University of Puerto Rico

Mayagüez Campus

Geology Department

Grain Size, Composition and Spectral Response of Deposited Sediments in Mayagüez Bay

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I. Abstract

This project help to determine if the suspended sediments in the Mayagüez Bay have different grain sizes, compositions and spectral responses. This question is very important because recent efforts to use remote sensing to study the water quality parameters in this Bay have found high spatial and temporal variability. Since suspended sediments are affecting the signal received by remote sensors, it is necessary to better understand their characteristics. During this time of the year (January to May) the main source of suspended sediments is the sea floor. Regular cold- fronts are responsible for strong waves, which produce large re-suspension of the sediments deposited in the bottom. Therefore, this study will collect samples from the bottom for the laboratory analyses. Eleven (11) stations are visited along the Bay, from the Añasco to the Guanajibo Rivers. To determine the spectral response, the GER-1500 spectroradiometer, with a spectral range from 400 to 1050 nanometers and the HR-1024 spectroradiometer with a spectral range in the far infrared regions, are used. For the grain size the sieve shaker was used and for the mineral composition are the XRD tests. The grain size distribution demonstrates that the offshore stations have grains with lower diameter than the onshore samples. The composition of the grains shows more carbonates on Añasco River and more terrigenous in Yagüez River. Along the three rivers is show the lack of organic matter. The XRD analysis shows the presence of quartz and halite as common mineral in the samples. The reflectance curves demonstrate that the stations with finer grain sizes are A2, Y2 and G2, reflects more than the others in the dry measures. These results will also help to understand the dynamics of suspended sediments in Mayagüez Bay and provide recommendations for future application of remote sensing in this region.

Key Words: suspended sediments, grain size, composition, HR-1024 spectroradiometer, GER-1500 spectroradiometer.

II. Introduction

Two distinctive seasons have been identified in the Mayagüez Bay (Gilbes et al., 1996), a dry season (January to May) and a rainy season (August to November). Each season has a large influence in the dynamics and amount of sediments in the Bay. During the rainy season, river discharge controls the concentrations of suspended sediments. During the dry season a large amount of sediments are re-suspended due to strong waves (Fernando Gilbes, personal communication). Recurrent cold fronts that travel across the Caribbean region during winter produce such wave action. Since this research project will take place during this winter-spring semester, it will focus on the dynamics of re-suspended sediments from the bottom.

In this study case, sediments are re-suspended by the effect of the cold fronts. A front is the transition zone between two air masses of different temperatures and a cold front occurs when cold dry stable polar air is replacing warm and moist air

(Donald, 2007). The repeated cycling of cold-front passages leads to positive feedback with transport onshore during both pre- and post-front conditions, and effective attenuation of wave energy over the muddy inner shelf inhibits erosion at the coast (Kineke et al., 2006).

Mayagüez Bay is located at 18° 10' N and 18° 16' N of latitude and 67° 10' W and 67° 14' W of longitude. This Bay is affected by the discharge of the Güanajibo, Yagüez and Añasco rivers (Figure 1). However, for this study its bathymetry (depth conditions) is also very important. The southern region of the bay is shallower than the northern region, which produces more re-suspension there due to wave action (Fernando Gilbes, personal communication).

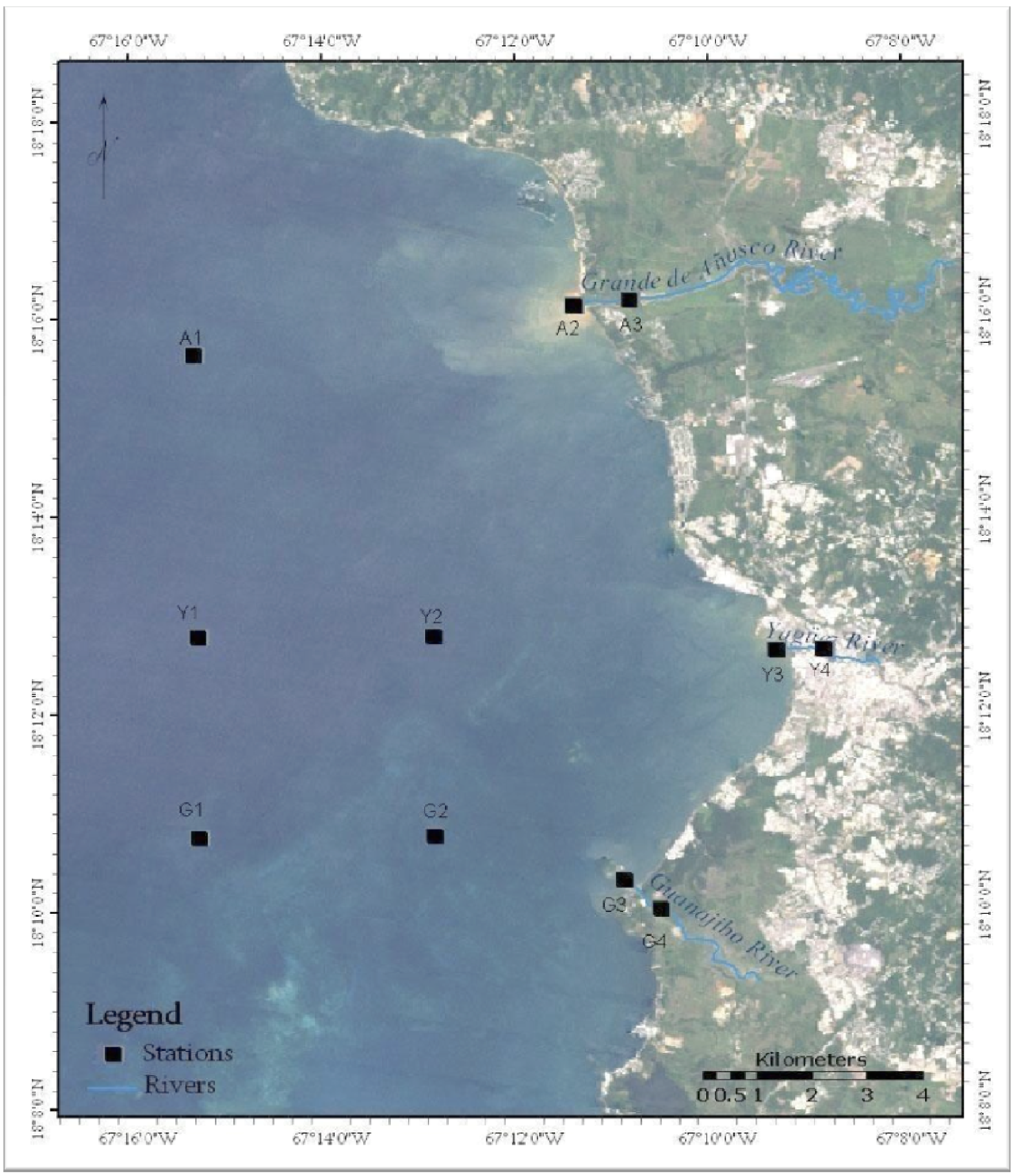


Figure 1: Study area and proposed sampling stations (adapted from Hernández, 2008)

The geology of the Mayagüez Bay is composed by Alluvium of the Quaternary (Curet, 1986). But it is not the only formation that is important in this area. The geology of the rivers that discharge into this Bay is also important. One of them is the Güanajibo River located at the south of the Bay. The formations that compose this river basin are from Cabo Rojo, whose most abundant rock is the serpentinite. North to it, we found the Yagüez River, which is composed by the Yauco Formation. The Yauco Formation is composed of volcanic sandstone, siltstones, mudstones, claystone and limestone and the most abundant minerals are calcite, chlorite, epidote and quartz. Another formation that has effects on the types of clasts and sediments that arrive in the Mayagüez Bay is the Maricao Formation. It is composed by volcanic breccia with large phenocrysts, conglomerates, volcanic sandstone and limestones. The most common minerals are augite, plagioclase, hornblende and magnetite. The last unit through which the Yagüez River cuts is one composed by porphiritic augite basalts. It also has minerals scaprolite, plagioclase, magnetite and olivine (Curet, 1986). Those are the compositions of the sediments that are discharged into the Mayagüez Bay (Figure 2). The concentration of sediments derived from the bottom due to re-suspension or discharged by rivers is highly variable over time and space scales (Miller and McKee, 2004).

Figure 2: Geologic Map of the Mayagüez Bay (Curet, 1986)

Offshore facies also vary for Mayagüez Bay. There are six different facies along the Bay (Figure 3). The major composition is 30-40% of coarse sand with gravel; other compositions are biogenic deposits, carbonates, terrigenous and mud, which is found at the plumes of the rivers (Morelock et al., 1983).

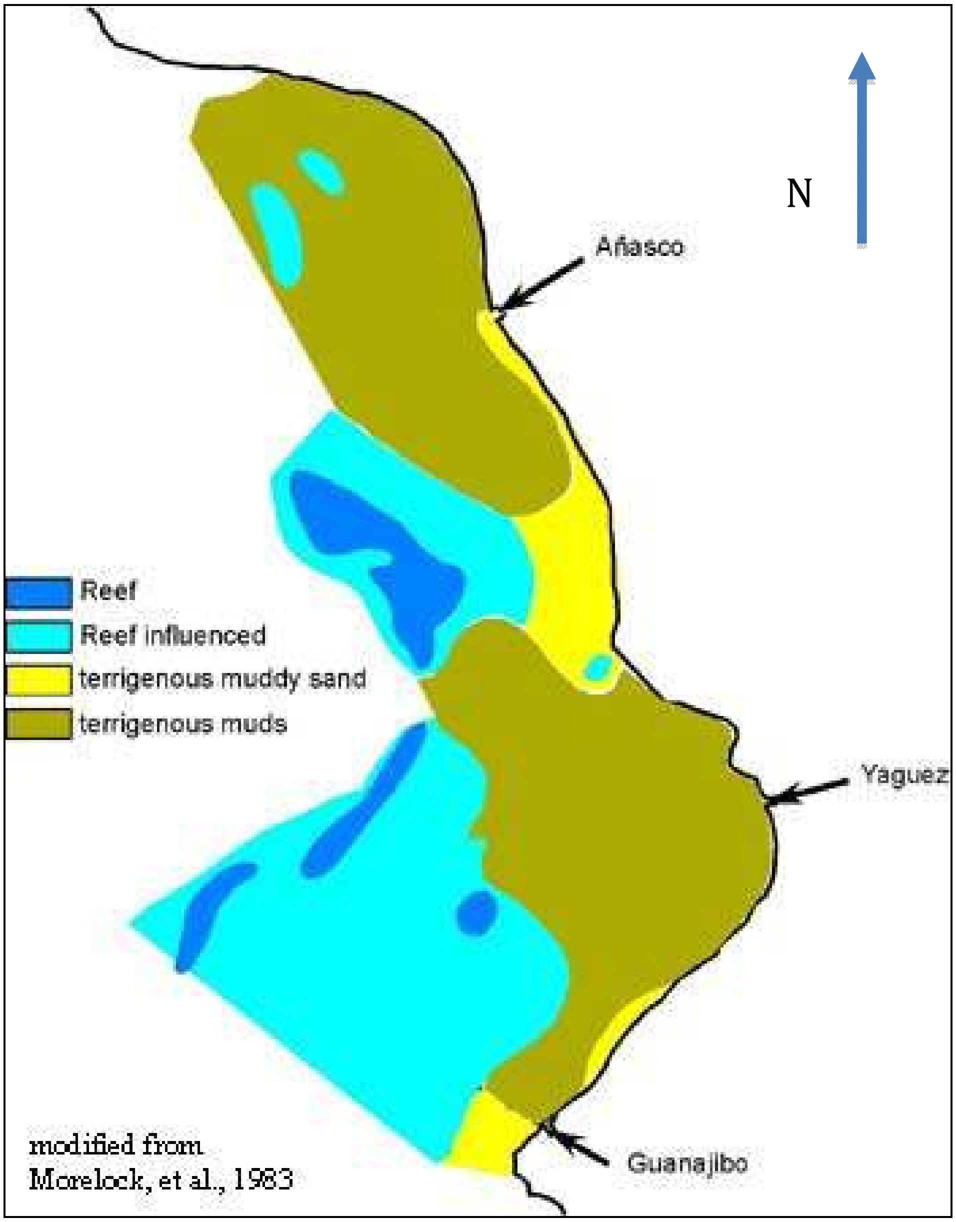


Figure 3: Facies on the Mayagüez Bay (Ramírez et al., 2003).

III. Objectives

The main objective of this study is to determine the grain size, composition and spectral response of the bottom sediments along the Mayagüez Bay. These results will also help to understand the dynamics of suspended sediments in Mayagüez Bay and provide recommendations for future application of remote sensing in this region.

IV. Methodology

The first step of this project is the collection of 11 samples and their laboratory analyses. These samples will be collected from the bottom along the Mayagüez Bay, in the west coast of Puerto Rico (Figure 1). The sampling stations will be located considering the mouth of the three main rivers: Añasco, Yagüez and Guanajibo. Five additional samples will be taken offshore for comparison (Figures 4a, 4b and 4c). The grain size and composition of the sediments collected from the bottom will be analyzed in the laboratory using standard techniques.

Figure 4a: Vessel Pez/Mar used for offshore sampling. ***Figure 4b***: Sampling with the sediment grab

Figure 4c: Sediment Grab

Granulation was use for the grain size using a sieve shaker (Figure 5). The sieves sizes utilized were 0.25Φ, 1 Φ, 2.75Φ, 3.50Φ, 3.75Φ and 4Φ (Table 1). To calculate the diameter of the grains in mm, the following formula was used;

$$D = D_0 \times 2^{-\Phi};$$

Where D= diameter, D_0 =reference diameter (equal to 1 mm) and Φ is the sieve size (Krumbein, W. C. and Sloss, L. L.,1963)

Φ	Mm
0.25	0.84
1	0.50
2.75	0.15
3.50	0.09
3.75	0.07
4	0.0625

Table 1: Sieves sizes in Φ and mm.

Figure 5: Sieve Shaker

The mineral compositions will be measured using the XRD machine. For this test is not necessary to pulverize the sample, only to dry them in an oven. The grain size used for this test is 4Φ and PAN.

Another test will be the percentage of carbonates or the terrigenous material. First the sample will be dried in an oven on a previously weighed glass slide 10% HCl is then added to the dry sediments to dissolve the carbonate present. They are weighted again and on the basis of the difference in weights, the percent of carbonates is determined. The remaining portion is the terrigenous material. The organic component is determined by adding NaClO at 10% instead HCl. Also for this test a grain size of 4Φ and PAN were used.

Reflectance spectra in the visible and infrared regions also were measured in the laboratory. The GER-1500 (Figure 6) spectroradiometer with a spectral range from 400 to 1050 nanometers will be used to determine the reflectance in the visible and near infrared regions (Chiques, 2005). The HR-1024 (Figure 7) spectroradiometer were used to make the reflectance measurements in the mid and far infrared regions.

Figure 6: Mixture of 7oz of sediment and water measurement with the GER-1500.

Figure 7: Mixture of 7oz of sediment and water measurement with the HR-1024.

The reflectance samples were taken in five different methods due on the samples. The first was on the dry sample, other was from a humid sample, other to the water and finally one measure was made to the addition of 7oz. of sediment to the water and the last one was after 5 minutes of the addition.

V. Samples

Eleven (11) samples were taken along the Mayagüez Bay. Three of them were in the mouth of each river and other three 30m from the mouth. The other five samples were collected offshore in the direction of the mouth of the Añasco, Yagüez and Guanajibo Rivers. The specific coordinates of each station are shown on Table 2. All of these samples were collected from the bottom of the Bay.

Station	Latitude	Longitude
A1	18° 16.00	67° 15.20
A2	18° 15’ 58.6’’	67° 11’ 17.6’’
A3	18° 15’ 59.3’’	67° 11’ 17.6’’
Y1	18° 12.20’	67° 12.95’
Y2	18° 12.20’	67° 9.78’
Y3	18° 12’ 28.7’’	67° 9’ 18.4’’
Y4	18° 12’ 28.7’’	67° 9’ 17.6’’
G1	18° 10.25’	67° 14.80’
G2	18°10.25’	67° 11.10’
G3	18° 10’ 6.2’’	67° 10’ 50.1’’
G4	18° 10’ 5.3’’	67° 10’ 51.1’’

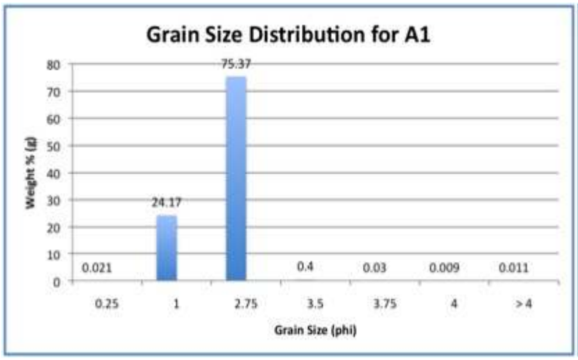
Table 2: Coordinates of the stations

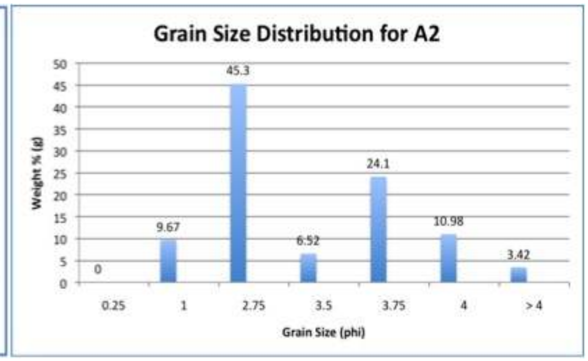
These samples were dried and processed as mentioned in the methodology section.

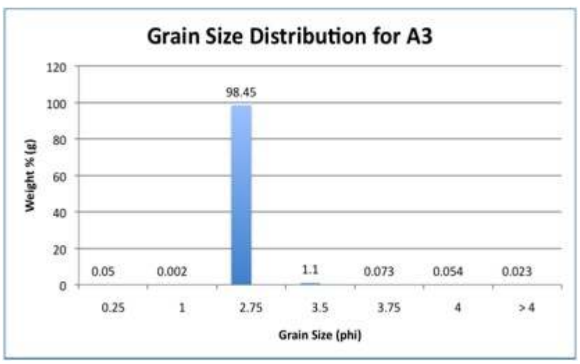
VI. Results

-Grain size Distribution

The grain size distribution along the three rivers was determined by different grain sizes. For Grande de Añasco River the dominant grain size is for 2.75Φ of diameter, showing a fine sand size.

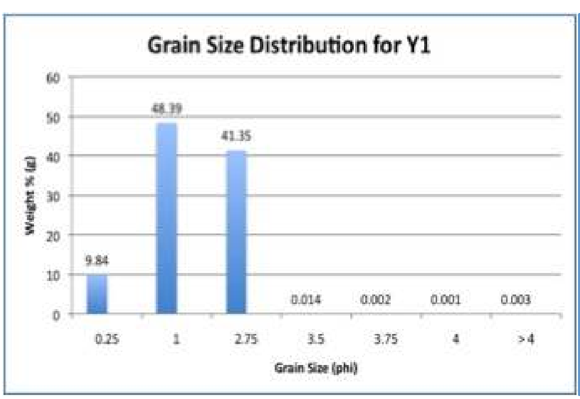


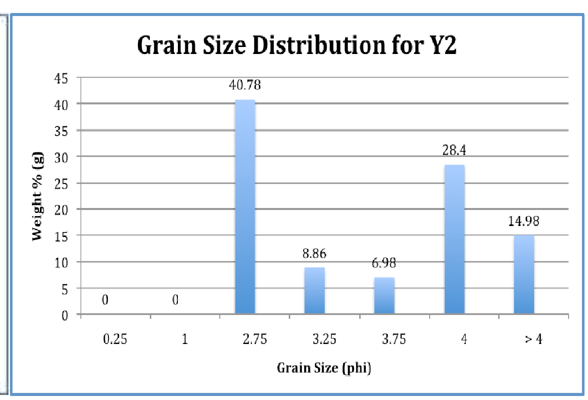


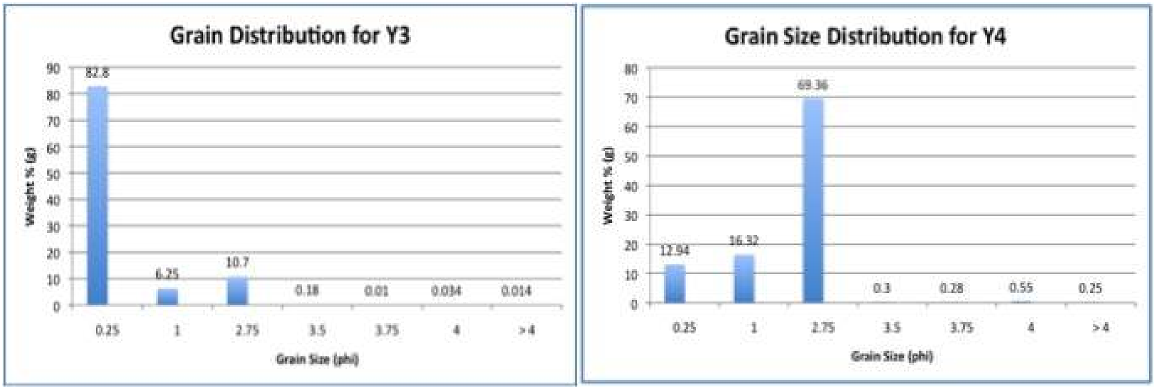


Grain sizes distribution for Añasco River, showing from the offshore station (A1) to 30m away from the mouth (A3).

The grain size distribution for the Yagüez River is very influenciated by very coarse sand to fine sand. The dominant grain size in this river is from 0.25 Φ to 2.75 Φ on the Y1, Y3 and Y4 stations but in the Y2 we have a large percent on more fine grains.

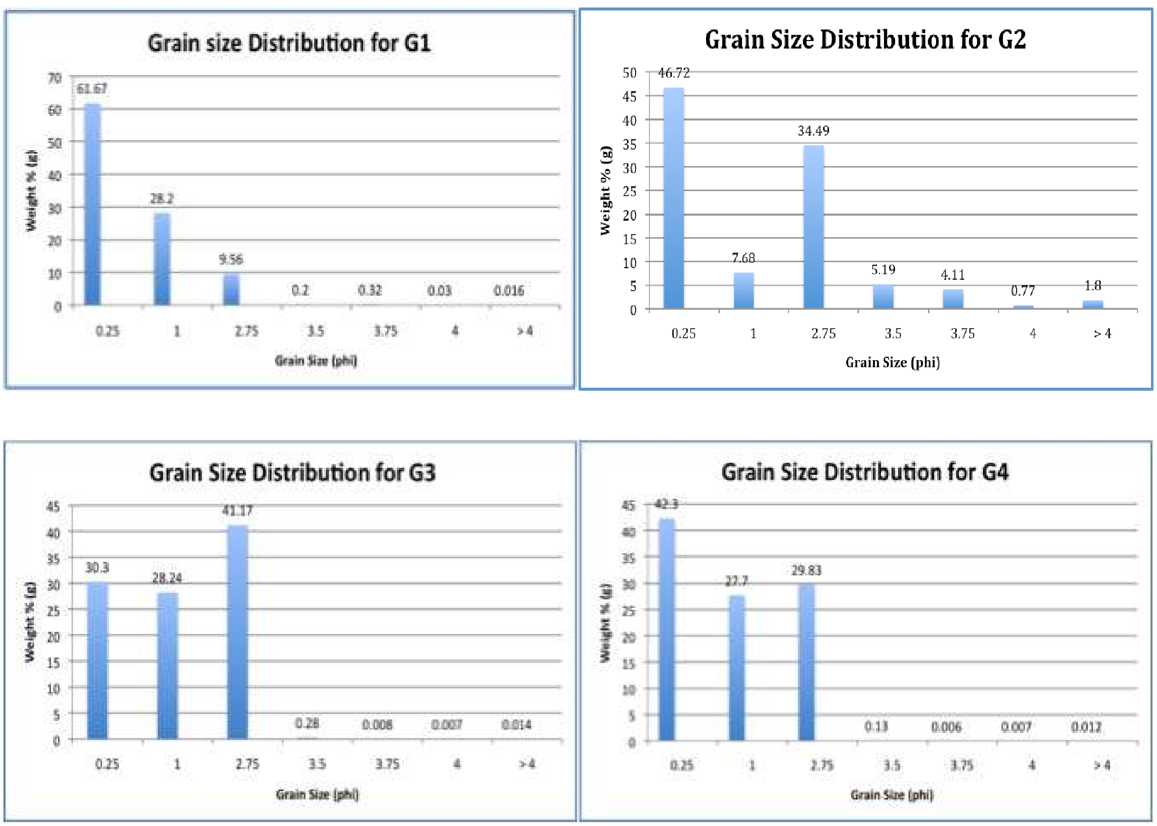






Grain sizes distribution for Yagüez River, showing from the offshore station (Y1) to 30m away from the mouth (Y4).

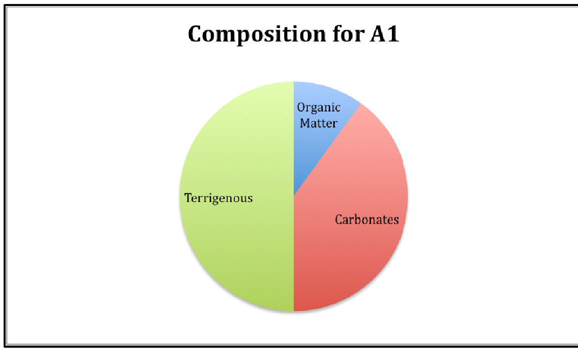
For the Guanajibo River, we have a that the dominat grain size is of 0.25Φ to 2.75Φ of diameter. Which implies a very coarse to fine sand sizes. For the G2 station the fine grains amount increases.

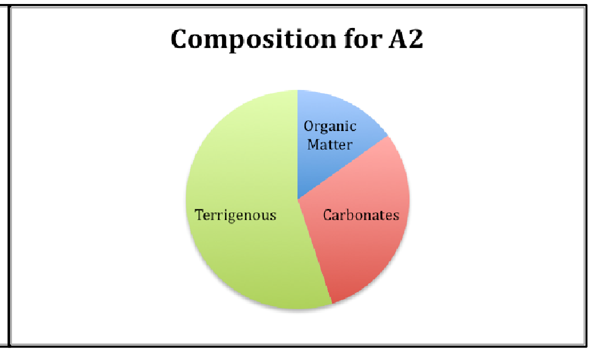


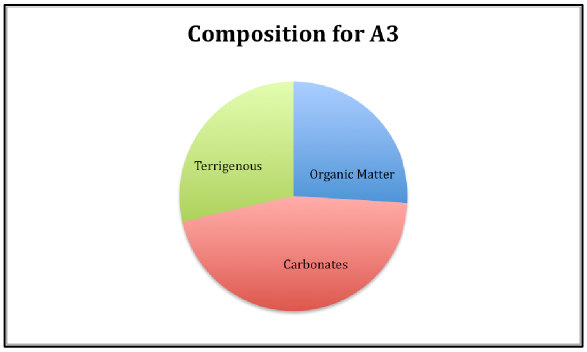
Grain sizes distribution for Guanajibo River, showing from the offshore station (G1) to 30m away from the mouth (G4).

-Grain Composition

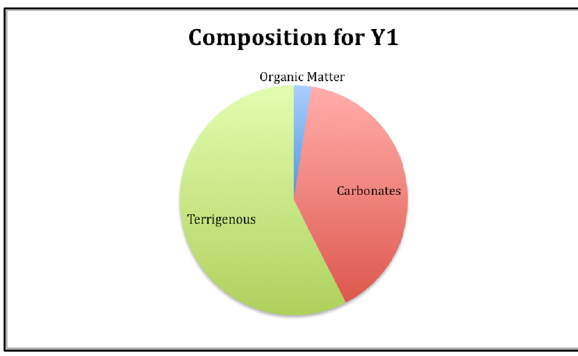
The grain composition for the Añasco River is by carbonates, also have a similar amount of terrigenous and a less amount of organic matter.

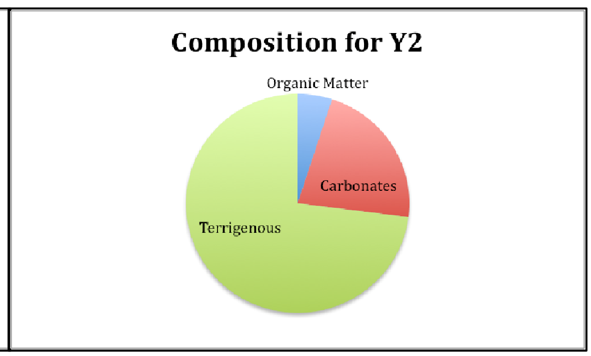


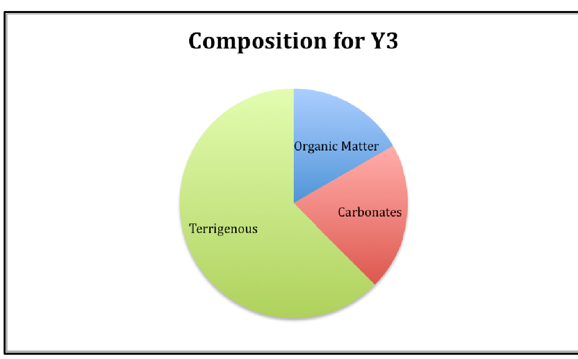


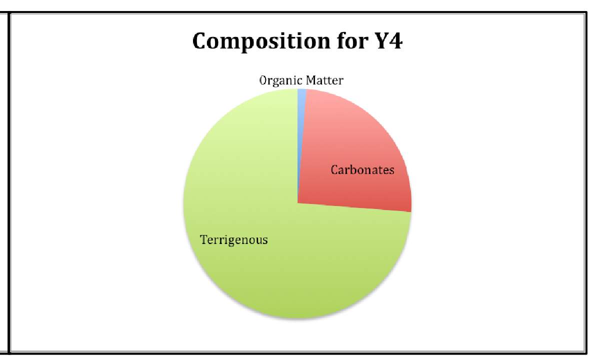


The grain composition of the Yagüez River is terrigenous material, followed by the carbonates and a little amount of organic matter.

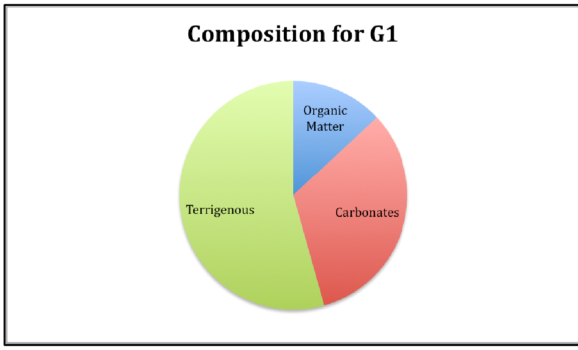


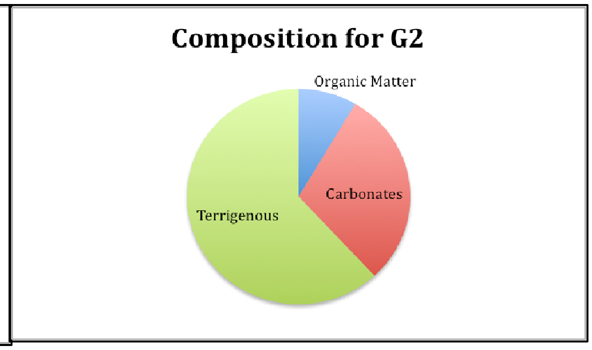


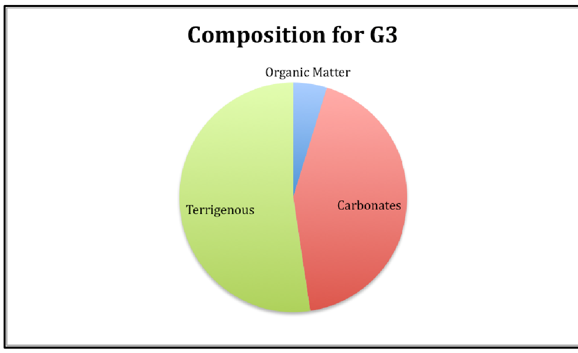


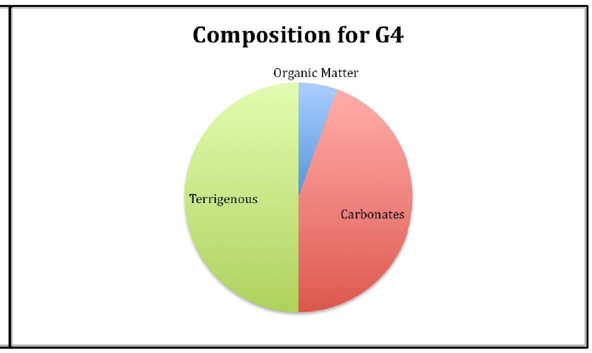


For the Guanajibo River we have a dominant composition of terrigenous grains, followed by the carbonates and a lower amount of organic matter.









-Mineral Composition

The XRD shows that the quartz and the halite are the most common minerals on the samples. Quartz is present in the following samples: A2, A3, Y2, Y3, Y4, G3 and G4. By the other way, halite is present in A1, G1, G2, G4, Y1 and Y2.

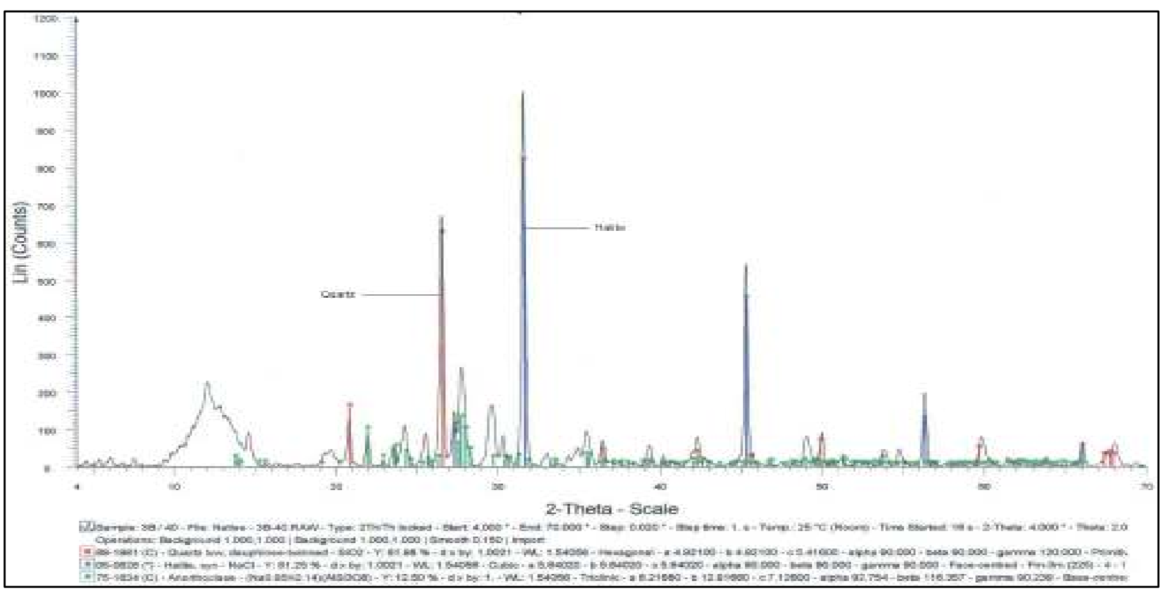


Figure 8: Example of XRD for G4 station, which shows quartz and halite.

-Spectral Response

GER-1500:

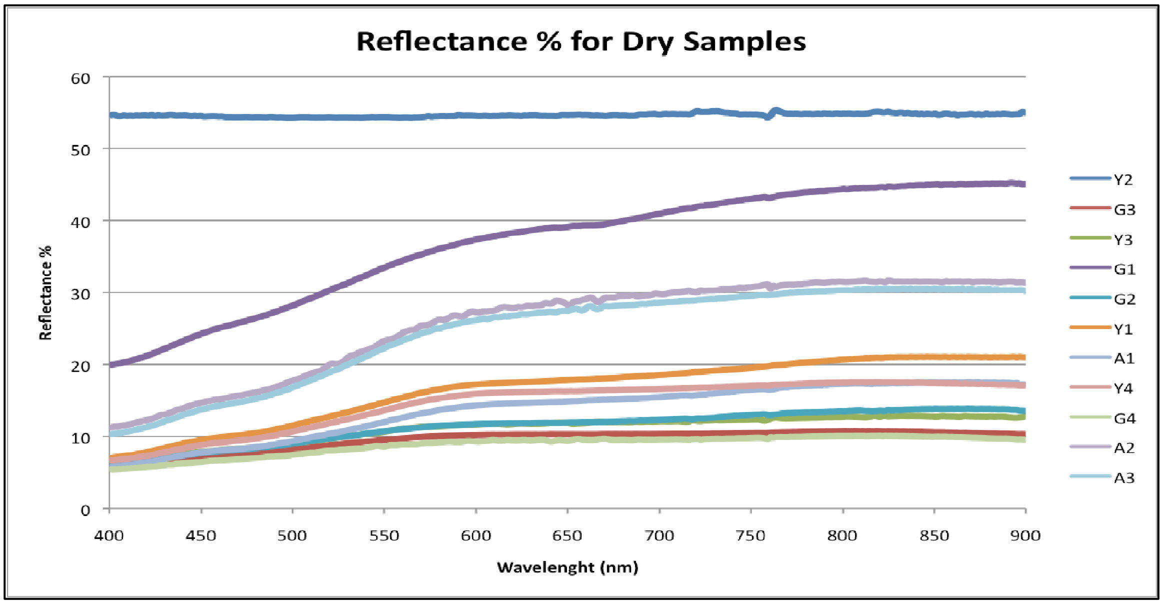


Figure 9: Reflectance curves for dry samples

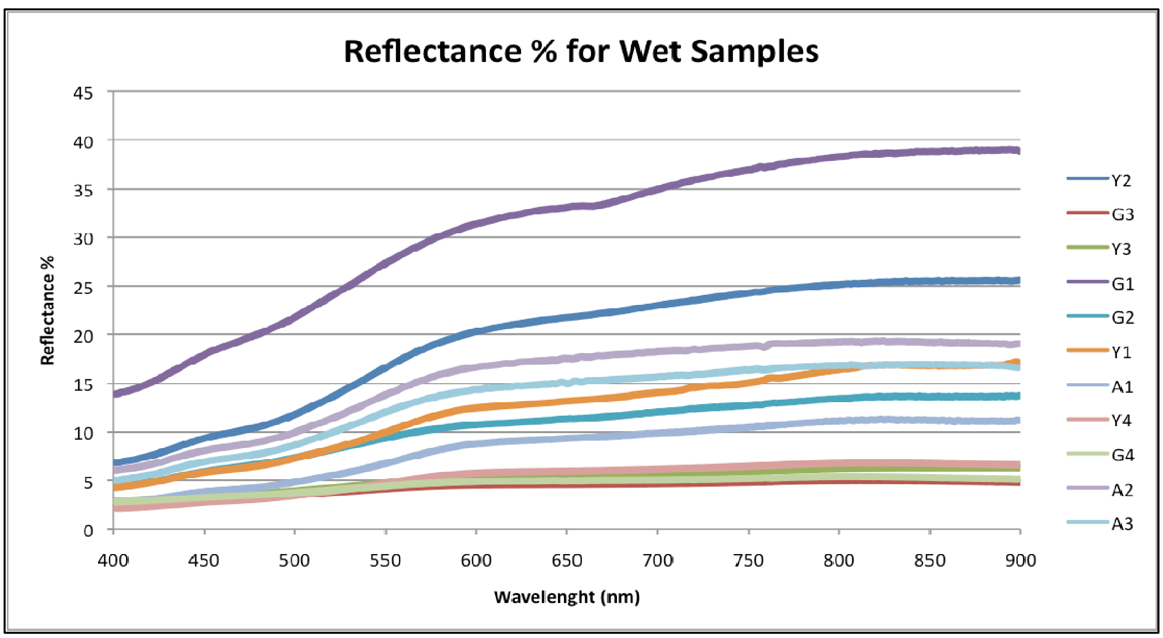


Figure 10: Reflectance curves for wet samples.

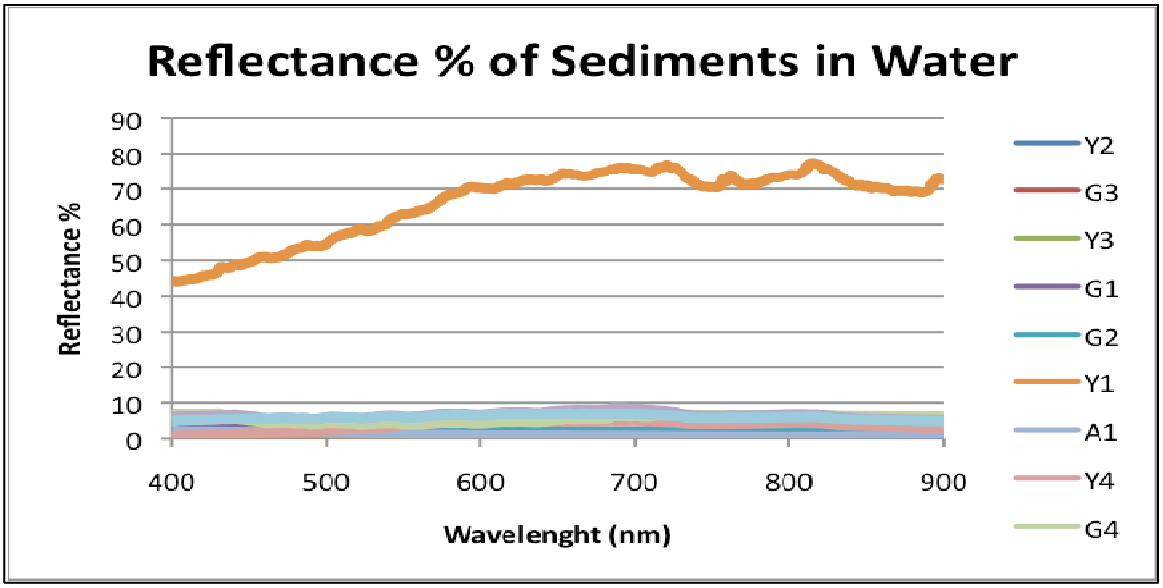


Figure 11: Reflectance curves for 7oz. of sample in water (these curves don't include the water reflectance).

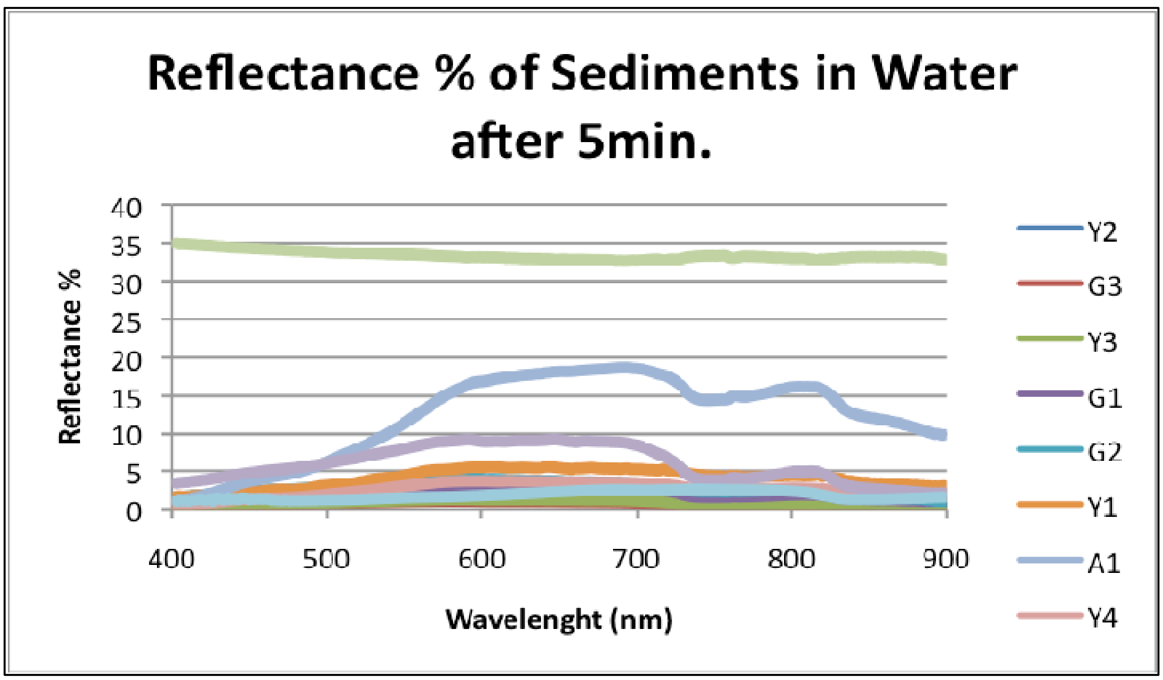


Figure 12: Reflectance curves for 7oz. of sample in water before 5 minutes (these curves don't include the water reflectance).

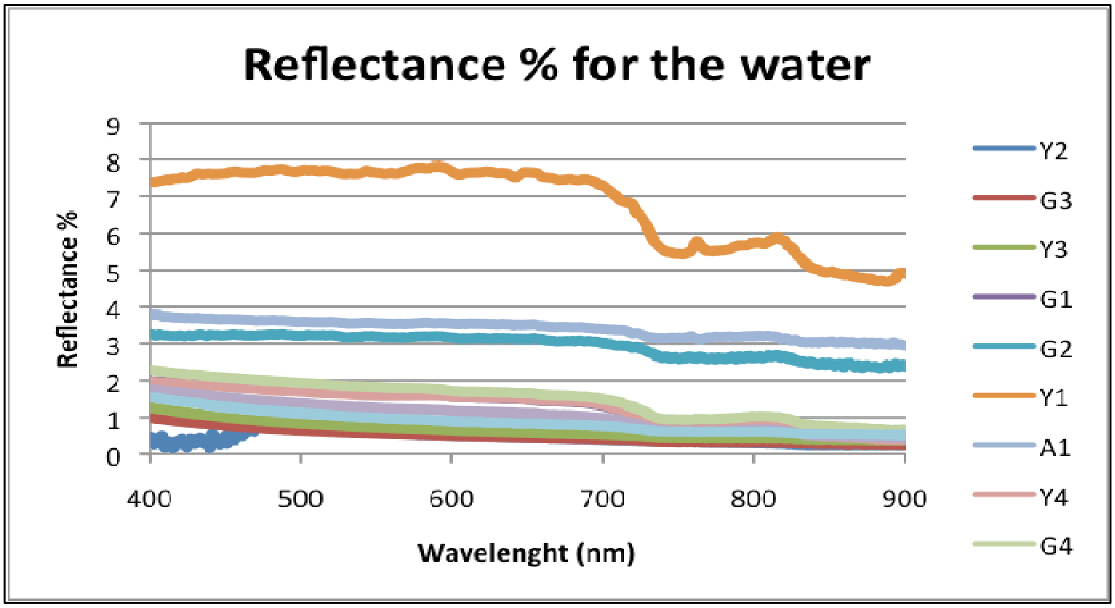


Figure 13: Reflectance curves for the water in which the sediments were added.

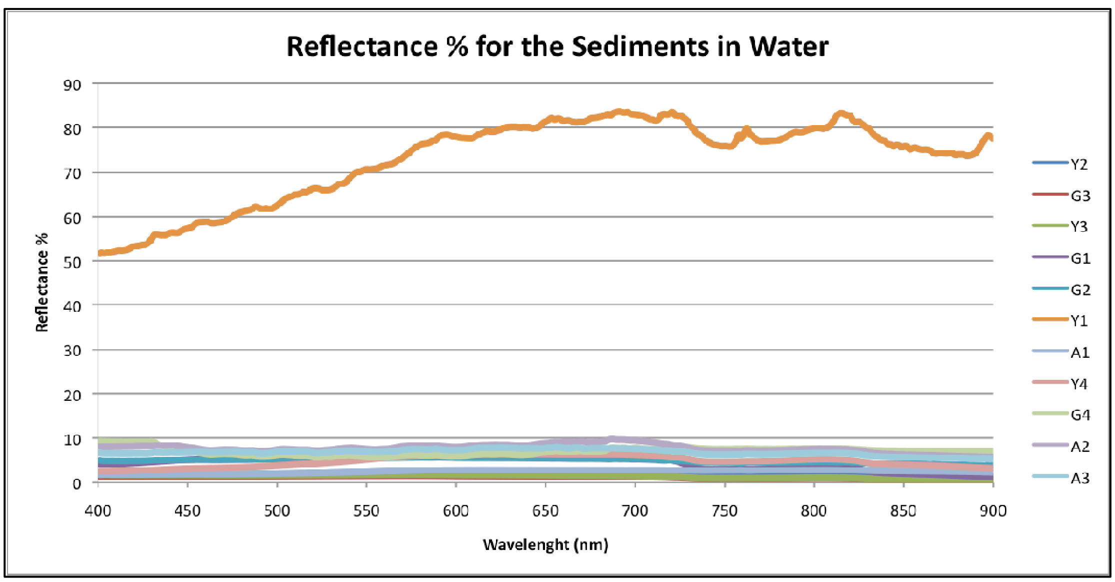


Figure 14: Reflectance curves for 7oz. of sample in water (these curves include the water reflectance).

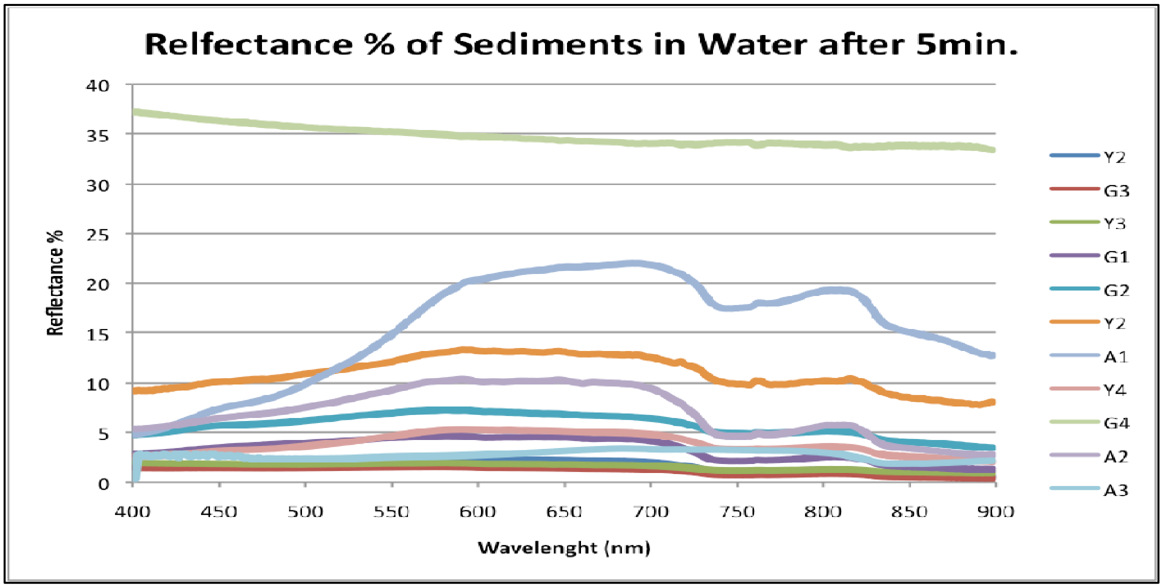


Figure 15: Reflectance curves for 7oz. of sample in water before 5 minutes (these curves include the water reflectance).

HR-1024:

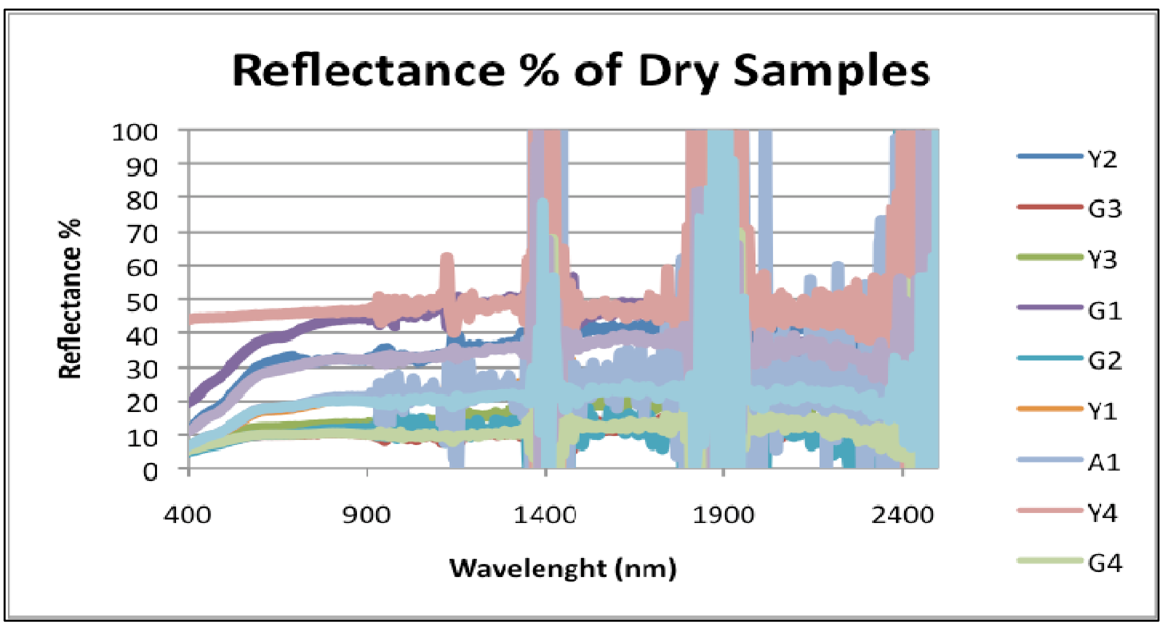


Figure 16: Example of the reflectance curves obtained by the HR-1024 for dry samples.

VII. Discussion

After analyzing the results of the experiments, the values of all these tests shows that all the sediments deposited along the Bay have different characteristics. The grain size distribution demonstrates that the offshore stations have grains with lower diameter than the onshore samples. Also the grain size varies along the different rivers; on the Añasco River the grains are smaller then in the Yagüez and Guanajibo. The composition of the sediments depends on the localization and the sources. In Guanajibo River we have more terrigenous components than in Añasco and Yagüez and the lack of organic matter was evident in all the samples. The XRD, mineral composition, reveals that the quartz is present in almost all the stations, which is reasonable because it is one of the most resistant minerals. Also demonstrate that halite is present, it because the samples were collected in a marine environment and when the sample was dried the salt precipitate and forms halite. The relation between the reflectance curves and the minerals on the sample is because quartz is present in almost all the samples, this mineral tend to have a high magnitude in the reflectance curve on the visible range (Chiques, 2004). The grain size also affects the reflectance curve in the visible range. Decreasing the grain size, increase the number of mirrors off which the light reflects (Vincent 1997) hence finer material will reflect more. However observations of the different experiments, when comparing the effect of the mineral composition versus grain size over the reflectance curve, the mineral composition influence the reflectance more than grain size (Chiques, 2004). On this research the stations with finer grain sizes are A2, Y2 and G2, which reflects more than the others in the dry measures. The reflectance percent on the sample after 5min. of mix the water and 7oz of sediments the Y3 station reflects more than the others (30%), this station have 83% of 0.25Φ grain size.

VIII. Conclusion

After finish this study of the bottom sediments of the Mayagüez Bay, I can conclude that they are difference on the grain sizes along the rivers that affect the study area. Also they are a difference of composition, but the minerals, quartz and halite are present in almost all the samples. The spectral response of the samples, in the visible range, also varies. I can note that the samples of more percent of fine sediments reflect more on the dry measure than the coarser grains. On the measures of the simulation of re-suspension, the coarser grain stations reflect more than the fine sediments. The measures of due on the infrared range are not valid to due comparisons in this study because the values are wrong. This is due to the card use for reference in the measures that not is allowed to reflect on those wavelengths. Although the results on this study will help to future works on the study of the area of the Mayagüez Bay.

IX. References

- Chiques, G., 2005, Spectral Characterization of Sandy Beaches in Western Portion of Puerto Rico: Mayaguez Campus, University of Puerto Rico Department of Geology, Unpublished Graduate Thesis, 55 p.
- Curet, A.F., 1986, Geologic Map of the Mayagüez and Rosario Quadrangle, Puerto Rico, U.S.G.S., scale 1:20 000.
- Donald C., 2007, Meteorology Today: An Introduction to Weather, Climate and the Environment, Thomson Learning, California, Eight Edition, 537p.
- Gilbes, F., López, J., and Yoshika, P., 1996, Spatial and temporal variations of phytoplankton chlorophyll-a and suspended particulate matter in Mayagüez Bay, Puerto Rico, Journal of Phytoplankton Research, Oxford University Press, FL, Vol. 18 no.1, 29-46 pp.
- Kineke G.C., Higginsa E.E., Harta K. and Velasco D., 2006, Fine-sediment transport associated with cold-front passages on the shallow shelf, Gulf of Mexico, Continental Shelf Research, , Vol. 26, Issues 17-18, p.
- Miller, R. L. and McKee, B. A., 2004, Using MODIS Terra 250 m imagery to map concentrations of total suspended matter in coastal waters, Remote Sensing of Environment, Vol. 93, 259–266 pp.
- Morelock, J., Kurt G. and Hernández, M.L., 1983, Oceanography and Patterns of shelf sediments Mayagüez, Puerto Rico, Journal of Sedimentary Petrology, Vol. 53, No. 2, 371-381 pp.
- Ramírez, W. and Morelock, J., 2003, Coral Reef Study, Mayagüez Bay, In Press.
- Vincent, R. K. 1997 Geological and Environmental Remote Sensing, Prentice Hall, Upper Saddler River, NJ, 357pp.

X. Acknowledgments

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