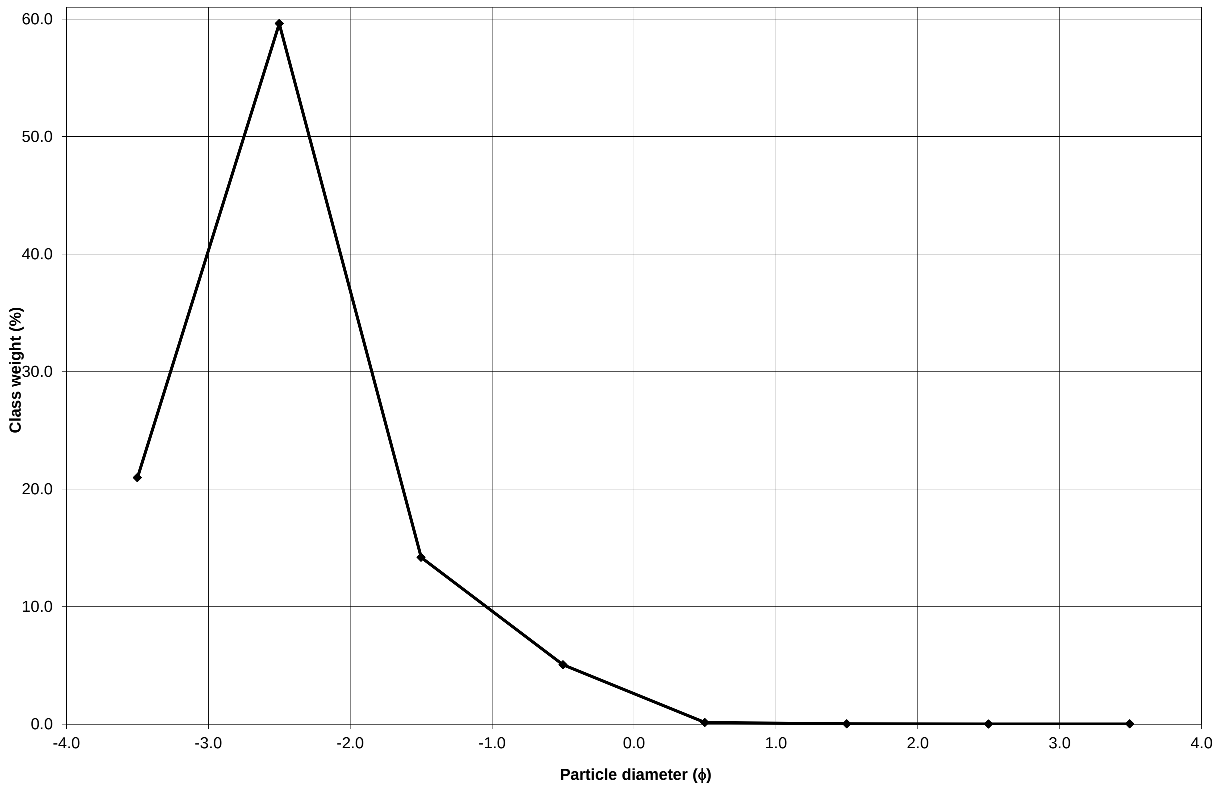
SAMPLE IDENTITY:	Lavadores (lower zone)
TEXTURAL GROUP: IGNORING GRAVEL FRACTION	Sand



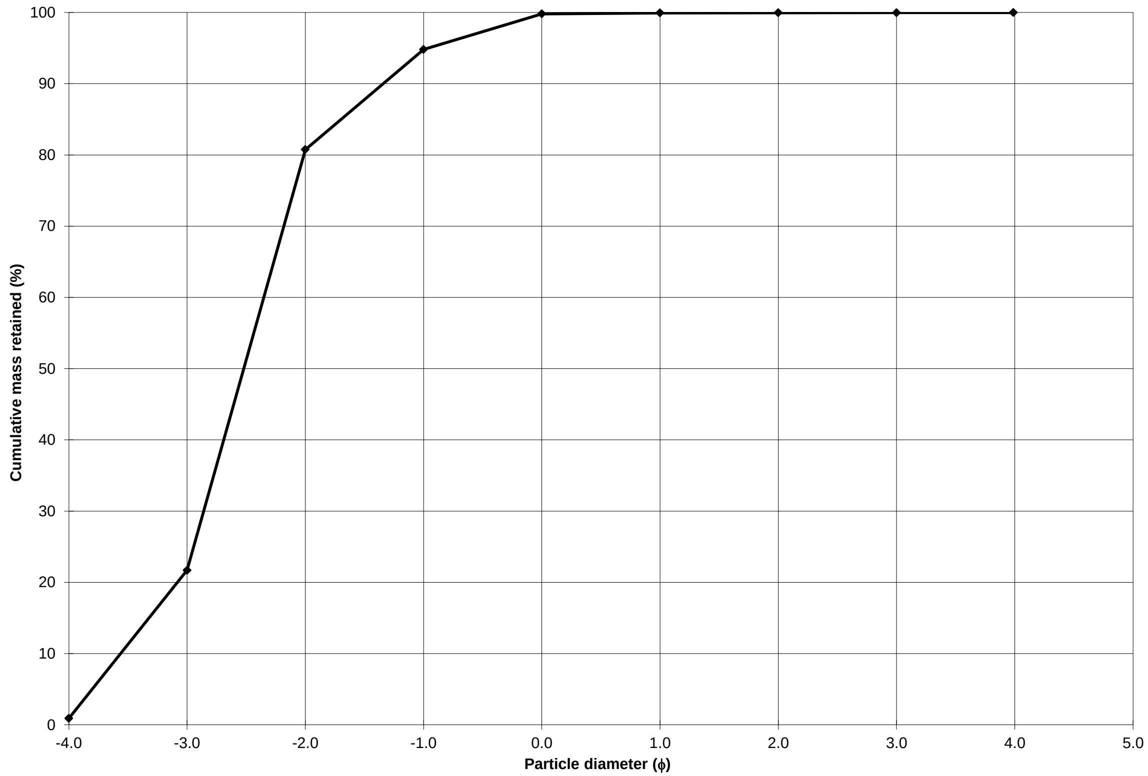
NOTE
Gravel is also present in this sample

Gravel:	94.8 %
Sand:	5.2%
Mud:	0.0 %

Very Coarse Gravel:	0.0%
Coarse Gravel:	0.0%
Medium Gravel:	21.7 %
Fine Gravel:	59.1 %
Very Fine Gravel:	14.1 %
Very Coarse Sand:	5.0%
Coarse Sand:	0.1%
Medium Sand:	0.0%
Fine Sand:	0.0%
Very Fine Sand:	0.0%
Very Coarse Silt:	0.0%
Coarse Silt:	0.0%
Medium Silt:	0.0%
Fine Silt:	0.0%
Very Fine Silt:	0.0%
Clay:	0.0%



Distribution (phi)



Cumulative (phi)