FINAL REPORT

Rehabilitation project for Viento Frío Beach, Colón Republic of Panama

Havana, Cuba
August / 2022

“IMPACT ASSESSMENT OF CLIMATE CHANGE ON THE SANDY SHORELINES OF THE CARIBBEAN: ALTERNATIVES FOR ITS CONTROL AND RESILIENCE”

Rehabilitation project for Viento Frío Beach, Colón, Republic of Panama.

August 2022

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REHABILITATION PROJECT FOR VIENTO FRÍO BEACH, COLÓN, REPUBLIC OF PANAMA

FINAL REPORT

I. INTRODUCTION

In January 2021, Contract 2/DECS/2021/01SS was signed between the Association of Caribbean States (ACS) and Inversiones GAMMA SA, company belonging to the Cuban Ministry of Science, Technology and Environment, with the objective of developing three executive beach rehabilitation projects in Viento Frío, Colón, Republic of Panama; Runaway Bay, Antigua & Barbuda; and Bonasse, Cedros Bay, Republic of Trinidad and Tobago.

However, due to the effects of the COVID 19 pandemic that affected the entire planet and had a direct impact on the availability of international flights, it was necessary to adjust the initial work schedule, which is why Supplement No. 1 to the Contract was signed, through which it is agreed to start the field work in September 2021, instead of the date originally planned for March of the same year.

By July 2021, ACS and GAMMA agreed to prioritize remote work (telecommuting) between GAMMA specialists and Focal Points, initiating the exchange of information and arrangements for logistical support of field expeditions to begin in the Republic of Panama.

Also in July, GAMMA delivered to the ACS the Service Inception Report, as well as a Contingency Plan aimed at facing the existing difficulties imposed by the health situation that affected the countries involved in the project and its impact on international flights, which still limited the possibilities of starting the field work of the projects on the scheduled dates.

In accordance with the Contingency Plan and as a result of GAMMA's arrangements with the airlines and the Cuban embassy in Panama, an advanced group of six Cuban specialists were able to travel to that country, together with the necessary equipment to start the field work on Viento Frío Beach, on August 13, 2021, 18 days before the date committed in Supplement No. 1 (September 1, 2021).

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The field work conceived in the Technical Task, which was part of the Contract to prepare the executive project for the recovery of Viento Frío Beach, was satisfactorily concluded in early October.

Among the main results of this stage, the following stand out: determination of the coastal system functioning, cartography coastal zone at a detailed scale, bathymetry of the seabed, sampling of sediments from the beach and the submarine slope, grain size analysis of sand samples collected in a field laboratory, and study and determination of the marine and terrestrial sand deposits, for their possible use as a borrow area in the rehabilitation and protection of Viento Frío Beach.

This report presents the results of the tasks carried out during the field work, as well as the complete study and design of the proposed solutions for the rehabilitation of this coastal sector, fulfilling the commitment to the ACS.

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II. PROJECT JUSTIFICATION

The continuous process of erosion to which the Caribbean coasts are subjected, both in the small island states and in those continental states that make up its entire basin, has been a constant source of concern and discussion in the different summits of heads of state of the Association of Caribbean States (ACS), as well as in other international forums and meetings.

The loss of territories due to coastal erosion, the effects on agriculture, infrastructure, communities, and the deterioration of the conditions to offer a high-quality tourism product, which for many of these states is their main source of income, constitute a problem that becomes of maximum priority for their own subsistence.

Understanding this problem, the Association of Caribbean States (ACS), with the assistance of Korea International Cooperation Agency (KOICA) and the technical supervision of Korea Institute of Ocean Science and Technology (KIOST), develop the project “Impact Assessment of climate change on the sandy shorelines of the Caribbean: Alternatives for its control and resilience”, which includes, under Component 4, section 4.1 Beach Rehabilitation Projects in Panama, Antigua & Barbuda and Trinidad & Tobago.

In the case of Panama, with an extension of 1,287.7 km of shoreline in the Caribbean basin, it is characterized by the proximity of the mountains to the sea with a great diversity of environments. Specifically, in the central area, where the Viento Frío town and Playa are located. There is a succession of narrow beaches between cliffs, inhabited by a population mostly qualified within the districts as living in extreme poverty, which puts it at a greater risk in the face climate change effects. (MiAmbiente, 2019).

As described in the report: *“Third National Communication on climate change in Panama”* (MiAmbiente, 2019), the latent impact due to sea level rise should be highlighted. Although there is a lack of records with sufficient coverage on the national coasts, there is evidence of its increase both thanks to specific records and the local perception of residents due to the loss of coasts and local infrastructure.

Continuing with this report, it is stated that; only tide gauge data indicates that in Puerto Colón (referred to as the Caribbean coast of Panama) the mean sea level increased 1.4 mm per year during the period 1909 and 1979 (USAID-BIOMARCC-GIZ, 2013). In relative terms, this implies an increase of almost 10 cm for those 70 years. However, the same study also analyzes this factor using satellite data for the period 1992-2012, and indicates an increase of 1.8 mm per year, which is equivalent to a total increase of 3.65 cm for this last period, representing a retreat of the beaches between 3.5 and 7 meters in 40 years.

Unlike many of the states in the region, the development of tourism towards the Caribbean coast of Panama is in its early stages. With the exception of Bocas del Toro Archipelago in the west end, Portobelo area in the central region, and San Blas Archipelago, in Guna Yala reserve, to the east of the country. In addition to other small undertakings that have some tourist development, economic activities in the area are focused on fishing, agriculture and livestock farming.

In the case of Viento Frío, located in the central region of the Panamanian Caribbean, it is a town made up of approximately 300 families, with a narrow beach 450 m long and protected on its front from waves from the open sea by a reef barrier with a high degree of deterioration. However, with a simple observation of its coastal sector, it can be detected that it has been subjected to an intense erosion process, the causes of which are the subject of a detailed analysis in the development of this project report. (Photo 1)

Photo 1. General view of Viento Frío Beach from its east end.

Given this scenario, the execution of a rehabilitation or enhancement project for this beach should seek the main objective of improving its aesthetic conditions, also influencing a more effective protection of the town against the effect of climate change-induced sea level rise, and thereby improving the living conditions of local population. With a better beach, the town can encourage

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leisure and recreation activities, creating new employment and income opportunities for its residents.

The solutions proposed and designed in this project respond to this objective, under the premise of not compromising the application of new actions to deal with sea level rise effects in future climate change scenarios. In addition, they are based on understanding the functioning of the coastal system, and applying economically and environmentally viable solutions.

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III. MATERIALS AND METHODS

- **Topography**

For the establishment of the topographic basis of the surveys, thanks to the support of the Climate Change Directorate of the Ministry of the Environment (MiAmbiente), on August 16, a meeting was held with the Director of the National Geographic Institute "Tommy Guardia" (IGNTG), lead entity of the Government of Panama for works in Geodesy, Topography, Cartography and Hydrography nationwide. The objective of this exchange was to learn about the working methodologies in the country, the existence of geodetic network points in the region, and the possibility of obtaining background information on bathymetric and topographic surveys in the study area.

As a result, it can be verified that there was very little background information that could be useful for the project, besides the fact that there were no points with known coordinates and heights that would allow us to tie our surveys to the national geodetic network. However, it was a fruitful exchange where the IGNTG showed great interest in collaborating, and provided us with information on the geodetic datum and the coordinate system used in the country (UTM 17 - WGS 84 – ITRF 2008). In addition, this institution was contracted to establish two points that would serve as the basis for our future surveys, thus leaving everything referenced to the system used in Panama.

As of Monday, August 23, with the participation of specialists and technicians from the Department of Geophysics and Special Studies of the IGNTG, the topographic basis was established to carry out the surveys of the beach.

In the sites previously identified by GAMMA specialists, two points with their landmarks were established and their corresponding coordinate and height data were defined, using a Trimble brand R8 GNSS receiver station. (Photo 2)

The coordinates were established using the reference of the network of CORS stations in Panama; while, for the height data, a point situated in Cuango town, which is located about 15 km east of Viento Frío, was used as a reference.

In order to verify the unevenness between the located points, a geometric leveling was carried out along the limit of the beach with the Viento Frío town (Figure 1). The coordinates of these points, as well as their height, obtained by the IGNTG, are shown in Table 1.

Table 1. Coordinates of the benchmark established in Viento Frío town by IGNTG.

List of UTM coordinates - WGS 84 – ITRF - 2008			
Benchmark	**Northing (m)**	**Easting (m)**	**Height (m)**
78-RA	1059738.526	674684.720	1.326
ACS	1059703.052	675040.831	1.226

Photo 2. IGNTG specialists during the work to establish the points for the creation of the topographic baseline.

Once the topographic basis was established with the collaboration of IGNTG, the conditions were created to carry out the topographic survey of the shoreline in Viento Frío town. It aimed at the morphological characterization of the coastal area and the position of the shoreline, essential elements for the design of future actions for the improvement or recovery of the beach.

This survey was carried out with the use of a Leica TS 10 Total Station (Photo 3), and its processing with the use of Leica FlexOffice Standard, Grapher 18 and Surfer 21 software.

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Figure 1. Scheme of the control geometric leveling between AEC and 78-RA points

Photo 3. Leica TS 10 Total Station

- **bathymetry**

In order to know the characteristics of the seabed relief and achieve a correct description of the coastal system functioning, through the application of mathematical models, a bathymetric survey was carried out on the entire beachfront and in areas that could potentially serve as sand borrow areas.

During these surveys, between September 21 and 30, 2021, 29 sounding lines were executed, with an orientation perpendicular to the coast and a density of 200 m, to depths close to 30 m. After completing the entire area planned at this scale, another 29 lines interspersed between the first ones were conducted, with equal density, to depths of 15 m, comprising the area between 10 and 30 m, at a work scale of 1:20,000, and in shallower depths at a scale of 1:10,000.

For the bathymetric survey, the following equipment was used, illustrated in photos 4 and 5.

- GPS Hemisphere VS 100.
- Stonex SDE 28 D Echosounder
- Laptop with HYPACK MAX 64 software

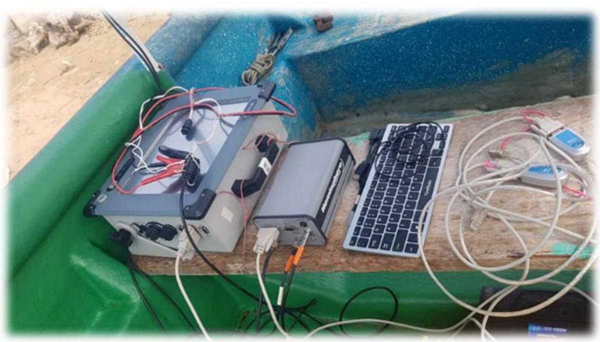

Photo 4. Stonex SDE 28 D Echosounder

Photo 5. Hemisphere VS 100 GPS receiver

For positioning, the Hemisphere VS 100 GPS receiver provides accurate and reliable position information at high update rates, which allows coordinate data to be assigned to each of the depth records obtained. For that purpose, it has a high-performance GPS engine and two multipath antennas for signal processing.

One antenna is designated as the primary GPS, while the other is designated as the secondary GPS. Knowing the fixed distance between the two antennas (by default 1.5m) allows the VS100 to restrict its search volume by calculating the heading data of the vessel.

This equipment works by finding four or more GPS satellites in the sky and using the information provided by them to calculate an appropriate position (within 2.5 meters). Since there is some error in GPS data calculations, it also tracks a differential correction, using the SBAS (Satellite Based Augmentation System) to improve your positioning accuracy to less than 1 meter.

For the work carried out, the antennas were located parallel to the center line of the vessel, with the primary antenna being installed in a position close to the stern and the secondary antenna towards the bow, separated from each other at 1.50 m (Photo 6).

Photo 6. Position of the GPS antennas on the boat

For depth determination, the echosounder transducer was mounted on the port side of the vessel, on the beam, thus managing to distance it from the sources of noise derived from the engine and the movement of the boat itself during the sounding work and at a depth of 0.60 m.

Before starting the measurements, the sound speed in the water was determined in the work area, using an AML brand sound speed profiler in the water column (Photo 7), and with these profiles, depths records were corrected in the post-processing stage.

Photo 7. AML sound velocity profiler

All the information from the echosounder and the GPS was collected on a laptop, using the Hypack Max 64 hydrographic software, where it was also processed and corrected. (Photos 8 and 9), (Plan 1)

Photo 8. Laptop during sounding work

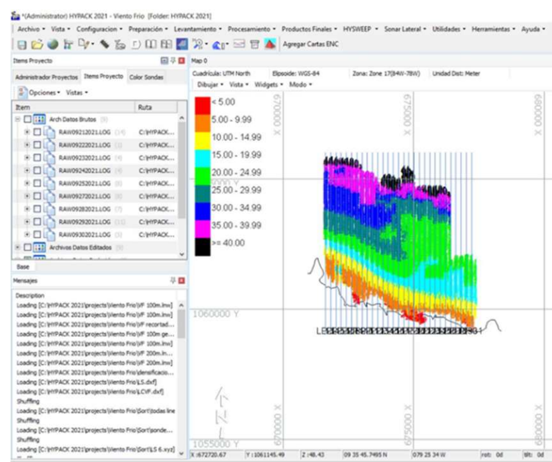

Photo 9. Line view in Hypack software.

- **Sedimentological sampling**

To carry out the sedimentological characterization of the beach, a total of 15 samples distributed along the entire shoreline were collected at representative points of the profile. In addition, during the explorations to locate a potential borrow area, a total of 12 samples were collected on the submarine shelf and 6 corresponding to the mouth of Cuango River, for a total of 33 samples.

For their grain size processing, a field laboratory was set up in one of the houses in town, where, following the methodology proposed by Petelin (1967) for the study and characterization of marine sediments, a Restsh 200 sieve shaker was used with a set of sieves of 0.063, 0.125, 0.25, 0.50, 1, 2 and 4 mm. Samples were sifted by the dry method, taking into consideration their sandy character.

The weight data per sieve were processed with Gradistat Version 4.0 software, developed by Simon Blott, from the Current Environments Research Group, Geology Department of the Royal Holloway University of London (Blott, 2001), obtaining the mean particle diameter (M), in units of mm and ø, and the standard deviation. For sediment classification, the one proposed by Wentworth (Shore Protection Manual, 1984) was used.

In order to know the genetic composition and origin of sediments, and considering their high homogeneity, a total of 3 samples were taken, one per each sampling area (beach, underwater slope and mouth of Cuango River). They were sent to the Geology Laboratory of the Cuban Institute of Marine Sciences.

For that purpose, after sifting the samples, fractions 2-1, 1-0.5 and 0.5-0.25 mm were chosen. Under the microscope, 200 grains of each of the fractions were randomly taken, from which the different groups were identified, according to their morphological characteristics. Finally, the percentages that each group represents with respect to the total sample were obtained.

- **diving exploration**

For the location of the sand borrow area for future execution of the project, and based on the bathymetric surveys, the exploration was carried out on a 15 km shoreline, from Punta Nicoya in the west end, to the front of the Cuango town on the eastern limit. The exploration was conducted by autonomous diving (Photo 10), in depths that ranged between 10 m and 40 m deep, always separated from the coast at a distance greater than 500 m, as recommended by the Mining Law of the Republic of Panama for mining of non-metallic minerals from the submarine shelf.

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Photo 10. Diving exploration work carried out jointly with specialists from the Directorate of Coasts and Seas of the Ministry of Environment of Panama

As a result of this work, several sand bodies were identified, which, however, did not have the necessary sediment quality for their use as borrow areas. In total, 20 diving stations developed, 12 of which were in sand bodies and 10 in reconnaissance transepts.

It should be noted that the participation of specialists and the diving equipment made available to us by the Directorate of Coasts and Seas of the Ministry of the Environment of Panama was very important for this work. During the work, the Panamanian colleagues, in addition to supporting the work, received training in the techniques of locating, sampling and exploring sand bodies in the open sea.

Considering that these works yielded negative results for the purpose of the project, it was necessary to find a borrow area located on land. After analyzing the available information and satellite images, it was possible to define this area at the mouth of Cuango River, which is the largest in the region and, in turn, the largest source of sediment input to the coastal system that comprises Viento Frío beach.

- **Meeting with the community**

Other important actions carried out during the execution of the field work were the meetings and interviews with residents of the area. This encounters enabled us to know the main concerns of the population regarding the beach, and they provided us with historical data; at the same time, during the exchange, the specialists from GAMMA and MiAmbiente explained the importance of the project, the effects of climate change on the coastal zones, and the contribution that they can offer based on the improvement and functioning of the beach.

It was an enriching experience that allows future actions planned and executed to be focused on the needs and concerns of the local population, the main beneficiaries of the project. (Photo 11)

Photo 11. Meeting of the GAMMA project team and MiAmbiente specialists with the community.

IV. PHYSICAL-GEOGRAPHICAL CHARACTERISTICS OF THE STUDY AREA

The Republic of Panama is geographically located at low northern latitudes (7°12'07" and 9°38'46" north latitude) and 77° 09' 24" and 83° 03' 07" western longitude. It is located in the easternmost and southernmost part of Central America, being the narrowest and longest territory in the Central American isthmus, with a west-east orientation. It limits to the north with the Caribbean Sea, to the south with the Pacific Ocean, to the east with Colombia and to the west with Costa Rica. (Figure 2)

Figure 2. Geographic location of the Republic of Panama

Panama has an area of 75,416.6 km^2, including inland waters, and is administratively divided into ten provinces, 78 districts or municipalities, three (3) indigenous comarcas – districts or counties – (Kuna Yala, Emberá, Ngöbe Buglé) with province status, two (2) comarcas (Kuna de Madungandí and Kuna de Wargandí) with corregimiento level (village or town), with which they complete a total of 648 corregimientos throughout the country.

As described by several authors (Stewart, 1968; Recchi and Metti, 1973; Graham, 1975), the origin and geological evolution of the Panamanian isthmus is closely linked to that of the neighboring continental regions that evolved in parallel. It is stated that it originated from the emergence of an arc of volcanic islands that went from the north of Costa Rica to the northwest of Colombia, built from the volcanic platforms. To this original archipelago correspond Nicoya and Ossa peninsulas in Costa Rica; Azuero peninsula, the eastern mountainous arc and the high blocks of southern Darién in Panama; and Chocó blocks in Colombia. Later, the most prominent mountains of this arc of islands were eroded and the sediments of said erosion were deposited towards the bottom of the waters of the Caribbean and the Pacific.

In the Miocene, the subduction of Cocos plate under the Caribbean occurs, activating volcanism and orogenesis. It is possible that these phenomena determined the formation of another arc of volcanic islands that correspond to the current Talamanca mountain range between Costa Rica and Panama, the Tabasará mountain range, the Veraguas and Coclé ignimbritic mountain ranges, the Anton Valley volcanic complex, and the numerous volcanoes of Capira.

The other great influential geological event in the natural history of Panama was the rise of a great geosyncline that took place during the Pliocene, located between the northeast of South America and the east of Panama, a consequence of the convergence of the South American and Nazca plates. This spectacular uplift formed the three branches of the Colombian Andes, and joined the Panamanian isthmus and the Cretaceous islands of Darién and Chocó with the great mass of the southern continent.

It is estimated that the formation of the Isthmus of Panama constitutes one of the largest and most important geological events that have occurred in the last sixty million years. In this way, the Isthmus of Panama influenced the global Oceanic Circulation System and atmospheric rainfall patterns, thus generating a great impact on the Earth's climate and its environment. (MyEnvironment, 2019)

Regarding climate, due to the low latitudes in which the Panamanian isthmus is located, it is classified in the tropical domain, subject to a great influence of the displacements of the Intertropical Convergence Zone (ITCZ), the topography, the location or east-west layout of the territory and access to two large oceanic masses.

In the *"Compilation of Hurricanes and cyclones in Central America and the Caribbean region"* (Méndez., 2010), it is stated that, due to its geographical position, Panama is the only country in the Central American isthmus that has been spared the direct blow of hurricanes; although those that form near Honduras and Nicaragua generate heavy rains that cause floods and landslides, especially in the Caribbean basin, where each year they cause hundreds of casualties. (Figure 3)

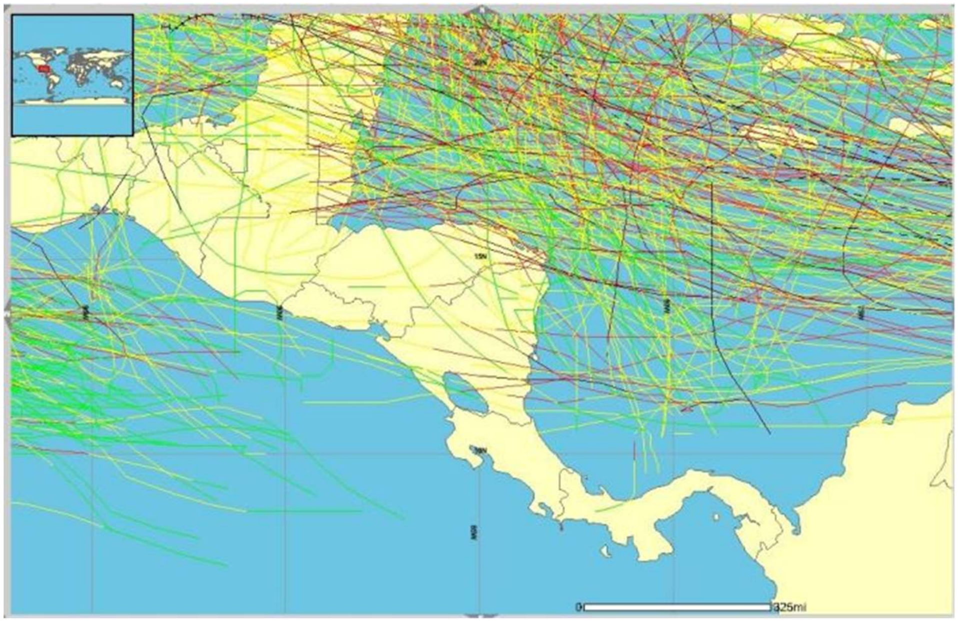

Figure 3. Hurricane paths in Central American and Caribbean region between the years 1851 – 2000. (Méndez, 2010). As can be observed, in 149 years of records, only one tropical organism of this type has touched Panamanian land.

Unlike most of the countries in the region, hurricanes or cyclones in Panama take a backseat as extreme erosive events for its coasts. The greatest significance of these organisms are their associated rains, and the waves that reach Panamanian coasts from the zone of formation or path through the Caribbean Sea.

Pluvial regime is characterized by originating, essentially, due to four ascendancies: thermal convection, ascending by convergence, coastal ascending and orographic ascending; in addition to presenting different characteristics depending on the slope.

On the Caribbean slope, the uniformity of rainfall throughout the year stands out, and in much of the area there is no defined dry season. On this slope, rainfall totals are high or very high, very often exceeding 4,000 mm per year. This is fundamentally due to the large amounts of moisture supplied by the permanently warm Caribbean waters, reinforced by coastal marine currents.

Annual temperature averages fluctuate between 24 ºC and 28 ºC and remain close to these values throughout the year. The annual thermal amplitudes are minimal in the lowlands of the Caribbean (1.9 ºC), and in the Pacific they fluctuate between 1.5 ºC and 2.5 ºC. This regime of constantly high temperatures is a consequence of the low latitudes in which the isthmus is located;

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At these latitudes, the thickness of the atmosphere traversed by solar radiation is less than at middle and high latitudes and, moreover, the incidence of radiation is stronger.

The strongest winds for the country are registered from December to May, with an average speed of 16.5 km/h, being February the month that registers the highest average speed, with 23.1 km/h. On the contrary, during May to December the average wind speed is calmer, being September the month with the lowest average speed, with 9.7 Km/h.

IV.1. Evaluation of the beach and current state

Viento Frío Beach is located in the corregimiento of the same name, belonging to Santa Isabel district, Colón province, on the Caribbean coast of Panama. It extends with a length of 450 m and an approximate Northwest-Southeast orientation. (Figure 4)

Figure 4. General location of the study area

In general, this coastal sector can be classified as an inland beach, protected from the direct action of deep-water waves by an intertidal barrier of coral origin, where the greatest exchange of water occurs through an opening 120 m wide in its Central sector, in addition to the overflow at times of high tide and strong waves. Once inside this barrier, two channels with a sandy bottom bifurcate, which maintain their depth due to the ebb and flow currents generated by the tide. The first of these channels extends from the center to the westernmost part, with a maximum depth of

4 m; while the second extends to the east with a maximum depth of 9 m, ending at the mangrove coast adjacent to the beach. (Figures 5 and 6)

Figure 5. General view in plan of Viento Frio Beach.

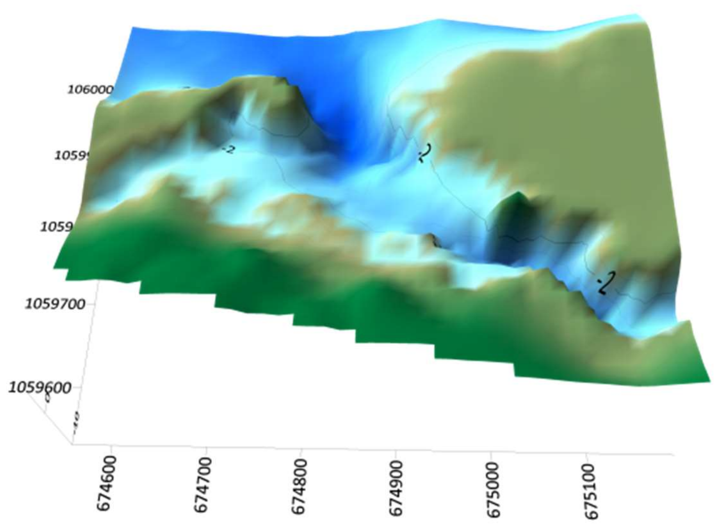

Figure 6. 3D digital model of the main morphological elements of Viento Frío Beach.

Once behind the barrier, towards the beach area, the coral terrace re-emerges, dominating almost the entire area that should be occupied by the underwater slope of the profile. Despite its short length, three sectors can be distinguished in this coastal stretch (Figure 7), with their typical profiles that characterize it.

Figure 7. Typical sectors of Viento Frio Beach.

1. The eastern sector, 90 m long, is made up of a small inlet with shallow waters, whose limits are: to the east, a dock for boats and to the west, the abrasive terrace that extends towards the rest of the beach. The profile in this area is characterized by having totally lost the emerged area and, in its place, the protective walls of the existing houses extend nowadays. As for the submerged profile, it has a gentle slope up to an average distance of 25 m from the shore, where it falls abruptly to form a navigable channel with a depth of 6 m. (Figure 8, photo 12)

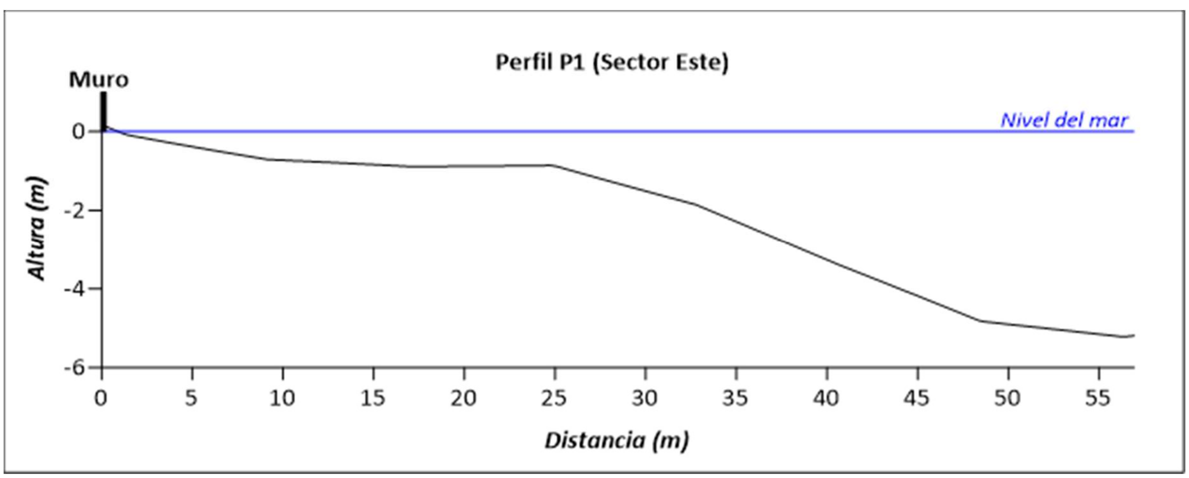

Figure 8. Typical profile of the eastern sector of Viento Frío Beach.

Photo 12. General view of the eastern sector of Viento Frío Beach.

2. Next, in the Central sector (Figure 9, Photo 13), with a length of 200 m, the beach is characterized by also presenting an incomplete profile with a narrow strip of emerged sand and a total absence of dunes, in whose position there are houses and, in some sections, it borders directly on the street. As for the submerged profile, it is occupied by an intertidal terrace of coral origin whose width varies between 66 m and 33 m. In general, the strip of sand or emerged beach has an average width of 15 m.

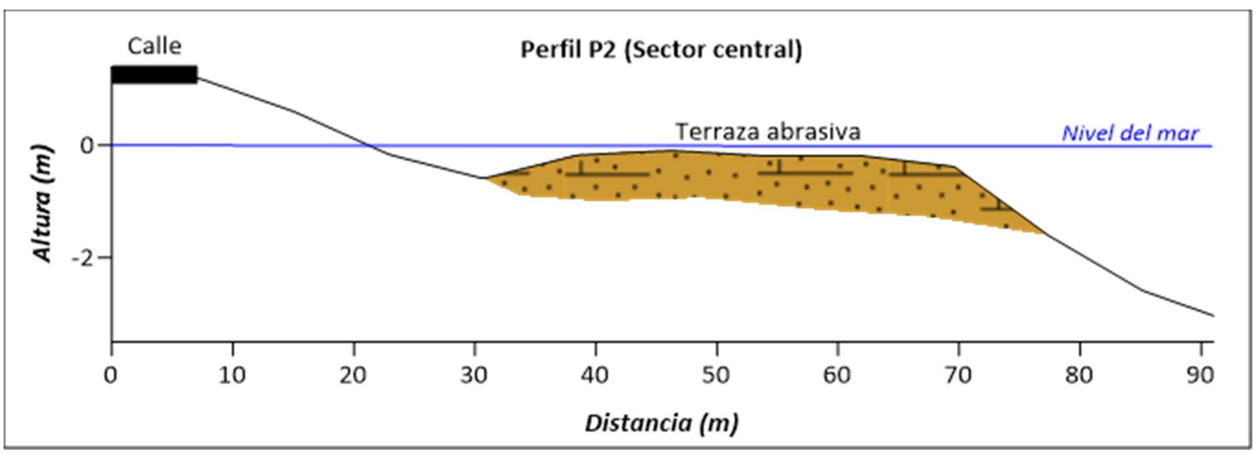

Figure 9. Type profile of the Central sector of Viento Frío Beach.

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Photo 13. General view of the Central sector of Viento Frío Beach.

3. Finally, at the western end, with a length of 160 m, the terrace is divided and alternates, next to the profile of emerged terrace and sand, two small stretches of beach with sand on the underwater slope. Likewise, the absence of coastal dunes is maintained, with the existence of houses in their position. The average width of the beach in this sector is 20 m. (Figure 10, Photo 14)

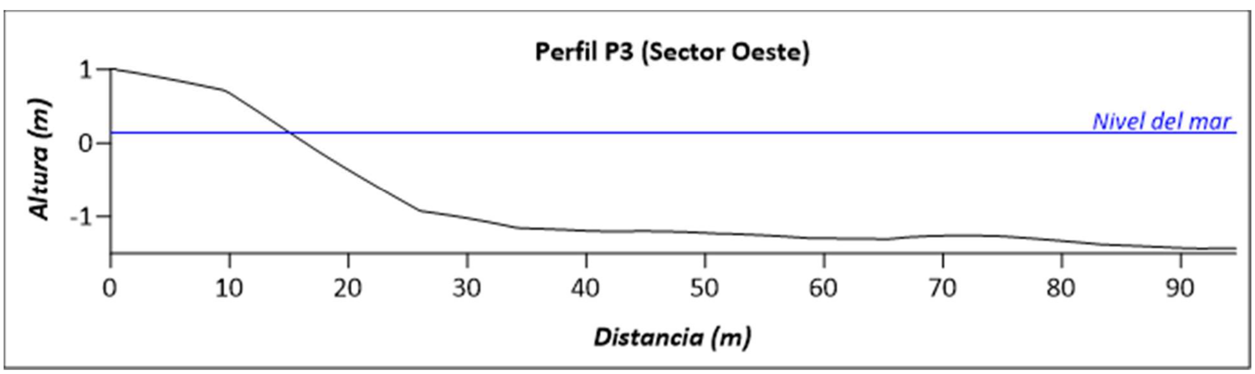

Figure 10. Typical profile of the western sector of Viento Frío Beach.

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Photo 14. General view of the western sector of Viento Frío Beach..

Regarding sediments, as can be observed in Table 2, they are classified as Fine Sand, with an mean particle diameter (M) of the type sample of 0.19 mm, according to Wentworth classification, proposed in the Shore Protection Manual (1984), without observing remarkable differences that force to particularize the possible solutions for this cause. It should be noted that, especially in the western sector, next to the sand, there is a large amount of pebbles and boulders, which may be an indicator of the deficit of new inputs to the beach from the original source that led to its origin, predominating the destruction of the stone structure of the reef barrier over other marine organisms such as calcareous algae, corals or mollusks, among others.

To know the genesis and composition of the sediments, due to the high homogeneity present in the samples, the analysis was only carried out on one of them (M9), corresponding to the foreshore of the profile that describes the Central sector. According to the results obtained, in the sample the remains of biogenic origin predominate, which represent 73.7% of the sample divided into its different groups, where the calcareous algae remains present the greatest abundance with 48.6% of the total, followed by mollusks with 10.6% and bioclasts (remains that can be identified as of biogenic origin but, due to their wear or conglomerates, it is impossible to identify their genetic group) with 14.5%. The rest represents sediments of terrigenous origin with 22.8%, while other groups, also mostly of biogenic origin, represent 3.3% (here there are foraminifera, bryozoans, echinoderm spicules, sponges, among others).

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Table 2. Results of grain size analysis of the samples from the Viento Frío Beach.

Sample	Sieve Range								M		Stand. Dev. (Ø)	Wentworth Classification
	>4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.062	< 0.062	(mm)	(Ø)		
M1	0	0.3	0.5	6.4	82.1	10.4	0	0	0.35	1.521	0.46	Medium Sand
M2	0.6	2.1	2.6	6.8	57.4	29.6	0.2	0	0.31	1.609	0.82	Medium Sand
M3	22.5	23.5	9.7	4.2	29.7	9.9	0	0	1.53	-0.613	1.33	Very Coarse Sand
M4	42.3	31.1	12.0	3.9	7.4	3.3	0	0	3.37	-1.752	1.01	Very fine sand and gravel
M5	35.4	14.2	5.5	23	20.0	21.9	0.7	0	0.56	0.643	1.353	Coarse sand
M6	0.5	0.6	1.8	3.3	30.5	60.3	2.7	0	0.23	2.064	0.752	Fine sand
M7	0	0	0.3	1.4	62.5	34.8	0.4	0	0.28	1.838	0.527	Medium Sand
M8	0	0	0	0.5	30.6	66.6	2.1	0	0.22	2.204	0.510	Fine sand
M9	0.9	0.2	0.9	3.8	45.6	43.4	4.2	0	0.24	1.947	0.722	Medium Sand
M10	3.4	5.9	6.7	26.2	48.2	8.9	0.7	0	0.40	0.979	0.991	Medium Sand
M11	1.3	4.2	4.3	9.9	40.6	35.9	3.3	0	0.30	1.595	1.080	Medium Sand
M12	0	0.2	0	0	4.5	78.0	17.0	0.2	0.16	2.620	0.489	Fine sand
M13	0.7	1.8	0.9	3.1	20.8	62.0	10.5	0.2	0.21	2.222	0.883	Fine sand
M14	0.4	1.3	1.9	3.9	12.0	53.4	25.5	1.5	0.18	2.467	0.996	Fine sand
M15	0	0	0.1	0.7	3.5	55.7	38.5	1.5	0.14	2.861	0.618	Fine sand
Type S.	**7.2**	**5.7**	**3.1**	**5.1**	**33.0**	**38.3**	**7.1**	**0.2**	**0.19**	**1.639**	**1.232**	**Fine sand**

As can be observed, the laboratory results confirm the predominance of calcareous sediments of marine origin, although the sample also shows a high percentage of sediments from sources on land through the small but numerous rivers and streams that flow into the region. In general, the sediments have a great maturity, especially the majority group of calcareous algae, which appear with their very polished angles, evidence of a high exposure to drag by currents and waves. Regarding its color, these sediments do not have the typical light cream color found in other regions of the Caribbean, despite having a very similar origin; instead, it is light brown, as it is probably dyed by the interaction with other sources of organic matter input, such as the mangrove forests that surround the area in its eastern sector.

An interesting feature is that, despite this being the most general description of the sample, percentages of very angular algae and mollusks remains were also found, which is an indicator of recent inputs. This peculiarity, together with the existence of boulders from the destruction of the barrier reef that borders the beach, indicates that, at present, part of the sediment is still being contributed from this area. Although the health of this reef is not the best at present, there is a large colony of Halimeda algae and other calcareous organisms that are part of the source of input, although without the abundance of past eras when the formation of this beach occurred.

In the exploration carried out outside the barrier, in a wide area that includes from Punta Macolla, in the West, to Cuango town (Length 20 km), in the East, through bathymetric surveys and diving stations (Plan 1), it was possible to detect that the shelf generally extends with a gentle slope until it reaches a depth of 40 m at a distance of approximately 5 km from the shoreline.

Figure 11 shows a cross-section of the shelf to a depth of 40 m at the very front of Viento Frio. The main characteristic in this zone is that, immediately after the barrier that protects the beach, the bottom is dominated by the existence of sandy-clayey sediments, up to a distance of approximately 2,500 m and 25 m deep. From this point a rocky bottom extends, with the existence of furrows with very poorly sorted coarse sand and an abundance of species of algae, corals, gorgonians, sponges and other benthic species, which are biogenic sand producers. Once this zone, which varies in width over 2,000 m along the entire coastal zone, is exceeded, the depth falls abruptly until it reaches 40 m deep, where the predominance of sand-clay sediments is observed again.

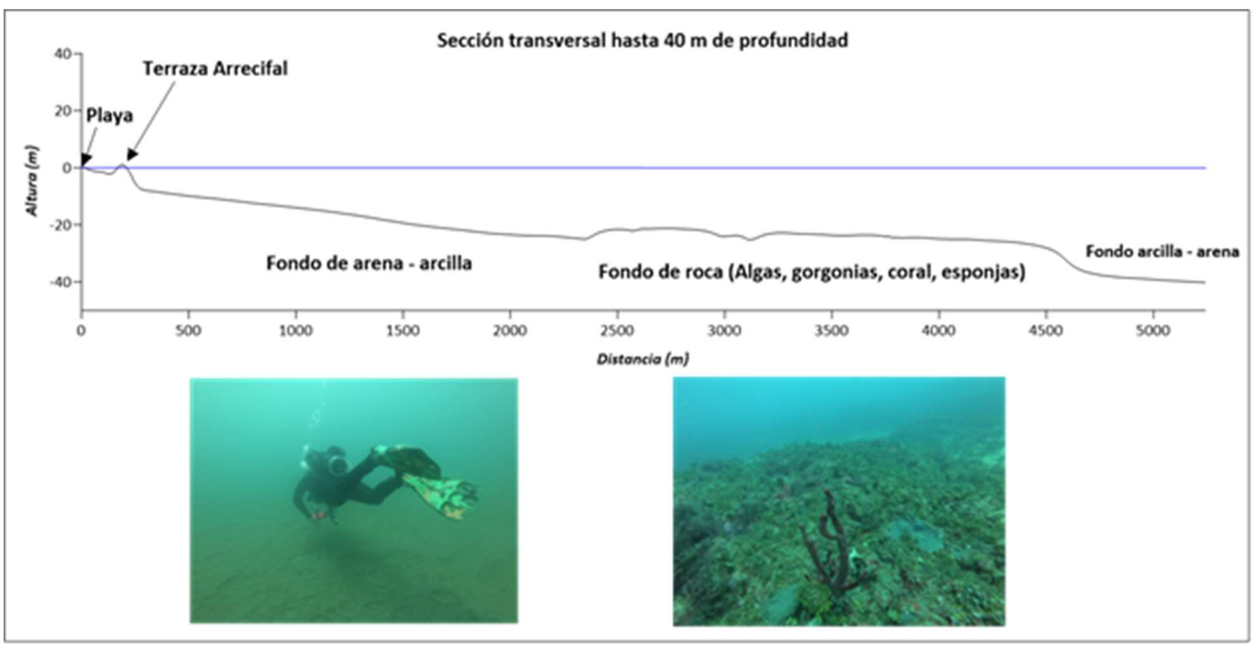

Figure 11. Cross-section of the submarine shelf from Viento Frío Beach to a depth of 40 m.

This biogenic sand production area also constitutes a source of sediment input to the system; its existence explains the formation of several sectors of biogenic beaches, in addition to Viento Frío, along the entire coastal zone.

In short, Viento Frío Beach is a small strip of sand 450 m long, formed inside a cove protected by an intertidal terrace of coral origin. On the shoreline, cumulative and abrasive forms are combined with an incomplete beach profile, due to the absence of dunes, and in a good part, the existence of a stone or lapié terrace in the area that the underwater slope of the beach should occupy. Anthropogenic modifications to the system have contributed to the loss of the emerged area in the eastern sector and contain it in the rest.

The sediments are classified as fine sand and are mostly of biogenic-marine origin, although they present a high percentage of terrigenous material. They are light brown in color, as they are stained by the interaction with organic matter input from the mangrove forests and the numerous rivers and streams that flow into the area. The main sources of sediment inputs can be located in two zones. The first is the barrier of coral origin that protects the beach, where there is an extensive colony of algae and other calcareous organisms. The second is the sector of the submarine shelf located about 2,500 m from the coast and 25 m deep.

IV.2. Characterization of the hydrodynamic regime

Due to the low latitudes in which the Panamanian isthmus is located, the climates all belong to the tropical domain, subject to a great influence of the displacements of the Intertropical Convergence Zone (ITCZ), topography, location or east-west orientation of the territory and access to two large oceanic masses.

According to studies carried out by the Electricity Generation Company (ETESA, 2016), among other factors, the climate in the region is determined by the influence of the semi-permanent North Atlantic Anticyclone, generating an almost permanent influence of trade winds from the northeast in the lower layers of the atmosphere.

To carry out the analyzes and assessments for this project, and given the difficulty of finding meteorological data that could be related to the work area, the data series of oceanographic buoys 42058 and 42059 were taken. These buoys are located in the Eastern Caribbean, positioned at a distance of approximately 700 km and 1400 km respectively, and belong to the National Oceanic and Atmospheric Administration (NOAA) of the United States government. (Figure 12)

From the hourly daily records of these buoys, the wind rose was constructed, collecting the 16 years of measurements between the years 2005 - 2021 (Figures 13 and 14), after filtering the series to discard erroneous or lost data. Hourly data were averaged to reduce them to a daily data, in the case of wind speed, to determine the mean value, the arithmetic mean was calculated directly and, in the case of wind direction, to determine the mean value, the mean angle.

Likewise, Tables 3 and 4 were created, where the volume of observations broken down by classes (speed segments) and courses are summarized.

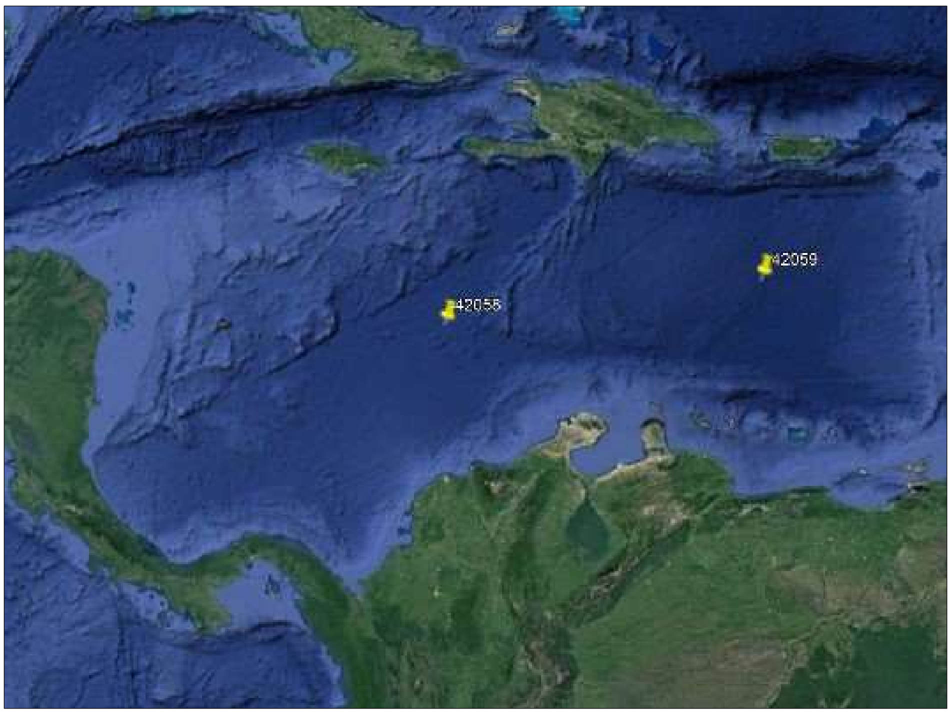

Figure 12. Location of oceanographic buoys 42058 and 42059, belonging to NOAA, in the Eastern Caribbean.

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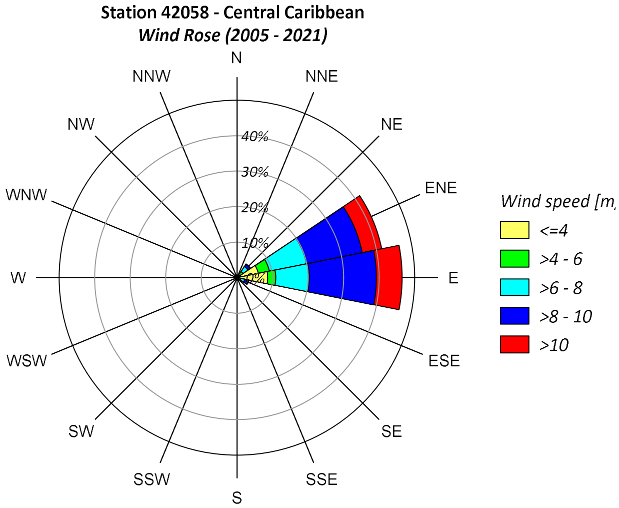

Figure 13. Wind rose for all directions. NOAA station 42058. Measurement period 2005-2021.

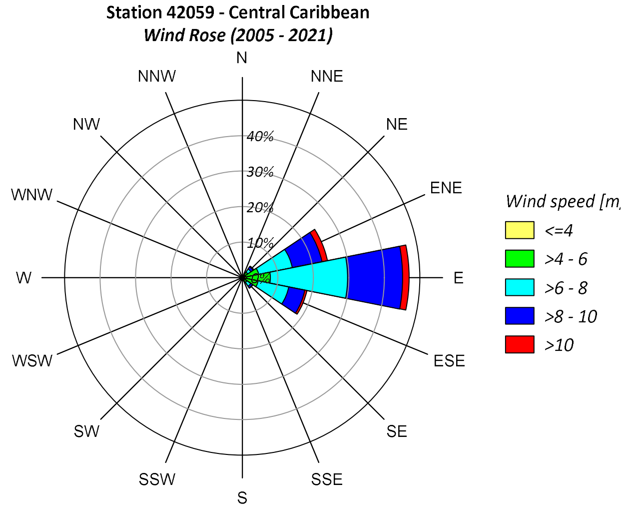

Figure 14. Wind rose for all directions. NOAA station 42059. Measurement period 2005-2021.

Table 3. Summary of winds by direction for NOAA station 42058.

Directions	Wind speed (m/s)					Frequency
	< 4	4 - 6	6 - 8	8 - 10	> 10	
N	376	70	98	29	18	0.26%
NNE	459	657	353	90	31	0.70%
NE	1394	3233	3884	1720	300	4.66%
ENE	13856	7178	24064	36109	12549	41.50%
E	19530	5101	21241	42709	16417	46.48%
ESE	1156	1354	2467	2284	517	3.44%
SE	636	454	338	183	64	0.74%
SSE	445	286	89	46	13	0.39%
S	423	162	70	32	10	0.31%
SSW	288	118	85	59	22	0.25%
SW	311	126	76	58	42	0.27%
WSW	299	98	51	21	34	0.22%
W	307	63	29	22	7	0.19%
WN W	286	48	30	8	4	0.17%
NW	361	57	15	3	2	0.19%
NNW	374	86	29	2	3	0.22%
Total	**40501**	**19091**	**52919**	**83375**	**30033**	**100.00%**

Table 4. Summary of winds by direction for NOAA station 42059.

Directions	Wind speed (m/s)					Frequency
	< 4	4 - 6	6 - 8	8 - 10	> 10	
N	393	127	182	18	6	0.26%
NNE	442	531	248	91	26	0.48%
NE	2497	2657	2930	2088	656	3.92%
ENE	2660	10379	26517	23544	4380	24.45%
E	3399	18473	59936	42739	5028	46.95%
ESE	2463	10156	24198	12735	1578	18.53%
SE	1394	2983	3630	1618	346	3.61%
SSE	699	749	717	260	74	0.91%
S	234	181	156	57	41	0.24%
SSW	157	97	56	16	8	0.12%
SW	128	59	22	5	6	0.08%
WSW	90	66	28	15	5	0.07%
W	85	92	67	4	3	0.09%
WNW	100	73	37	6	0	0.08%
NW	117	74	36	27	6	0.09%
NNW	105	75	63	18	6	0.10%
Total	**14963**	**46772**	**118823**	**83241**	**12169**	**100.00%**

According to the wind rose shown in figure 13 and table 3, corresponding to the data of buoy 42058, those between the east southeast and northeast directions represent 96.08% of the total cases of the records, more concentrated in the east (46.48%) and east northeast (41.50%) directions, which demonstrates the marked influence of the trade winds on the Eastern Central Caribbean region. The average wind speed recorded was 7.7 m/s and the maximum was 33.2 m/s, the latter associated with the passage of Hurricane Matthew in October 2016.

On the other hand, in the case of buoy 42059 (Figure 14 and Table 4), the predominant wind directions are concentrated between the SE and NE (97.46%), with those from the east predominating with 46.95% of the cases. Unlike buoy 42058, a greater dispersion is observed for this position, with significant values in the ESE (18.53%) and ENE (24.45%) directions, also showing the predominance of trade winds influence in this area of the Caribbean Sea. The mean speed recorded was 6.93 m/s, while the maximum was obtained on September 29, 2016 with a value of 22.5 m/s, which can also be associated with the influence of Hurricane Matthew.

Taking into account the information provided, it can be asserted that, for the study area, the east component winds predominate, governed by the trade winds, which have an occurrence of more than 85% of the registered cases.

The shoreline in the work area has an east-west orientation, so the influence of the winds on the hydrodynamic processes that take place in its vicinity will be concentrated in the 1st and 4th quadrants in the directions between east northeast and the west northwest. (Figure 15)

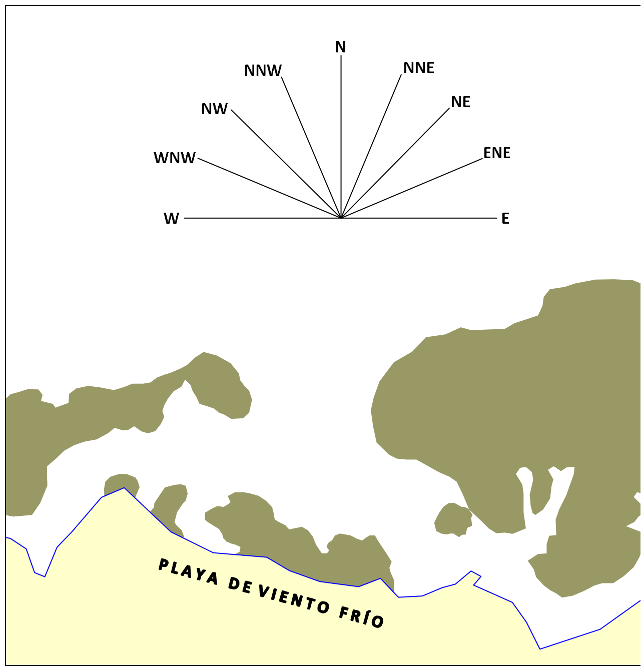

Figure 15. Wind directions that influence the hydrodynamic processes in Viento Frío Beach.

Taking the results of the data series of buoy 42058 (Figure 13, Table 3), the closest to the work zone, it can be observed that 47.7% of the cases occur from WNW to ENE directions, which, in terms of time means 5.8 months a year with winds from these directions.

Continuing with the results obtained from buoy 42058, it also provides wave data (direction, period and height). From the wind analysis, and taking into account the directions of interest for the study area, the series was filtered and reduced to these directions. Figure 16 shows the wave rose (Hs) for all directions, and Figure 17 shows the wave rose (Hs) for the directions of interest, as well as the summary tables of the volume of observations, broken down by segments of height and directions (Tables 5 and 6).

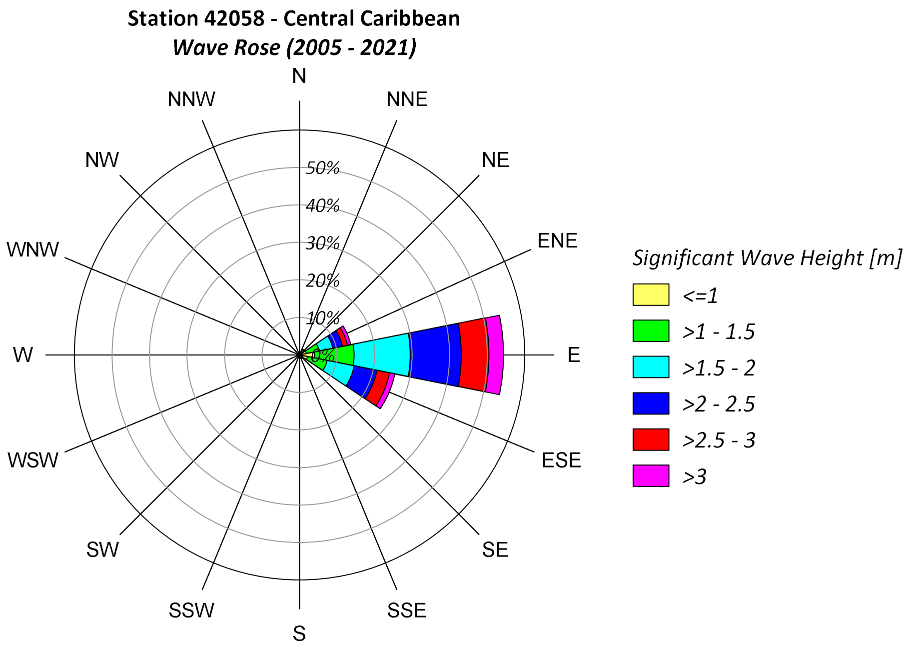

Figure 16. Wave rose for all directions. NOAA station 42058. Measurement period 2005-2021

Table 5. Summary of waves by directions for NOAA station 42058.

Directions	Significant Wave Height (m)				Frequency
	< 1	1 - 2	23	> 3	
N	189	97	43	29	0.45%
NNE	216	151	63	31	0.56%
NE	440	436	319	187	1.74%
ENE	1595	2987	3176	2284	13.89%
E	3437	9093	12902	11755	54.36%
ESE	1847	4567	6378	5326	25.87%
SE	197	259	192	154	1.10%
SSE	47	19	22	1	0.08%
S	66	33	8	0	0.12%
SSW	139	79	16	1	0.28%
SW	101	38	14	8	0.25%
WSW	103	35	18	2	0.19%
W	101	48	26	1	0.21%
WNW	183	48	16	11	0.31%
NW	191	38	18	5	0.30%
NNW	121	72	34	9	0.29%
Total	**8973**	**18000**	**23225**	**19804**	**100.00%**

From the wave rose and the summary table referring to all directions, the highest percentage of occurrence (94.12%) of the waves that were recorded in the central zone of the Caribbean Sea takes place from east northeast to east southeast, which is in correspondence with the results of the analysis of the wind series. Likewise, it stands out that for the east direction, 54.36% of the cases were registered.

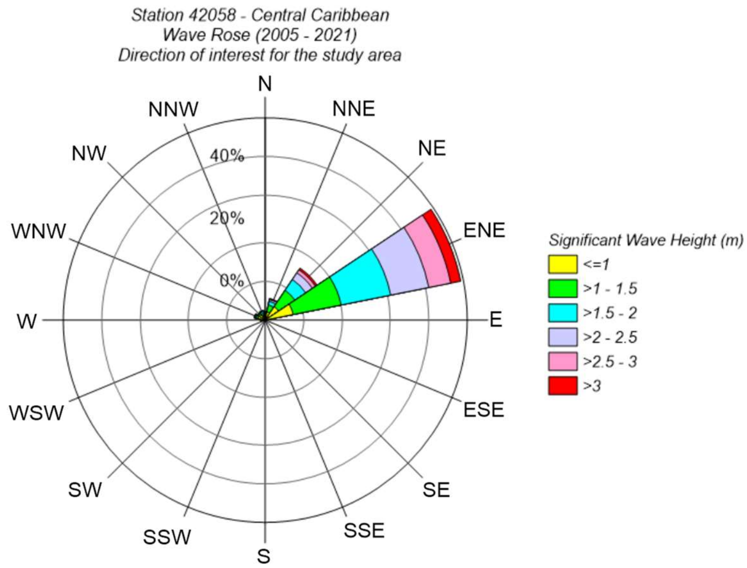

Figure 17. Wave rose for directions of interest. Buoy 42058, measurement period 2005 - 2021

Table 6. Summary of waves by directions of interest for the study area. NOAA Station 42058.

Directions	Significant Wave Height (m)				Frequency
	< 1	1-2	23	> 3	
N	189	97	43	29	2.76%
NNE	216	151	63	31	3.55%
NE	440	436	319	187	10.64%
ENE	1595	2987	3176	2284	77.31%
WNW	183	48	16	11	1.99%
NW	191	38	18	5	1.94%
NNW	121	72	34	9	1.82%
Total	**2935**	**3829**	**3669**	**2556**	**100.00%**

Once the data is filtered for the directions of interest, the results presented in Figure 17 and Table 6 are obtained. As can be observed, the predominance of the wave directions of the first quadrant is maintained, where the ENE directions represents the 77.31% of all recorded measurements, followed by NE directions with 10.64%.

From the data obtained from buoy 42058, the mean scalar regimes of the parameters of sea conditions, significant wave height (Hs) and peak period (Tp) in indefinite depths for the Central Caribbean Sea were determined, which, they have been drawn up on a maximal Gumbel probability paper (Figure 18 and 19).

These mean regimes represent the mean annual wave conditions for the Central Caribbean Sea, where waves from tropical storms are not taken into account, considering the latter of interest to determine the extreme wave regime in the area.

Panama is not located in the typical path of tropical storms or hurricanes that move through the Caribbean basin; however, eventually, it could be touched by one of these organisms. To date, there is only a record of Hurricane Martha, in November 1969, which, in its short journey, moved directly over Panamanian land. (ETESA, 2010)

Yet, the country is affected in one way or another by the climate conditions associated with these tropical organisms in their movement through nearby latitudes. Rains are the main impact reported so far, but undoubtedly, the generated waves reach the coasts and cause damage to them.

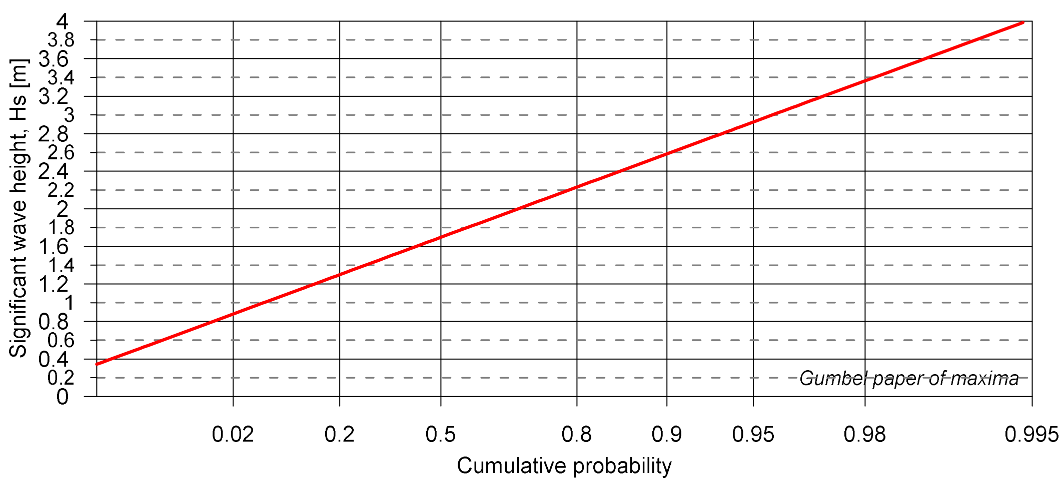

Figure 18. Typical mean regime of significant wave height at indefinite depths. NOAA station 42058. Measurement period 2005-2021.

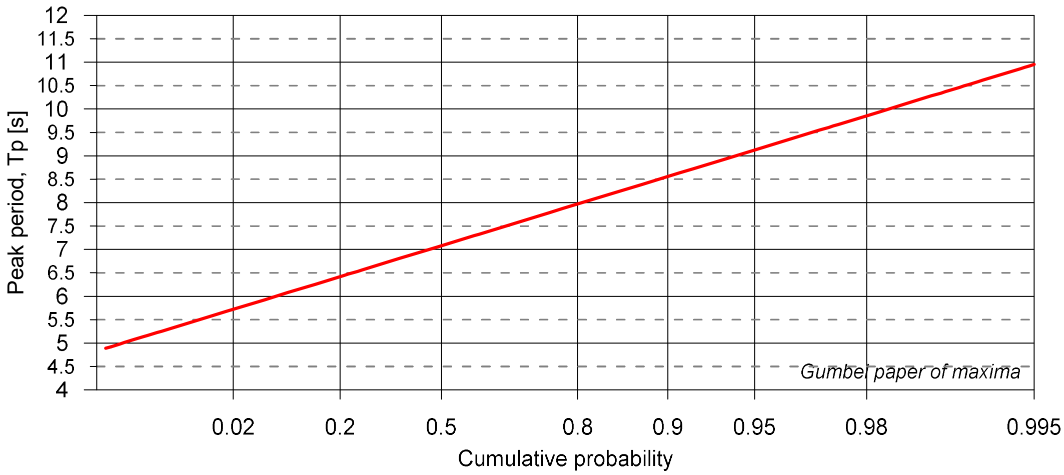

Figure 19. Typical mean regime of the peak period at indefinite depths. NOAA station 42058. Measurement period 2005-2021.

Due to its location in the Central Caribbean, buoy 42058 is capable of recording a large part of the waves associated with tropical storms that, in one way or another, affect the Panamanian coasts. Therefore, following the same methodology, its data was processed and Figure 20 shows the extreme regime of significant wave height obtained, adjusted to a Gumbel distribution of maxima.

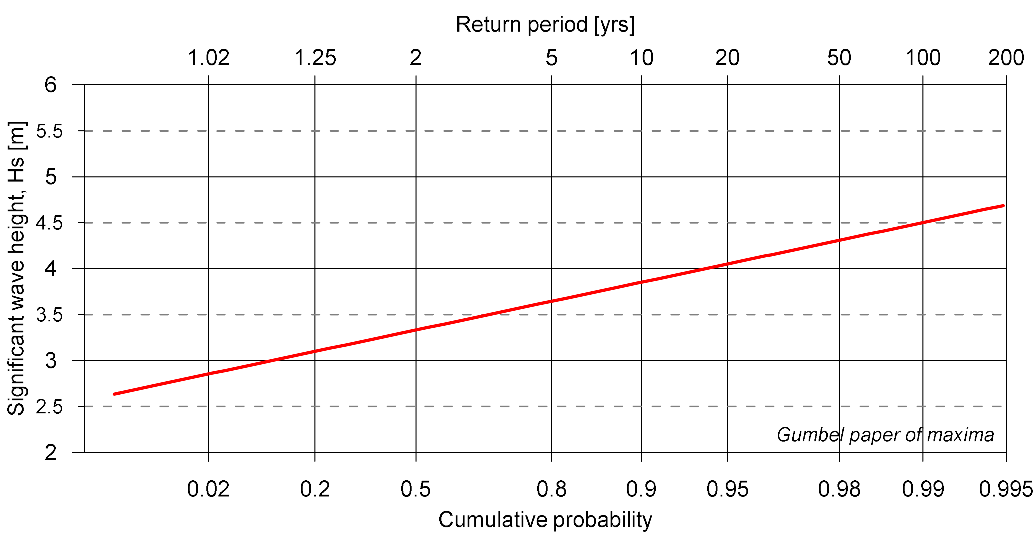

Figure 20. Significant wave height extreme regime at indefinite depths. NOAA station 42058. Measurement period 2005-2021.

IV.3. Characterization of wave dynamics by modeling wave fronts.

Wave propagation towards the coast produces transformations in the wave fronts, mainly caused by the phenomena of refraction, diffraction, breaking and dissipation by the seabed, and therefore, alterations in the spatial distribution of wave energy are also produced.

To characterize wave dynamics it is necessary to propagate wave fronts from deep waters in the Caribbean Sea towards the coast. These propagations have been carried out using the Oluca-SP Wave Propagation Model, of the Coastal Modeling System (SMC), developed by the Oceanographic and Coastal Engineering Group of the University of Cantabria, Spain.

Spectral waves were propagated, using a frequency spectrum type TMA (Texel Marsen Arsloe) (Bouws *et al*., 1985), which is applicable in areas near the coast where depths are shallow and wave is affected by the seabed and defined from a JONSWAP spectrum. The propagations were carried out for the 2 scenarios indicated in Table 7 and the results are shown in this section.

Table 7. Wave parameters for scenario modeling.

Parameter	**Scenarios (Waves)**	
	Usual	**Storm waves**
Significant Height (Hs)	1.7m	4.1m
Peak Period (Tp)	7s	12s
directions	NE, N, ENE	NE, N, ENE

The wave data used for the model runs refer to the mean scalar and directional regimes of the sea condition parameters at indefinite depths.

The usual wave scenario corresponds to the mean annual conditions (50% probability) shown in figure 18, which describes the average regime for the directions of interest in the coastal zone of Viento Frío.

For the extreme wave scenario, an event with a probability of occurrence of 5 years was simulated.

The graphic results of the modeling presented in this study are the isolines and wave direction vectors (significant wave height Hs), which will allow the spatial characterization of wave behavior on its way to the coast.

The wave propagations results are presented in Annex 2, together with all the mathematical modeling carried out for the different scenarios. Typical situations for the two modeled scenarios are discussed below.

Usual wave scenario.

The usual wave is the one that represents the mean annual conditions, which are produced by the trade winds. This scenario is one of those responsible for the cumulative stages of the beaches.

Figure 21 shows the result of the simulation carried out for the east-northeast direction, in Viento Frío area, which is the predominant direction, therefore, representative of this scenario.

The analysis of Figure 21 shows that, under usual conditions, the waves propagate with an incidence angle of 45° with respect to the coastal zone. When approaching the abrasive terrace, the wave trains begin to suffer effects in the direction of propagation, which are visible within the breaking zone, damping all their energy when interacting with this natural element. Only in the existing opening, approximately 115 m wide, very dissipated wave trains are maintained, with waves of less than 0.5 m prevailing towards the beach area.

Under these conditions the effect of waves on the transformation of the profile is practically null due to its low energy.

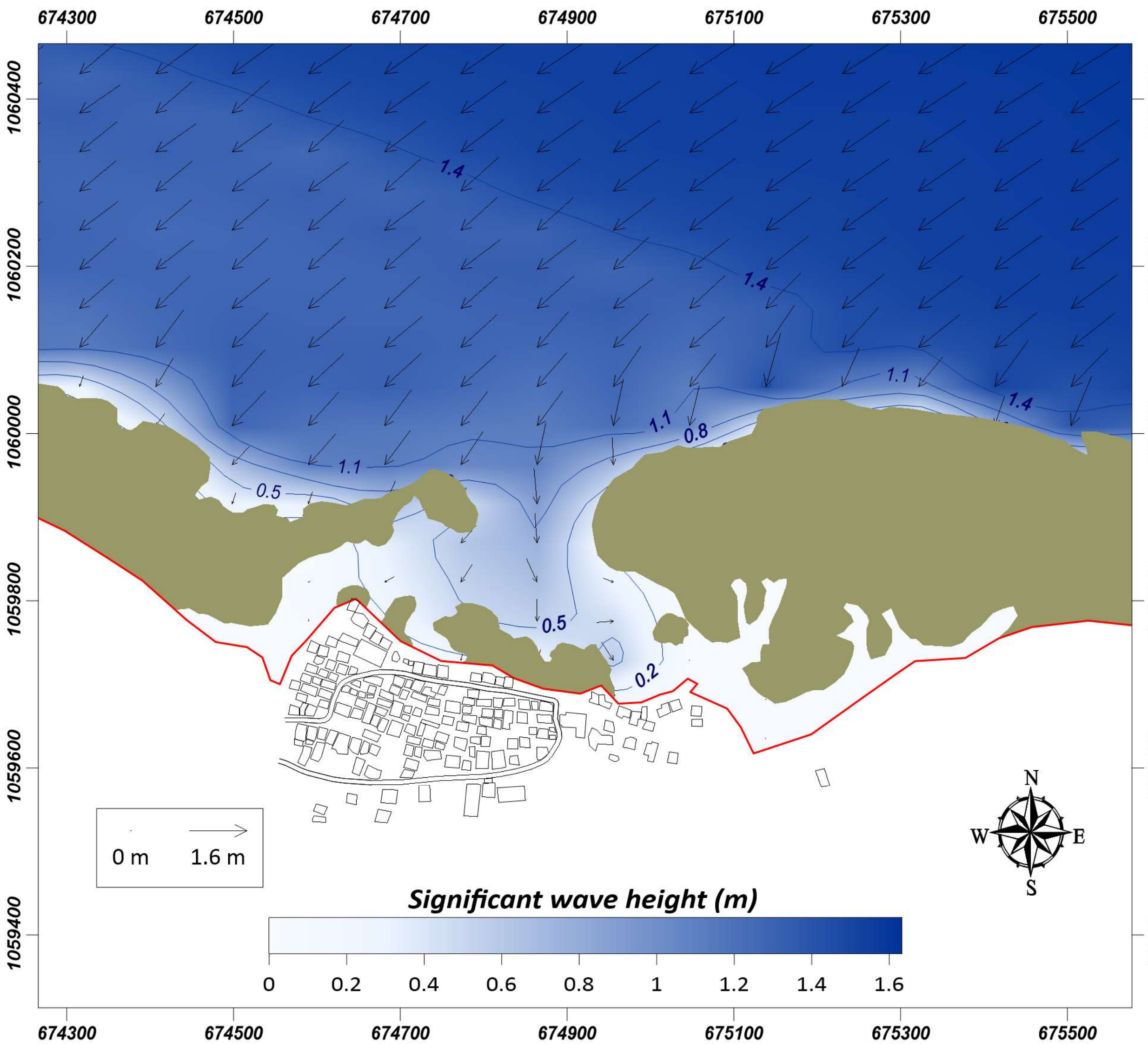

Figure 21. Distribution of isolines, vectors and magnitude of significant height for Viento Frío Beach. Usual wave, Northeast (ENE) direction.

Scenario under storm waves

It has been shown in various studies under certain circumstances that the loss of sand and the total disappearance of beaches have one of their direct causes in the waves associated with extreme weather events, such as depressions, tropical storms and hurricanes.

Figure 22 shows the simulation carried out for the impact of a wave generated by a tropical storm with the characteristics described above, selecting the east-northeast direction as it predominates in the area even under these conditions.

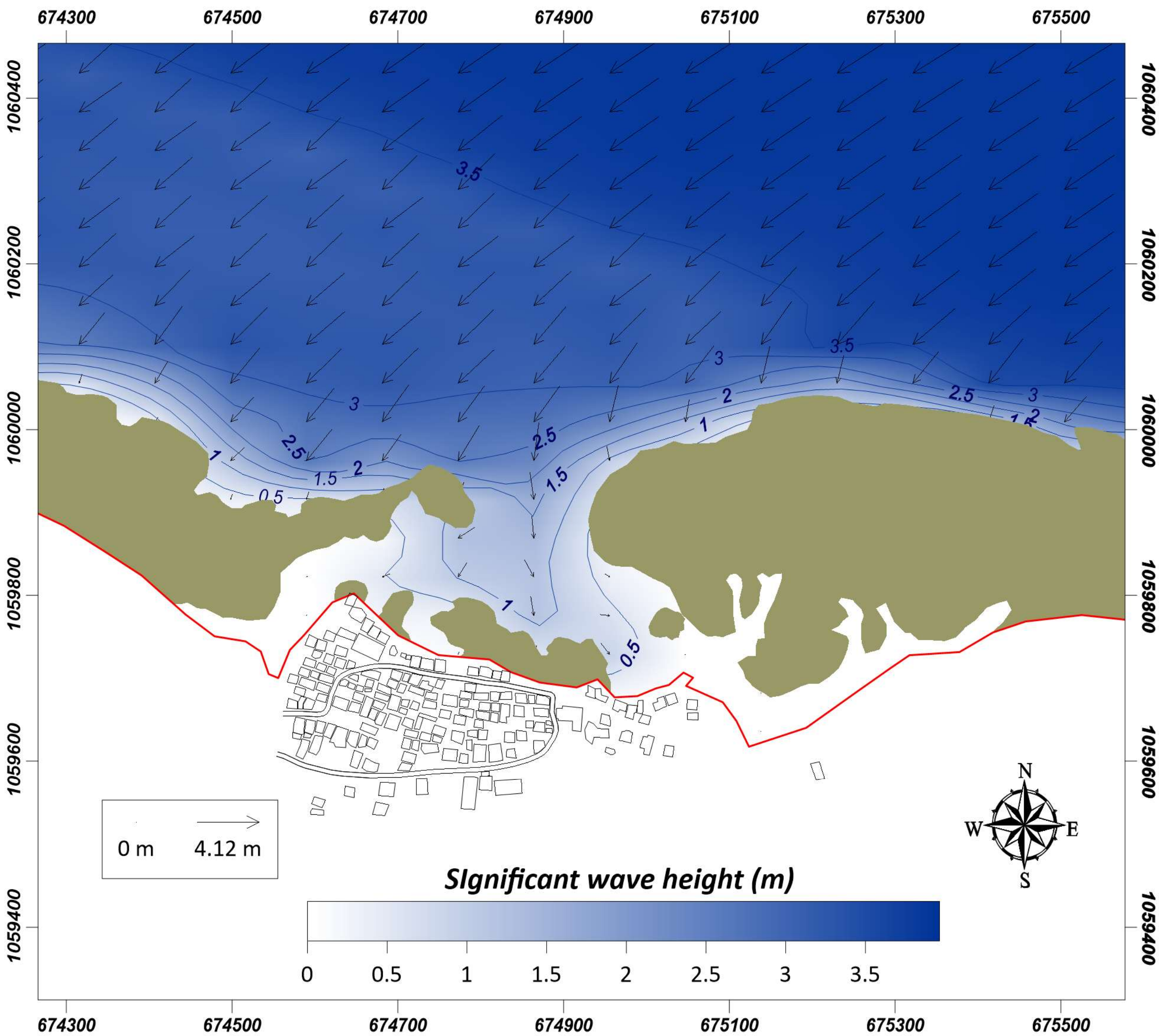

Figure 22. Distribution of isolines, vectors and magnitude of significant height for Viento Frío Beach. Extreme waves, direction Northeast (ENE).

Under these circumstances, the generated wave trains adopt a propagation scheme similar to that generated under usual conditions.

As can be observed, wave dissipation through shoaling and breaking processes begins more than 500 m from the shore in front of Viento Frío Beach, approaching this distance towards the east, where they practically reach the exterior terrace with a height of 3.5 m. As in the previous case, the outer reef barrier dissipates all the energy of the waves that reach it with a height between

1.5 m and 2 m. Only transformed wave trains pass through the central opening, with a height of 1 m, which directly affect the Central sector of the beach.

This wave propagation distribution scheme, similar to, but greater in magnitude than that produced for normal conditions, determines the circulation system and sediment distribution along the coastal strip of the study area.

Circulation system

Within the breaking zone, waves generate a series of currents, which depend on the angle of arrival at the coast and wave height. These currents, called longshore or breaking currents, are particularly important in the equilibrium disposition of a beach, and more specifically, in its shape in plan, given the sand transport capacity.

To determine these breaking currents, the COPLA model, developed by the GIOC of the University of Cantabria, Spain, was used. The modeling carried out is presented in Annex 2.

As an example, Figure 23 shows the simulation carried out for waves in an extreme regime produced by a tropical organism with an east-northeast trend, with similar behavior for the other modeled scenarios.

The transformation and breaking of waves generates a chaotic circulation pattern towards the inner part of the beach, for both normal and storm conditions, due to the existence of reef barriers and the transformations that the waves undergo when interacting with them. Thus, it is very difficult to establish a sediment transport pattern for this beach.

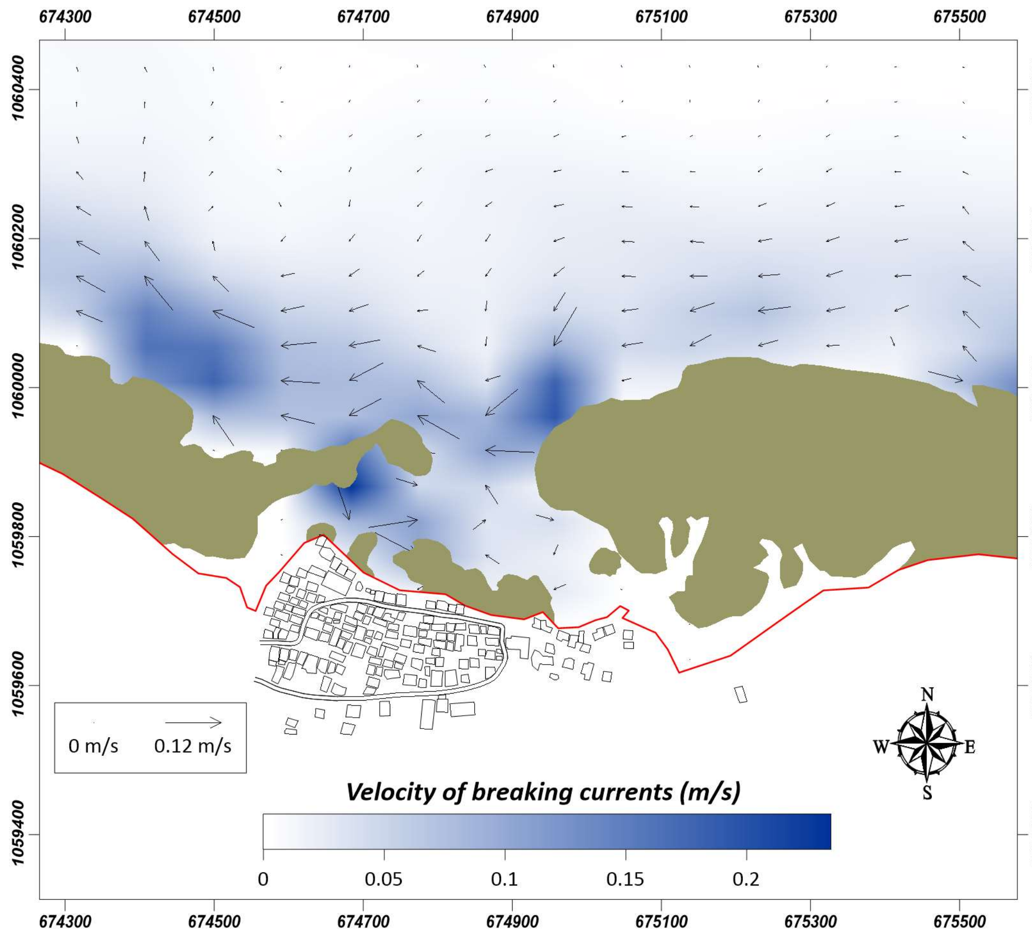

Figure 23. Distribution of vectors and magnitude of breaking currents in the coastal sector of Viento Frío. Extreme regime, East Northeast (ENE) direction.

IV.4. Evidence and causes of the erosion process

During the field work carried out, it was possible to detect several pieces of evidence that demonstrate the continuous process of erosion to which this beach is subjected. Some of them are:

1. Rocky outcrops on the foreshore
2. Total loss of the emerged area in the eastern sector
3. Effects on coastal vegetation and facilities
4. Formation of erosion gullies due to poor storm drainage
5. Narrow sand strip, no dunes and low berm height

Photo 15. Rocky outcrops on the beachfront (West Sector).

Photo 16. Total loss of the emerged area of the beach in the eastern sector.

Photo 17. Effects on vegetation and facilities (East Sector).

Photo 18. Erosion gullies due to poor storm drainage.

Although it was not possible to have photos or data that would allow evaluating the conditions of the beach years ago, we received repeated information from the inhabitants of this area about the existence of a wider beach in the past, where one could even practice sports such as volleyball and soccer, something impossible these days. Likewise, according to these testimonies, it was possible to walk and sunbathe on the emerged area of the beach in the East sector, which does not exist nowadays.

All this evidence shows that Viento Frío Beach has been subjected to a constant process of erosion, the magnitude of which is impossible to quantify due to the lack of regular measurements. However, based on the testimonies of the residents, it is possible to estimate a loss in beach width of between 15 m and 20 m approximately in the last 20 years, at a rate of between 0.75 m and 1 m of retreat per year.

The causes that have generated this process can be divided into:

1. Natural causes:

    - Climate change-induced mean sea level rise. It is a common cause that affects several beaches worldwide, and coasts in general. It is known that in recent years the trend is towards rising sea levels and flooding of low-lying and vulnerable areas, as is the case of Viento Frío.

    - Possible increase in the frequency and intensity of hurricanes and tropical storms. Although Panama is not characterized by being directly affected by this type of organism, as is the case in other regions of the Caribbean basin, the waves and surge that they generate in their path towards higher latitudes do affect the coast and they shape the landscape, generating impacts on the sandy coasts at that moment.

    - Decrease in sediment input to the beach from sediment sources. Although it is difficult to quantify and assert that there is a decrease in sediment inputs, the evidence of the erosion process itself shows an imbalance between input and output. As explained above, one of the main sources of sediment input to the beach in past geological eras was the barrier of coral origin that protects it and that, at present, is in a fairly deteriorated condition, prevailing the inputs due to the erosion of the barrier's stone material, and the colony of Halimedas algae and other calcareous organisms that inhabit on it.

    - Inadequate morphology for profile accretion and stability. For the existence of a beach and its stability, it is essential that certain conditions are met. Among them, the most significant are a constant source of sediment inputs capable of maintaining the balance between the system's inflows and outflows, a favorable hydrodynamic regime and a profile morphology that allows cumulative processes, and the correct functioning of the equilibrium profile. In the case of Viento Frío, the existence of the intertidal terrace in the area that the underwater slope of the profile should occupy is an element that amplifies the erosive processes and hinders the dynamic balance of the beach.

2. Anthropogenic causes (Human activity)

- Existence of facilities on the dynamic profile of the beach. One of the most common causes of erosion on sandy shorelines, and beaches in particular, is the existence of facilities built on the dynamic profile. Since ancient times, the different civilizations have had a close link with water sources, both sea and rivers. Thus, it has been customary to bring constructions closer to the edge of them. However, this practice is harmful to the functioning of the beaches. In its interaction with the hydrometeorological elements, the emerged profile of the beach fulfills a very important function of defense against sea penetrations, as it is the main dissipative element of storm waves. Likewise, the wind generates onshore sediment transport, which, being hindered by the coastal vegetation, creates dunes, accumulations of sand that will also fulfill an important defense and reserve function to achieve equilibrium in the profile functioning. The walls, houses, hotels and other buildings obstruct this natural functioning and become elements that accelerate the erosive processes. In the case of Viento Frío, the town has developed closely linked to the sea, whether for fishing or recreational activities, and currently there are 22 houses and other facilities on the shoreline that affect its dynamic functioning, in addition to 100 m of walls in the East sector.
- Poor storm drainage. The development of the town and its paved streets, also very close to the coastal zone, produced a change in the pluvial runoff. Currently, water drainage takes place mainly at two points along the beach, where water flow reaches large volumes and strong currents that run towards the sea through the beach, eroding it and sending volumes of sediment seaward, thereby also favoring erosion processes.
- Sand mining for construction. During the field work, it was possible to appreciate that in the area sand mining for construction is a common practice, something that was also confirmed by its inhabitants, being an activity that they see as something natural and necessary. However, this action, also common in other coastal areas, becomes an element that favors erosion processes by extracting unquantified sand volumes that amplify the losses occurring naturally.
- Sand mining from the shelf. In the submarine shelf of this area, in depths between 30 m and 40 m, for years there have been concession areas for the exploitation of marine sand. Although the distance at which these mining actions have been carried out, as

well as the depth, do not allow a direct relationship to be established with the erosion on the coastal zone, it is possible that damage has been generated to the sand-producing ecosystems that influence the imbalance of input to the beach.

Another element that affects the image of this beach is the constant arrival of tree trunks, branches and human waste on the coast. Although this phenomenon cannot be linked as a cause of erosion, it must be taken into account to improve the aesthetic and landscape image. It is almost impossible with engineering solutions to exert any influence on this phenomenon. The only possible solution would be to establish a constant cleaning and sanitation plan that allows for waste disposal outside the coastal zone.

Once the causes of erosion have been identified, it is unavoidable that the solutions for the rehabilitation of Viento Frío Beach require a combination of engineering and adaptation solutions.

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V. STRATEGY FOR THE RECOVERY AND PROTECTION OF VIENTO FRÍO COASTAL SECTOR.

The solutions to improve the aesthetic conditions of the beach, as well as its strengthening to enhance its function as a defense against the effects of climate change, must be a combination of engineering solutions and management and adaptation measures, even more in the long term and with further studies, the application of ecosystem-based adaptation techniques is a viable solution.

Ecosystem-based solutions refer to a set of actions or policies that harness the power of nature to address some of the most pressing societal challenges, such as the growing risk of natural disasters or Climate Change. These solutions involve protecting, restoring and sustainably managing ecosystems in ways that increase their resilience and ability to address these societal challenges while safeguarding biodiversity and improving human well-being.

This approach has gained momentum in various parts of the world over the last two decades, resulting in various policies and guides that align with the incorporation of natural processes in engineering, for example, Shoreline Management Plans (United Kingdom, 2006), Building with Nature (Netherlands, 2012), Living shorelines (USA, 2016) and Nature-based solutions in Program of the International Union for Conservation of Nature, recently renewed in 2021.

In particular, an ecosystem-based alternative for flood and erosion risk mitigation is "green infrastructure". After its implementation, this infrastructure seeks to conserve, or recover if necessary, the mass and energy flows that allow connectivity between ecosystems, their functioning and resilience.

The selection of a successful solution will depend on an adequate diagnosis that includes a resistant, resilient and specific design for the site to be intervened, given the complexity of the coastal processes, as has been done in this Project.

Within the green infrastructure solutions, there is the so-called **"Enhanced engineering with the use of ecosystems".**

In this type of green infrastructure, traditional protection measures, both rigid and soft, are modified to change physical processes (for example, wave intensity and sediment transport), producing benefits to the natural processes that are maintained or adapt by imitating natural ecosystems. For example, the filling of beaches and the revegetation of coastal dunes with native plants are measures of this type that have proven to be effective.

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The proposed set of measures can be classified as:

- Short-term measures (<3 years)
- Medium-term measures (3-7 years) -

Long-term measures

According to this time scale (short, medium and long term), actions are proposed for each scale.

V.1. Short- and medium-term measures

Thus, and taking into consideration the current level of study, the use of the beach and the characteristics of the area where it is located, the following short- and medium-term strategy is proposed:

1. Management and adaptation measures

Due to the causes that provoke or accelerate the erosion processes, it is proposed to advance in the following measures:

- Advance in the elimination of the facilities located on the first coastline. This measure becomes complex to apply at this time, since there is no legislation in the Republic of Panama based on the operation of coastal systems that limits the extension of properties on the dynamic profile of the beach. In addition, the vast majority of the facilities are private, whose owners are residents of the area, many of them with low incomes.

- Sanitation of the coastal zone. One of the greatest impacts that this beach receives is contamination by solid waste from the sea. The existence of logs, algae, remains of marine animals, plastics and all kinds of waste causes a high landscape impact and directly affects the use of the beach for recreational purposes. For this reason, a periodic sanitation and cleaning program for the sand strip must be established.

Eliminate storm drains to the beach. The elaboration and execution of a project is needed to eliminate the discharge of stormwater runoff towards the beach, offering new solutions to this problem.

Completely eliminate the extraction of sand from the beach. This common practice in various sectors of sandy coasts is one of the most harmful for the correct functioning of the beach, for which it must be eliminated immediately, while offering the residents of Viento Frío other alternatives that allow them to obtaining this important material for construction.

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As it is possible to appreciate, these measures will affect the current dynamics of the Viento Frío population, which is why their application must be the result of a thorough analysis and the participation of the inhabitants themselves, giving them alternatives to compensate for the possible effects that they will be subjected. That is why they are not solutions that, although necessary for the stability of the beach, can be applied immediately. First, a coastal management and environmental awareness program must be created, taking into account that the execution of a project or the taking of measures to improve the beach must always be an action that contributes to raising the standard of living of the population and this is an active part in the actions.

Advancing in this type of strategy leads to continuous work in the medium term, so if you want to provide more agile solutions, it will necessarily be necessary to intervene in the dynamic system of the beach, which will not only improve the sector more expeditiously, also offering a better response from the beach to climate change, but it will also provide the necessary time for the application of the previously proposed measures.

From the diagnosis made to the beach, one of the main causes of the current deterioration is given by the loss of sand volumes and the deficit of new income to it. Undertaking actions that immediately provide the necessary sediments to achieve a new balance of the system through the execution of engineering actions, is shown as a viable alternative in the shortest term.

2. Engineering solutions

In the field of coastal engineering and in particular the maintenance or restoration of beaches, there are a large number of solutions that can be applied depending on the characteristics of the coastal system, the causes that generate erosion processes, their intensity or the final objective of the intervention.

In general, these are divided into two large groups: hard and soft, although in recent years hybrid solutions have also become widespread, which combine aspects of both groups, even ecosystem-based solutions are taking more and more prominence, whose main disadvantage consists in the slowness with which the practical results for the restoration of the beach are obtained, although in the long term they can be decisive. (Wong, 2018)

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Taking into consideration the current state of Viento Frío beach, its geomorphological characteristics, the functioning of the coastal system and the objectives pursued with the restoration, the application of hard solutions such as breakwaters, breakwaters, boardwalks or similar, as well as unnecessary and probably ineffective, it becomes extremely expensive, which is why this possibility is ruled out and the application of soft solutions is proposed, such as the artificial feeding of sand and the restoration of coastal dunes and their vegetation in those sectors that allow it, advancing in parallel with the adaptation and ordering measures.

Years ago, the regeneration of the beaches was not conceived without the construction of breakwaters or other types of rigid structures, but it has now been proven that, in many cases, this type of action, although it rarely meets its objective locally, produces erosion in adjacent areas, so its implementation by itself is in disuse given the environmental problems it generates and its insertion in projects is recommended so as to combine hard work (stiffening of a stretch of coastline) and soft work (artificial nourishment or bypass).

The selection of artificial nourishment as an advanced technique for the maintenance of natural beaches was made based on its recognized ecological and aesthetic advantages with respect to other techniques (National Research Council, 1995).

These actions are addressed and developed in detail in the Project.

This type of actions, carried out jointly, have shown a high degree of effectiveness, since through their application the beaches are designed with a double function, for recreational use and as coastal zone protection works, returning, almost instantaneously, the deficit in the volume of sediments required for the recovery of its conditions:

- Morphological: conforming a well-developed and complete profile, with the presence of the different morphological elements typical of its structure (mainly submarine bars, berms and dunes, the latter revegetated with species typical of Caribbean beaches), and a notable increase in width of the sun exposure strip.
- Aesthetics: advancing in the gradual restoration of the natural aesthetic and landscape values of the original ecosystem, through the rehabilitation of the sandy profile and the corresponding coastal vegetation, as well as the elimination of the different polluting elements existing in the environment.

- Functional: conceiving a double use value for the recovered beach:
  - Recreational: to who's conditioning the achievement of the previously mentioned precepts will contribute, relative to the conformation of a profile with adequate solar exposure area and load capacity, and an attractive natural image. Representing new opportunities for the promotion of tourism and fishing activity, the valuation of land and the generation of jobs.
  - Coastal defense: taking advantage of the essentially dissipative nature of the beaches, with sufficient volumes of sand to form extensive, gently sloping profiles, with the presence of underwater bars, berms and powerful dunes, conceived under appropriate design parameters, which guarantee an efficient dissipation of the energy of the waves generated by extreme meteorological events, contributing to the confrontation with the increase in sea level caused by Climate Changes.

In the last decades of the 20th century, the application of this type of solution began to become general, with preference to the traditional rigid coastal defense works.

Juanes (1996), refers to 3 important examples in this regard:

- In the Republic of Georgia, in the Black Sea, the failure of several beach protection works through the construction of breakwaters and dikes until 1981, led to their replacement and the execution of artificial beach feeding projects, which among 1983 and 1987 benefited 47.5 km of coastline, with the discharge of 9,224,600 m^3 of sand and gravel (Kiknadze, et al. 1990).
- In Spain, between 1983 and 1988, more than 300 actions were carried out on the coasts, with 70% of the budget allocated to beach rehabilitation projects through artificial beach feeding (MOPU, 1988).
- In the United States, around 1988, there were already reports of 60 beaches on the Atlantic coast, 35 on the Gulf coast and 30 on the Pacific coast, which had been, or were periodically benefited, by the application of artificial beach nourishment. It was then estimated that these works had exceeded the order of 300 million m^3 of sand dumped for the recovery of more than 600 km of coastline (Leonard et al., 1990). In the latter case, the example of Miami, Florida, is a remarkable reference. The breakwater field that existed there until the 1970s had to be demolished, giving way to the dumping of more than 10 million m^3 of sand between 1977 and 1982. The application of this technique in Miami has continued, from In fact, in May 2022 a new project began for the dumping of some 600,000 m^3 of sand on 3,500 m of beach.

In the United States, the artificial feeding of beaches has become almost the only coastal defense procedure today, after years of applying harsh solutions that, far from recovering the beaches, caused the intensification of erosion processes, with very expensive projects to remove rigid structures placed on hundreds of kilometers of coastline.

In most European countries such techniques have been used extensively and with notable successes that have been duly recognized.

In the Caribbean area, Cuba has been a pioneer in its application for the recovery of its beaches, highlighting in particular the example of Varadero, which has been subject to sand dumping of more than 3.5 million m^3 between 1987 and 2020, highlighting the project executed in the summer of 1998, for 1,087,000 m^3 of sand along 12 km of the beach.

The experiences of Varadero led, locally, to the implementation of an Integrated Coastal Management Strategy, which has also included the demolition of more than a hundred existing structures in the dune, which contributed to the erosion of the beach, the removal of the invasive vegetation in the coastal zone, the reconformation and reforestation of several kilometers of dunes, and the construction of rustic walkways to access the beach that guarantee the preservation of the dunes and their vegetation; among other actions.

Likewise, the investment program for the recovery of the Varadero beach was one of the bases for the conception of the National Investment Program for the Recovery of Beaches in Cuba, later integrated into the Cuban State Plan to Confront Climate Change (Task Life). Adding this program and the initial experiences, more than 5 million m^3 of sand have been spilled on several of the country's main tourist beaches, occasionally resorting to the use of rigid coastal defense

rigid coastal defense structures, in specific cases where investigations have indicated their need.

On the beach of Cancun, in Mexico, the dumping of more than 5.2 million m^3 of sand between 2009 and 2010 stands out, in a project carried out to recover the beach from the effects of the passage of the powerful Hurricane Wilma in 2005. Around 2021 local sources they indicated the existence of four other projects, awaiting financing to start their execution, for almost 7 million m^3 of sand to be dumped as a whole, for the recovery of the beaches of Cancun, Carmen and others on the Riviera Maya and the island of Cozumel.

Examples of projects of this type with proven effectiveness are common in many parts of the world, which reaffirms that for short-term restoration it is one of the most applied and effective techniques today. It should be noted that, unlike other restoration techniques, including those based on ecosystem management, it is the only one that is capable of contributing in a short time the volume of sand lost in many years, allowing the system to restore its dynamic operation.

In addition, it allows creating or recovering spaces for recreational activities, also serving as coastal defense against extreme erosive events.

Its main disadvantage is that, although it contributes in a short time the sand lost in several years and restores the operation of the profile, it does not act directly on the causes that generated the erosion processes and, therefore, it does not eliminate them, thus requiring with the passing of the years, new maintenance works or their complementation with coastal management programs and ecosystem-based restoration works.

However, the speed with which the profile is restored and the fact that new structures are not introduced in the coastal area make it the most environmentally friendly engineering solution and aesthetically superior to the creation of breakwaters, breakwaters or piers. It should also be noted that its application does not compromise the application of other measures in the future if necessary, as the base morphology of the coastal sector is not modified or costly and difficult to eliminate elements are introduced.

In the case of Viento Frío, because it is a small beach naturally protected by the coral terraces that characterize its front, with the application of this solution it is to be expected a high effectiveness that allows its durability over time and thus provide the weather need to take other measures in the longer term.

The actions stated and proposed for their execution in the short and medium term, are also aligned with the implementation of the concepts of Sustainable Development, Sustainable Tourism, and Adaptation to Climate Change based on Ecosystems.

In any case, regardless of the actions or strategies selected, the dynamic nature of a beach, especially in a scenario of sea level rise such as the one predicted as a result of Climate Change, makes it necessary for its management to continue over the long term.

V.2. Long-term measures

The long-term strategy for the rehabilitation and protection of the Viento Frío beach must take into account the expected effectiveness of the short and medium-term measures that are proposed, for which the monitoring of the morphological and sedimentological variations of the beach, as well as other physical and chemical parameters, such as the quality of bathing water and sediments, are essential for a correct diagnosis of the environmental quality of the beach.

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This strategy must start with the establishment of an environmental baseline, which serves as a reference for the establishment of environmental indicators, which allow decision makers to adopt the necessary preventive measures.

Taking into consideration that the erosion on the Viento Frío beach is caused mainly by natural causes, and to a lesser extent by anthropogenic causes, as well as the possible effects of Climate Change in the medium and long term, the long-term management strategy is can be synthesized into the following elements:

- Creation of a legal framework that promotes and guarantees the implementation of strategies and actions, aimed at the sustainable use of the coastal zone, with emphasis on the beaches.
- Monitoring of the effectiveness of the actions carried out that make up part of the short and medium-term strategy, and in general, of the evolution of the beach, to define the moment in which new actions are required.
- Other actions, such as those aimed at maintaining and protecting the dunes, and pollution control, must be evaluated, designed and executed as appropriate.

V.3 Borrow area

One of the most important steps for the application of Artificial Sand Nourishment is the location of a borrow area, with the sand volume and quality necessary to be introduced on the beach and at a distance from the action area that is economically viable.

To meet this objective, an exploration was conducted on the submarine shelf, based on the results of bathymetric surveys on a 12 km front between Punta Macolla, to the west, and the vicinity of Miramar town, to the east. In total, 20 diving stations were carried out, 12 of which were in sand bodies and 10 reconnaissance transepts.

As a result of the initial exploration works, 4 areas were identified with the greatest possibilities to be used as a borrow area for Artificial Sand Nourishment works in Viento Frío (Figure 24), whose reference coordinates can be found in Table 8.

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Table 8. Areas of sand deposits explored.

Zone	UTM Zone 17 N – WGS84	
	Easting	Northing
1	671808.70	1063666.14
2	674548.70	1061301.91
3	677930.66	1063071.17
4	681124.73	1059892.75

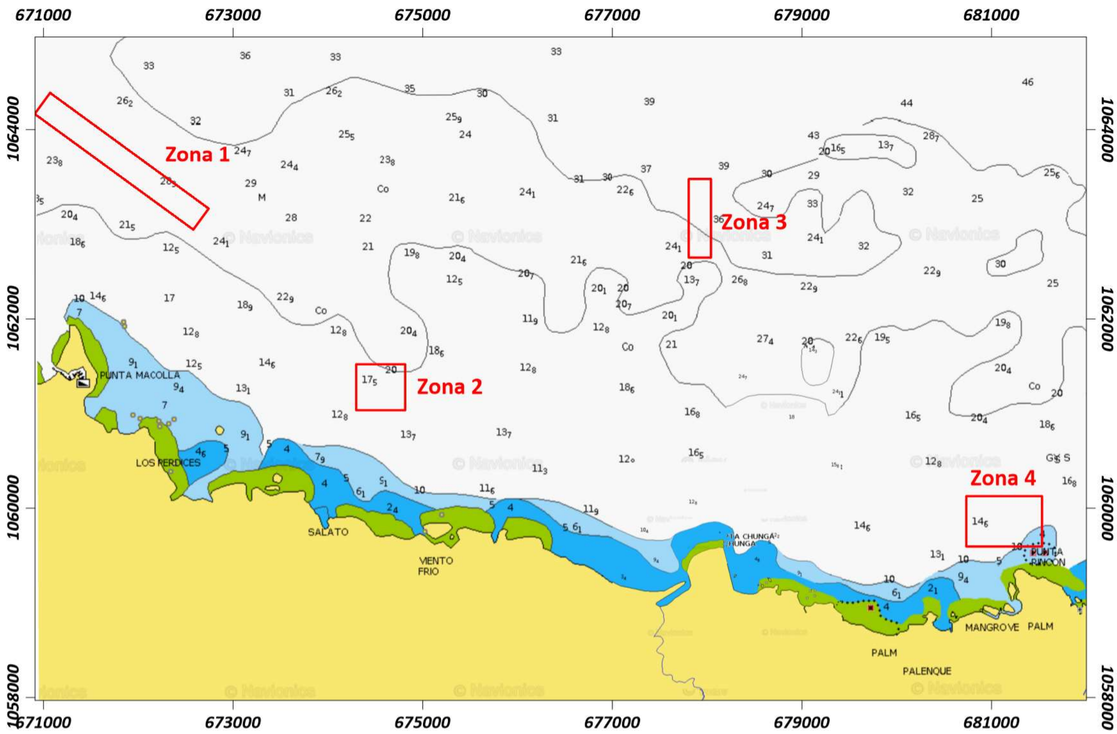

Figure 24. Areas identified as sand deposits with the possibility of being used as borrow area for Artificial Sand Nourishment works.

However, the results of the grain size analyses ruled out zones 1 and 3, because their sediments do not meet the necessary requirements to be used in the rehabilitation works of Viento Frío Beach. (Tables 9 and 10)

Table 9. Location of the stations in zone 1 and visual description.

Station	WGS 84 coordinates		Coordinates UTM 17N		Depth.	Description
	Latitude N	Longitude W	Easting	Northing	m	
1	9.61394	79.42725	672586.51	1063124.50	27	Very fine sand
2	9.62402	79.44115	671055.75	1064232.38	25	Rocks and coarse sand

Table 10. Results of the grain size analysis carried out on the samples in zone 1.

Sample	Sieve Range								M		Stand Dev. (Ø)	Wentworth Classification
	>4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.062	< 0.062	(mm)	(Ø)		
M1	0.0	0.1	0.0	0.5	4.8	29.9	49.9	14.1	0.107	3.221	0.793	Very fine sand
M2	Analysis was not performed. (Remains of shells and gravel)											

As can be observed in Tables 9 and 10, the sand in zone 1 is found at depths that range between 27 m and 25 m, at an average distance of 5.3 km from the beach. In general, patches of fine sand alternate in this zone with furrows or channels between rocks with very coarse and poorly sorted sand, impossible to extract for transfer to the beach. For these reasons, it is discarded as a possible borrow area.

For its part, the results of the exploration in zone 2 are presented in Tables 11 and 12.

Table 11. Location of the stations in zone 2 and visual description.

Station	WGS 84 coordinates		Coordinates UTM 17N		Depth	Description
	Latitude N	Longitude W	Easting	Northing	m	
3	9.59600	79.40919	674578.005	1061149.45	17	Fine sand Thickness: 1.60m
4	9.59624	-79.41000	674488.970	1061175.58	17	Fine sand Thickness: 1.60m
5	9.59705	-79.40909	674588.440	1061265.63	18	Fine sand Thickness: 1.60m

Table 12. Results of the grain size analyzes carried out on the samples in zone 2.

Sample	Sieve Range								M		Stand. Dev. (Ø)	Wentworth Classification
	>4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.062	< 0.062	(mm)	(Ø)		
M3	0.0	0.0	0.6	0.9	3.5	20.8	54.7	19.2	0.124	3.359	0.836	Very fine sand
M4	0.0	0.0	1.5	7.0	4.3	50.7	30.5	6.0	0.154	2.695	0.981	Fine sand
M5	0.0	1.0	0.5	2.5	3.9	37.6	42.5	11.6	0.124	3.013	0.985	Very fine sand
Type S.	**0.0**	**0.33**	**0.87**	**3.47**	**3.9**	**36.37**	**42.57**	**12.27**	**0.123**	**3.022**	**0.975**	**Very fine sand**

According to the presented results, the explored zone 2 is located at a depth that ranges between 17 m and 18 m, at an average distance of 1.8 km from the beach. The sand in this sector is classified, in its type sample, as very fine sand, according to the classification proposed by Wentworth (Shore Protection Manual, 1984). Due to the present depths and the continuity of the sand body, its use for Artificial Sand Nourishment works could be evaluated. However, there are reasons that cast doubt on its suitability, like the color of its sand (dark gray), as well as its grain size classification as very fine, and an average percentage of fine classifications of 12.27%.

Zone 3 is discarded immediately, since almost all of its sediments are classified as clays and silts, at depths ranging between 25 m and 38 m, at an average distance of 4.3 km from the beach.

Lastly, zone 4 was explored, which is located at an average distance of 5.8 km from the beach, near Miramar town.

Table 13. Location of stations in zone 4 and visual description.

Station	WGS 84 coordinates		UTM 17N Coordinates		Depth	Description
	Latitude N	Longitude W	Easting	Northing	m	
6	9.58481	-79.34923	681166	1059943	15	Fine sand
7	9.58514	-79.35007	681073	1059979	15	Medium to coarse sand
8	9.58364	-79.34722	681387	1059814	15	Fine sand
9	9.58359	-79.34874	681220	1059808	16	Fine sand
10	9.58294	-79.35194	680869	1059735	16	Fine sand

Table 14. Results of the grain size analyses carried out on the samples in zone 4.

Sample	Sieve Range								M		Stand Dev. (Ø)	Wentworth Classification
	>4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.062	< 0.062	(mm)	(Ø)		
M6	0.0	0.9	5.3	41.3	47.8	2.9	1.4	0.0	0.497	1.009	0.743	Medium Sand
M7	0.0	1.7	1.2	1.5	51.4	41.3	2.5	0.0	0.273	1.874	0.769	Medium Sand
M8	0.4	0.9	0.6	3.6	5.3	55.4	29.4	4.2	0.151	2.688	0.919	Fine sand
M9	0.0	0.0	0.6	3.7	5.9	30.4	51.5	7.5	0.124	3.013	0.901	Very fine sand
M10	0.0	0.6	1.3	5.5	4.9	37.7	41.8	7.7	0.139	2.849	1.043	Fine sand
Type S.	**0.08**	**0.82**	**1.8**	**11.1**	**23.1**	**33.54**	**25.32**	**3.88**	**0.204**	**2.287**	**1.157**	**Fine sand**

The results show that this area is made up of a clean and homogeneous body of sand, with depths ranging between 15 m and 16 m, ideal for working with trailing suction hopper dredgers, capable of dredging, transporting and depositing the sediment on the beach. The sand in its type sample is classified as Fine Sand, in a range very close to the Medium Sand classification, slightly higher than that of the beach, so that a high stability would be expected once deposited. Also, the percentage of fine classifications is only 3.88%, which facilitates the work of dredgers by reducing losses due to dilution, and also reducing losses once deposited due to differences in grain size.

As for its color, it is slightly darker than that of the native sand of beach, due to the fact that it is not subjected to the direct action of sunlight, and the calcareous organisms in its composition are stained by the inputs of fine sediments and organic matter from rivers and mangrove forests typical of the area.

In order to know more precisely its compatibility with the native sand of the beach, sample No. 6 was analyzed for its composition. According to the results, the sample is very similar in this parameter to the one analyzed in the M9 profile of the beach. Remains of calcareous algae predominate in it, representing 48.6% of the total, followed by remains of terrigenous origin with 22.8%. Bioclasts or remains of calcareous origin, that due to their degree of maturity, wear or conglomerates it is impossible to place in a taxonomic group, show a value of 14.5%. And finally, mollusk remains represented 10.6%, and other elements that were impossible to identify, although they can be defined as of biogenic origin, 3.3 %.

It is evident that zone 4 is outlined as the ideal zone to be used as a borrow area for Artificial Sand Nourishment works on Viento Frío Beach. However, for this beach, due to its dimensions, the sand volume to deposit is estimated to be between 45,000 m^3 and 50,000 m^3, a small volume for the costs required for the mobilization and demobilization of the dredging equipment necessary to carry out the operation.

For dredging in depths greater than 15 m, the transfer of sand to the unloading area and the subsequent pumping from a distance of approximately 600 m from the coast, a medium-sized trailing suction hopper dredger would be needed, the cost of which can be around USD 30 per cubic meter, or USD 1,500,000. The costs of mobilization and demobilization of all the equipment and pipes must be added to this amount, which for such a small sand volume can represent 50% or more, above the value of the cubic meter. That is, the final price of this operation could be around two million USD, an excessive cost for the recovery of this beach. The inclusion of other sectors in the area, such as Palenque, Miramar or Cuango, would be a feasible alternative for a better use of equipment and investment costs.

With the aim of locating a borrow area that would represent less technological complexity and, thus, lower costs, it was decided to explore the coastal area.

As a result of this exploration, it was determined that the area where there were sufficient volumes of sand, with the required quality to be transferred to Viento Frío beach, is found in the delta at the mouth of Cuango River. From there, the sand needed to be used in Viento Frío can be mobilized by using trucks. Although this way the recovery is not achieved with the same efficiency as if using a trailing suction hopper dredger, the lower technological complexity of the operation can directly affect execution costs.

Cuango River delta is located at the eastern end of the town of the same name, in the corregimiento of Santa Isabel, at an average distance of 13 km by road from Viento Frío Beach (Figure 25).

Figure 25. Location of Cuango River delta with respect to Viento Frío beach.

The sand bars that form at river mouths are very dynamic elements, which constantly change their position, configuration and sand volumes. For this reason, if it is decided to use this area as a borrow area for the works at Viento Frío, an update of the surveys and the estimation of the volume available to be extracted will be necessary.

During October 2021, when the surveys were carried out, an area of 10,730 m^2 with conditions for sand mining and an average thickness of 1.60 m in its sediment column could be determined, according to the drilling carried out, with which an available sand volume of 17,168 m^3 could be estimated. Figure 26 shows the configuration of this area, while table 15 presents the coordinates of its vertices.

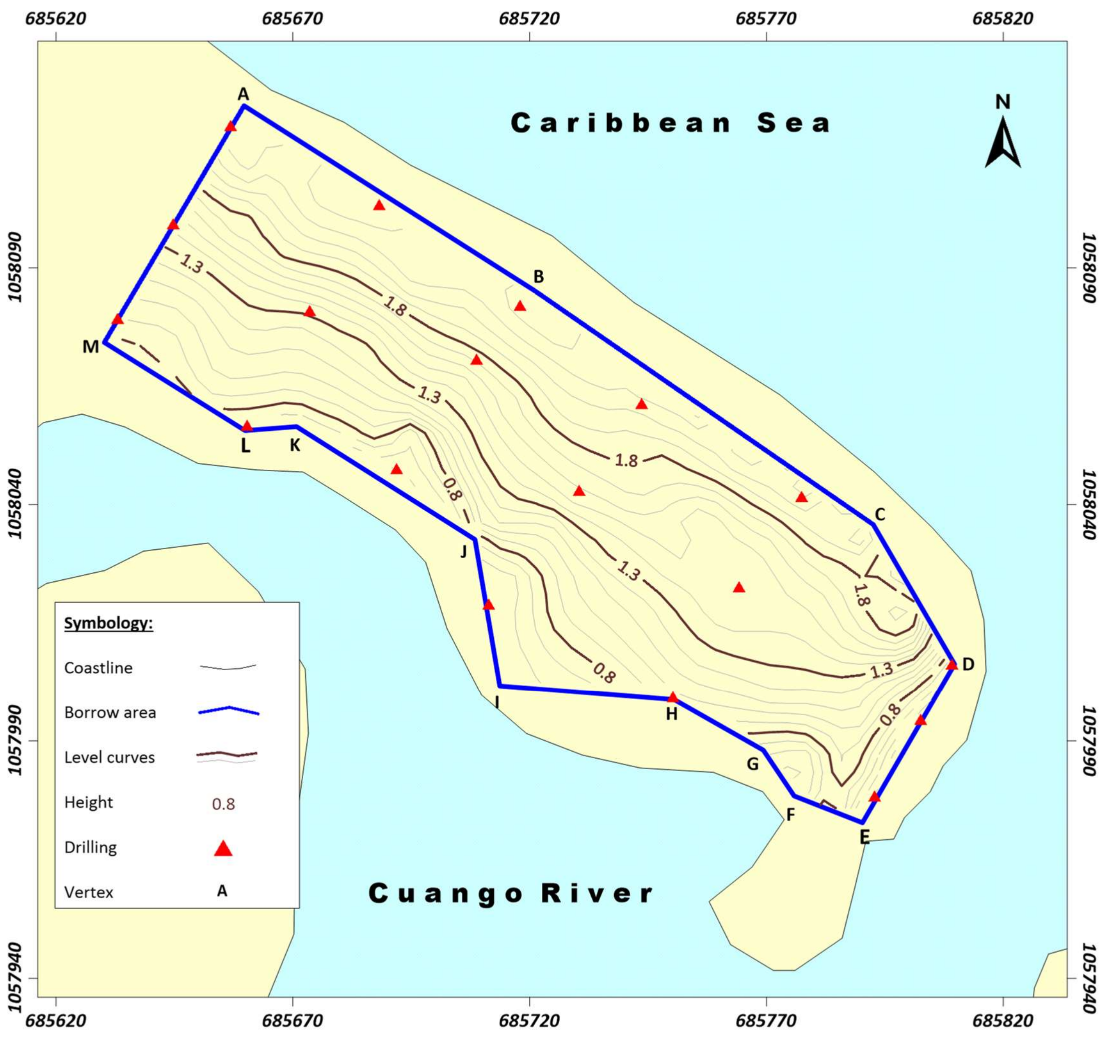

Figure 26. Borrow area at Cuango River mouth.

Table 15. Vertices of the borrow area in Cuango River (UTM Zone 17-WGS 84).

Vertex	X	Y
A	685659.80	1058124.01
B	685720.76	1058085.25
C	685792.52	1058035.57
D	685809.83	1058006.34
E	685790.35	105 7972.88
F	685775.75	1057978.59
G	685769.36	1057988.05
H	685750.21	1057998.88
I	685713.83	1058001.62
J	685708.47	1058032.64
K	685670.72	1058056.48
L	685660.00	1058055.56
M	685630.24	1058074.38

The results of the grain size analyses included in Table 16 show that the sand present in this area has a coarse grain size (0.51 mm), very close to the classification as medium sand, according to the scale proposed by Wentworth (Shore Protection Manual, 1984). On the other hand, the results of the analyses to know the sediment genesis, performed on sample DC 3, show that they are entirely of terrigenous origin, in correspondence with the main strong input in the area, which are the sediments carried by Cuango River.

Table 16. Results of the grain size analyses performed on the samples from Cuango River mouth.

Sample	Sieve Range								M		Stand. Dev. (Ø)	Wentworth Classification
	>4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.062	< 0.062	(mm)	(Ø)		
DC 1	0.0	1.3	4.8	18.4	47.3	25.5	2.5	0.0	0.36	1.486	0.921	Medium Sand
DC 2	1.2	8.5	38.6	26.6	17.1	7.1	0.7	0.0	0.76	0.272	1.094	Coarse sand
DC 3	1.3	9.6	42.2	24.1	16.2	6.0	0.5	0.0	0.80	0.176	1.074	Coarse sand
DC 4	12.5	16.0	39.0	21.0	9.1	1.9	0.3	0.0	1.46	-0.13	0.924	Very Coarse Sand
DC 5	0.0	1.5	4.5	19.2	46.0	25.8	2.8	0.0	0.36	1.487	0.937	Medium Sand
DC 6	0.0	3.4	7.8	30.8	45.8	10.9	1.1	0.0	0.48	1.064	0.944	Medium Sand
Type S.	**2.5**	**6.7**	**22.7**	**23.3**	**30.2**	**12.8**	**1.3**	**0.0**	**0.51**	**0.725**	**1.178**	**Coarse sand**

In short, due to the sand quality, its origin, grain size and volumes, zone 4, in front of Miramar town, is the most suitable to be used as a borrow area for Artificial Sand Nourishment works on Viento Frío beach. However, the need to use a highly expensive technology for its exploitation made it necessary to locate a source that could be exploited with more available technologies and at a lower cost.

That is why, despite the fact that the sand found at Cuango River mouth is not the most suitable, it is proposed to use it for the execution of the project, adapting the design of the solutions to the available volume.

V.4. Suitability of the sand to be used

The sedimentological characterization, of both the beach and the borrow area, constitutes one of the essential elements in the executive projects where artificial sand nourishment is applied. It allows establishing the grain size composition and the genesis of the sand, the results of which make it possible to define the areas with the best possibilities to use in restoration work. In the case of Viento Frío, due to the low volume required, it was decided not to use a borrow area on the submarine shelf, using instead an area at Cuango River mouth.

In previous chapters, the results of the grain size and composition analyses performed on the sands, from both the beach and the borrow area, respectively, were described. (Annex 1). The grain size study carried out allows obtaining the values of the type samples that are presented in the Table 17.

Table 17. Type sample of grain size of the sand on the beach and in the borrow area.

Beach Type Sample				Borrow Area Type Sample			
M (mm)	M (ϕ)	Stand Dev (ϕ)	Classif.	M (mm)	M (ϕ)	Stand Dev (ϕ)	Classif .
0.19	1.639	1.232	Fine sand	0.51	0.725	1.178	Coarse sand

Analyzing the values in the table 17, it can be concluded that there is a marked difference between the type sample of the beach and that of the borrow area, in terms of the values of mean diameter (M). In the case of the native sand (beach), it is classified as fine sand where M = 0.19, being much higher in the value in the borrow area, where M = 0.51 mm.

A slight increase in the mean diameter of the sand in the borrow area, with respect to that on the beach, is appropriate to achieve greater stability of the sand grains when depositing the sediment in artificial nourishment works, as recommended by the Shore Protection Manual (1984).

The quantitative assessment of the volume of additional filling that is required to obtain the real dimensions of the project is carried out, taking into account the sand losses that will be produced

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by natural selection, sediment transport and the redistribution by grain sizes, from the calculation of the overfill ratio R_A according to the methodology proposed by James (1975) in the Shore Protection Manual (1984) and in the Manual on Artificial Beach Nourishment (1990).

This methodology allows quantifying R_A factor graphically, using the abacus proposed by James (1975) (Figure 27), considering that R_A is the value by which the project's fill volume must be multiplied, with the aim of compensating for foreseeable losses based on the grain size differences between the native sand and the introduced sand.

The values of the mean diameter M (ϕ) and the standard deviation $\sigma(\phi)$ of the introduced sand (borrow area) were taken from the type sample that appears in Table 17; doing likewise for the values of mean diameter M (ϕ) and standard deviation $\sigma(\phi)$ of the native sand (beach).

The value of the abscissa in the abacus was calculated through the following ratio:

$$\frac{M_{\phi b} - M_{\phi n}}{\sigma_{\phi n}} = \frac{0.72 - 1.64}{1.23} = -0.75$$

The value of the ordinate in the abacus was calculated through the following ratio:

$$\frac{\sigma_{\phi b}}{\sigma_{\phi n}} = \frac{1.18}{1.23} = 0.95$$

As can be observed in Figure 27, the red circle marks the point of intersection between the sand in the borrow area and that on the beach, located in the stable quadrant of the graph; thus, it is expected that the material deposited on the beach behaves in a stable manner, the factor R_A taking a value equal 1.00.

Obtaining a value of R_A = 1.00 allows establishing that the filling volume does not need adjustments, due to differences in the grain size between the native and the introduced sand.

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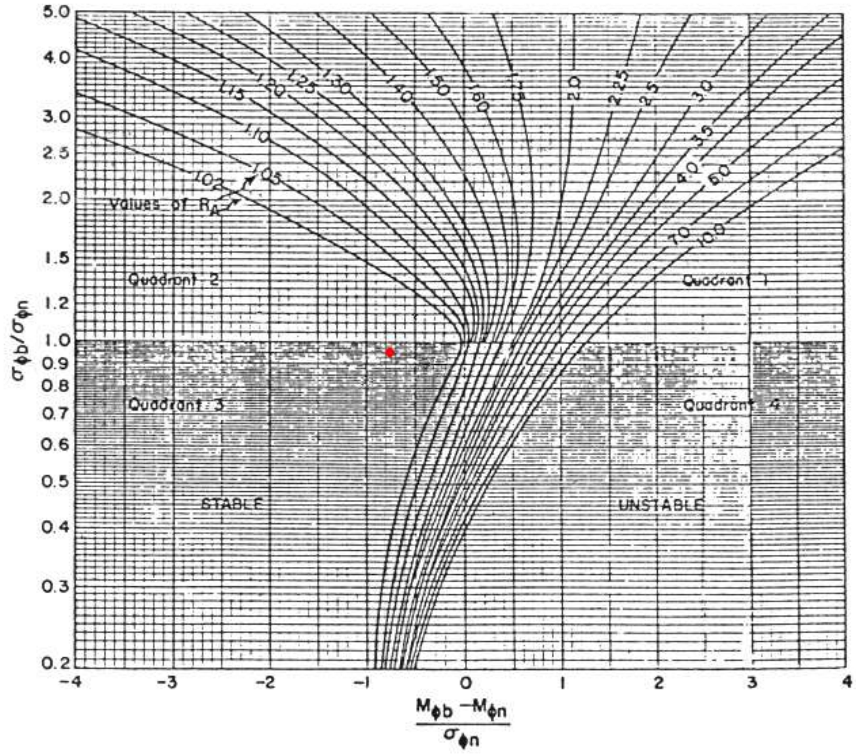

Figure 27. Overfill ratio R_A according to James (1975).

V.5. Calculation of filling volume

Taking into consideration the current conditions of the beach, the stretch to benefit from artificial sand nourishment will include the entire 450 m of beach, whose limits of are shown in Table 18 and Figure 28.

Table 18. Coordinates of the limits of the filling area.

West		East	
UTM Zone 17 North	**Geographic (WGS84)**	**UTM Zone 17 North**	**Geographic (WGS84)**
X: 674631.79	Lat : 09°35'02".11	X: 675032.25	Lat: 09°35'02".12
Y: 1059813.73	Long: 79°24'31".52	Y: 1059695.55	Long: 79°24'18".41

Regarding the calculation of the filling volume, international experience shows that various criteria are used for its estimation, although there is agreement that the density of the deposits should not be less than 60 m^3 per linear meter of beach (Juanes *et al*., 1996). However, this is a premise that cannot be fulfilled in this case; the dimensions of the beach, the sand volume available in the borrow area and, above all, its morphological characteristics do not allow it.

Figure 28. Limits of the beach to regenerate.

For the design of beaches, a formulation is generally used that allows the equilibrium profile to be determined from certain wave conditions and a given sediment, recognizing as equilibrium profile, the average profile around which the different seasonal or temporal variations are produced in a centered manner. These are smooth algebraic curves with one or more sections and generally easy to handle and calculate.

There are several models of the equilibrium profile, which allow evaluating the sand volume required to guarantee an increase in beach width. Many of these models are based on the one proposed by Dean (1977, 1991).

$$h(y) = A \times y^{2/3} \quad (1)$$

Where:

h(y) = depth at distance "y"

y = horizontal distance from the shoreline

A = dimensionless parameter related to sediment characteristics

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Knowing the equilibrium profile within a beach regeneration project is essential for two main reasons:

1st. It allows estimating the distance from the coast at which the closure depth is reached and, therefore, the stability of the sand.

2nd. It serves to determine the volume of material required for artificial sand nourishment.

Most beach engineering works are concentrated on the emerged part. However, when artificial nourishment is performed, the injected sand is distributed throughout the entire profile within the breaking zone, to a depth known as the closure depth (h*) of the active profile, obtained by Hallermeier (1981b) and later modified by Birkemeier (1985).

$$h^* = 1.75 \times H_{S12} - 57.9 \times \left(\frac{H_{S12}^2}{g \times T_S^2} \right) \quad (2)$$

Where:

H_{S12} = Significant wave height exceeded only 12 hours a year.

T_S = Significant wave period associated with H_{S12}

If the size of the introduced sand is similar to that of the native sand, the post-fill beach profile should be equal to the pre-fill profile, but extended towards the sea, in an “inverse” manner to the Bruun’s Rule (Bruun, 1962), which basically expresses that, for a given sea level rise, the shoreline will retreat uniformly to maintain a constant equilibrium profile (Figure 29).

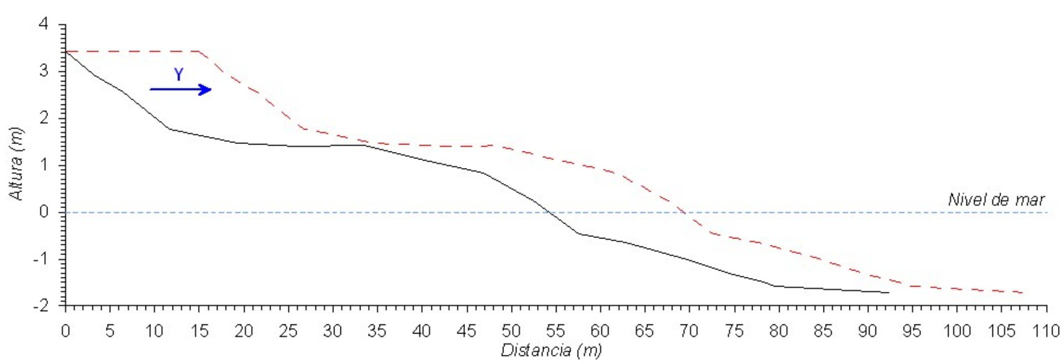

Figure 29. Off-shore displacement of the active profile as a consequence of the fillings.

Restoring the beach is, therefore, the reverse process where the profile will be rebuilt seaward. The Shore Protection Manual (1984) states that when the height of the berm is B and the closure depth is h* (Figure 30), to achieve a beach width Y, a volume V of sediment per linear meter of beach will be required, according to the expression:

$$V = (B + h^*) \times Y \tag{3}$$

In the event that the grain size of the filling sand differs from the native grain size, Dean's method (1991) allows determining the sediment volume necessary to achieve a desired dry beach width.

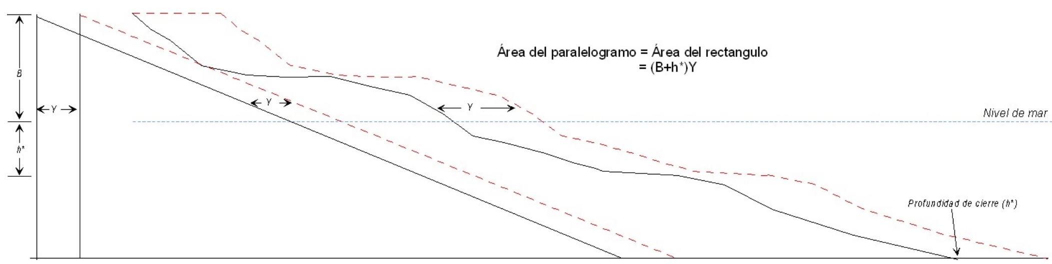

Figure 30. Sand volume per linear unit of length of the beach resulting from beach filling.

This author defined three basic types of filling profiles. Depending on parameter A of the native material (A_N) and the filling material (A_R), it may happen that the filling intercepts or does not intercept the native profile before the closure depth, or that it is submerged.

To determine whether or not a filling profile intercepts the native profile, Dean (1991) arrives at the following inequalities:

$$Y\left(\frac{A_N}{H}\right)^{3/2} + \left(\frac{A_N}{A_R}\right)^{3/2} < 1 \quad \text{The profile is intercepted} \tag{4}$$

$$Y\left(\frac{A_N}{H}\right)^{3/2} + \left(\frac{A_N}{A_R}\right)^{3/2} > 1 \quad \text{The profile is not intercepted} \tag{5}$$

Where:

A_N = value of the scale parameter A of the native sand

A_R = value of the scale parameter A of the introduced sand

H = closure depth of the active profile

Y = beach width to be achieved

In the case of profiles that do not intersect, the sediment volume to be deposited is determined by the expression:

$$V = B \times Y + \frac{3}{5} H^{5/2} \left[\left[\frac{Y}{H^{3/2}} + \left(\frac{1}{A_R} \right)^{3/2} \right]^{5/3} A_N - \left(\frac{1}{A_R} \right)^{3/2} \right] \qquad (6)$$

Where:

V = volume of sediment in cubic meters per linear meter of beach

H = closure depth of the active profile

B = height of the berm

Y = beach width to be achieved

A_N = value of the scale parameter A of the native sand

A_R = value of the scale parameter A of the sand to introduce

For profiles that do intersect (when inequality (4) holds true), the volume needed to obtain a determined beach width is given by:

$$V = B \times Y + \frac{\frac{3}{5} \times A_N \times Y^{5/3}}{\left[1 - \left(\frac{A_N}{A_R} \right)^{3/2} \right]^{2/3}} \qquad (7)$$

To apply the methodology proposed by Dean (1991), it is necessary to define the closure depth of the active profile (h*), by expression (2), for which the parameters H_{S12} and T_S must be determined.

To solve this expression, the parameters defined from the data provided by buoy 42058 were taken and are presented in Figures 18 and 19 of section IV.2, where H_S = 4 m and T_S = 11s, obtaining a value h* = 6.21m

From evaluating (4) and (5), it is concluded that the filling profile intercepts the native profile before the closure depth.

By applying the corresponding expression (6), it is determined that the volume per beach unit necessary to obtain a dry beach 15 m wide with a berm height of 1 m is 23 m^3/m.

The calculations were made with the help of the Coastal Engineering Tutor (TIC), a computer tool belonging to the Coastal Modeling System (SMC), which brings together the most widely used formulas and methods in the field of coastal engineering.

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The problem to be solved with the TIC is: given a beach profile with a certain native sand, calculate the sand fill volume needed per linear meter of beach, to achieve a certain advancement of the shoreline. The result was already presented above.

To carry out this calculation, the mean diameter (D_{50}) is needed, as well as the density of the native and filling sand, which are known data, as well as the characteristics of the wave to which the area is subjected.

To solve this problem, the model takes the following as starting hypotheses:

- The equilibrium profile of the beach is a Dean profile, even though there is a rocky slab, a characteristic that occurs in a wide sector of Viento Frío.
- The equilibrium profile is no longer applicable beyond the closure depth.
- Each profile is independent of the adjacent ones and there is no longshore transfer of material.
- Losses of material due to washing, segregation, dispersion, etc. are not taken into account. The relevant corrections must be applied to the filling volume finally obtained (loss of fines, feedback factor, overfill ratio, or others)

When a filling is made, the filling sand is not immediately rearranged according to its equilibrium profile, but initially adopts a certain shape, unrelated to wave action and that depends on the construction procedure used in the regeneration.

In the case of Viento Frío Beach, the unloading method will use trucks carrying sand extracted from the mouth of Cuango River; therefore, there will be no losses due to hydraulic processes. The deposited sand will later be reshaped to profile using heavy equipment, with which the resulting geometry will present a more controlled slope; although, when working in the area of interaction with the sea, it will always be obtained a different profile from the one that will be produced with the final profile or filling profile.

In addition, an estimate of this transitory situation is made using TIC, assuming that the sand is placed according to a quasi-horizontal surface, which at a certain distance from the coast falls with a constant slope until it intercepts the native profile. This provisional profile is called the dumping profile.

The results of running TIC are both numerical and graphic. The parameters used for the calculations are those that have been determined in previous sections, taking as a starting point the fact that it is desired to achieve a beach with a width of at least 15 m after reaching dynamic equilibrium.

The calculated numerical results are presented in Figure 31, and Figure 32 shows the graphic results, for the theoretical profiles (native, filling and dumping).

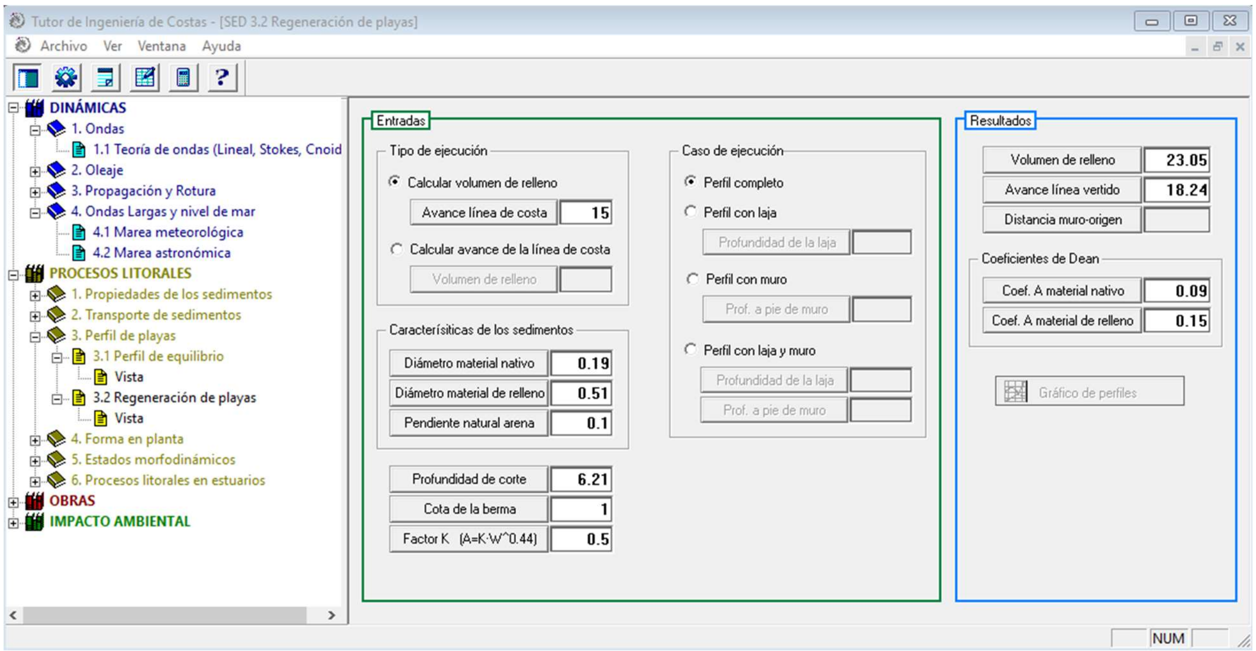

Figure 31. Calculation of the filling density and the advance of the dumping line, using the sands of Cuango borrow area.

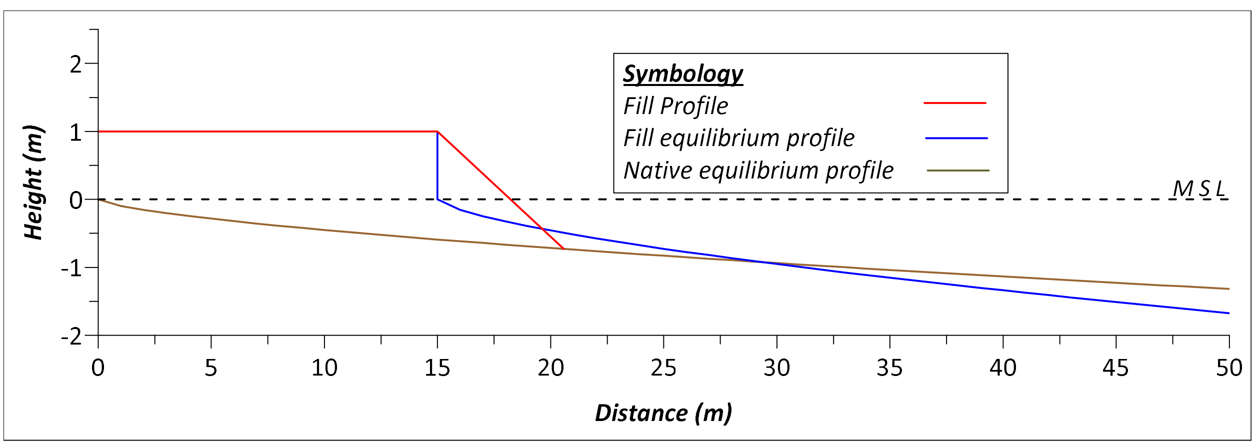

Figure 32. Representation of the equilibrium profiles (native and filling) and dumping profile, using sand from the borrow area at the mouth of Cuango River.

The filling volume value determined in Figure 31 (23 m^3/m) will not need to be corrected with the overfill ratio R_A to compensate for the losses that would occur during sand deposition, given the grain size differences between the introduced and the native material, as explained in section V.1.2. Therefore, to bring it to a more affordable figure for the executing agency, it is determined that a density of **25 m^3/m is needed** to achieve a width of 15 m of beach, once the dynamic equilibrium of the profile has been achieved. Multiplying this value by the beach length of 450 m, it will be necessary to provide a total volume of **11,250 m^3** to meet the project requirements.

Plan 2 shows the design profiles, which have been drawn up based on the beach profiles measured in August 2021, also considering that these are representative of the beach sectors where they are located. Table 19 shows the distribution of the sand volume by sectors.

Table 19. Distribution of sand volume by beach sectors.

Sector	Length (m)	Density (m^3/m)	Volume (m^3)
East	90	25	2,250
Center	200	25	5,000
West	160	25	4,000
Total	**450**	**25**	**11,250**

VI. EXPECTED EFFECTIVENESS OF THE PROJECT

At the end of the Artificial Sand Nourishment works, the material deposited on the beach is subjected to the action of waves, the currents induced by them and the wind. As a result of the action of these agents, a sand movement is established, following a morphodynamic functioning scheme, which causes the natural rearrangement of sediments, remaining in a position called equilibrium.

When evaluating the effectiveness of a project of this type, the greatest interest is to know its durability or useful life. Commonly, this assessment is made on the basis of quantifying, in terms of shoreline retreat and/or loss of sand volume, as well as the effects on dunes and backshore in the face of extreme erosive events.

In the case of Viento Frío Beach, under mean annual conditions, there are no large variations in beach profile, due to the low energy with which waves reach the shore. However, the extreme conditions caused by storms are responsible for the maximum damage that can occur.

Although storms are directly responsible for the moments of greatest erosion on the beach, it should be noted that the frequency of occurrence of this type of event is low in the Panamanian Caribbean; therefore, once the proposed solution is applied, it should be expected that the loss of the deposited sand will maintain low values.

Nevertheless, in much of this coastal sector, the morphology is not the most suitable for the sand to remain in the emerged part, due to the existence of an abrasive terrace that prevents the usual functioning of the beach profile.

The greatest challenge of the current project is, therefore, to achieve the stability of the artificially deposited sands in the medium and long term, to maintain a beach with appropriate aesthetic and functional conditions in the face of the challenges derived from climate change and mean sea level rise. Unfortunately, in Panama there are no records of shoreline retreat or of volume losses caused by coastal erosion; so we do not have statistical data to make an estimate. However, for other Caribbean countries, although the measured retreats show high variability, an average of around 1 m/year can be observed. Assuming this mean retreat value, for the current case, it can be estimated a period of 14 years for 60% of the discharged volume to be lost, provided that there are no hurricanes or other extreme hydrometeorological events that accelerate the sand loss process, being these events unusual for Panama.

With the sand filling, an emerged beach 15 m wide will be instantly achieved. However, from the emerged profile, sand will begin to move towards the underwater slope, until the shoreline adopts its equilibrium position, finally reaching a backshore width of 15 m on average.

It is important to note that this reduction in the beach width should not be understood as a loss; in any case, it should be interpreted as the natural rearrangement of the sand along the profile, where some of it in the emerged zone moves towards the submerged part.

It is recommended that, at the end of the sand filling works, regular monitoring of beach behavior is established, in order to identify critical sectors and plan preventive mitigation actions.

VII. MODE OF EXECUTION OF THE WORKS AND ESTIMATED TIME

VII.1. Execution mode of the works

The execution of the work must go through three (3) stages, which will guarantee its success:

1. Conditioning of the beach and preparation of works
2. Transport and storage of sand
3. Shaping of the design profile

Conditioning of the beach and preparation of works

At this stage, actions must be undertaken to facilitate the execution of the works, removing obstacles from the beach that prevent the free movement of heavy equipment and the correct redistribution of the material after it has been deposited.

The obstacles mainly found on this beach are drift wood brought by the sea, some old abandoned structures, and the villagers' boats. Also, in the borrow area, it must be prepared for the operation of machinery and trucks during sand mining work.

Another important action for this stage is the delimitation of the work area and the access pathways. Although due to the scope of the works and the method that will be used for the mining, transfer and deposit of the sand, they do not require that the entire beach or borrow area be closed, personnel from outside the project must be prevented from staying in areas where project staff is working with heavy machinery.

Transport and storage of sand

As explained in previous chapters, Viento Frío Beach has a total length of 450 m and, according to its characteristics, it was divided into 3 sectors for its study and solution design. In this same sectorization, the execution of the work must be organized.

Section V.1 and Plan 2 describe the characteristics of the proposed borrow area at the mouth of the Cuango River, which is located at an average distance of 13 km from the beach and, at the time of the field works, had a usable area of 10,730 m^2 and a possible volume to extract of 17,168 m^3, according to the measured thickness (1.60 m). As per the proposed design, the volume to be used on the beach will be 11,250 m^3, so it will only be necessary to extract a layer 1.05 m thick from the entire area to meet the proposed objective. It is important that this thickness is met, so as not to overexploit any sector of the sand bar and weaken its power. Mining in this area will be carried out with the use of a front loader, which will be extract and deposit the sand in the trucks that will finally transport it to the work area. Also with the use of this machinery, the bar will be reshaped once the work is finished.

After completing the route between Cuango and Viento Frío, the trucks will access the beach through the area west of the school, at coordinates X: 674862.89; Y: 1059689.51, as shown in Plan 4, through the Central sector, initially depositing the sand in the area adjacent to this access, where it will be rearranged to shape the design profile with the use of a front loader and a bulldozer.

As the material is deposited in the area, work will gradually advance eastward, until the entire section is covered up to the limit with the eastern sector. Once this section is covered, and using the same access point, the direction of the advance is reversed, moving towards the West sector.

When the work has sufficiently progressed to the west, workers can begin to use the existing access point at coordinates X: 674762.68; Y:1059708.16 (Plan 4), further to the town center, from which it will be necessary to cover the entire remaining section due to the impossibility of accessing it with trucks because the coastal area is occupied with houses and other facilities. The trucks must advance over the filling already shaped, to enable the work of the machinery in charge of distributing the material and shaping the design profile.

Lastly, once the Central and West sectors have been completed, work will proceed on the East sector, which becomes more complex as it does not currently have an emerged beach, giving rise to the need to create the base to be able to work with the heavy machinery. Due to the occupation of the shoreline, this sector can only be accessed from its eastern end, in the area adjacent to the pier at coordinates X: 675034.06, Y: 1059693.83 (Plan 4). Once the filling is done, then the machinery will be able to access the area to carry out the final shaping of the design profile.

During the operation, it is very important to keep strict control of the volume deposited against the advance per linear meter of beach, so as not to run the risk of not covering all the sectors, or reaching the end with excess material.

The coordinates of access to the beach are summarized in table 20, as well as the limit coordinates of each sector and its length.

Table 20. Limit coordinates of the sectors and accesses points to the beach. (UTM Zone 17 – WGS 84)

Sector	East Limit		West Limit	
	Easting	Northing	Easting	Northing
East	675035.37	1059699.82	674946.16	1059703.51
Central	674946.16	1059703.51	674763.45	1059732.56
West	674763.45	1059732.56	674639.54	1059819.49
Access 1			674862.89	1059689.51
Access 2			674762.68	1059708.16
Access 3			675034.06	1059693.83

Conformation of the design profile

This stage refers to the work that must be carried out once the sand has been deposited on the beach, in order to comply with the design parameters established in the project.

For shaping the design profiles with the proposed densities (Plan 2), it will be necessary to carry out an intense work rearranging the deposited sand, with the use of heavy equipment (bulldozer, front loaders), which begins from the moment in which the unloading of trucks is finished.

The execution mode for this work of carrying and rearranging the material must be supervised by the designer, which fall under the Author's control tasks, since the correct execution of this action will ensure minimizing the sand loss and guaranteeing the proper density for each section executed.

Once the sand deposition work has been completed, the final shaping of the profile must be carried out, eliminating the possible unavoidable deformations that are created by the work of heavy machinery.

Likewise, in the borrow area, profiling and shaping work will be conducted, once the work has been completed, to guarantee that this sand bar is shaped in the most natural way possible.

VII.2. Estimated time

Taking into account the distance to the borrow area (13 km) and the state of the road, an average speed of 20 km/h is assumed for each trip, for which only for transportation, it would take an hour and thirty minutes to complete a round trip cycle. Also adding the material loading and unloading times and possible unforeseen events, a complete cycle can take around two and a half hours, with which, for an 8-hour shift, each truck will be able to make three (3) trips. If the contractor makes available five (5) trucks for the work, each capable of transporting 10 m^3, then for one day of work a total of 150 m^3 of sand can be deposited on the beach.

Fulfilling these conditions, and taking into consideration that the total volume of sand is 10,750 m^3, the execution time can be 12 days, to which a total of seven (7) days must be added for contingencies, for a total 19 working days.

This estimate is highly variable; if more trucks are available and it is possible to work efficiently them, also creating the necessary conditions for night work, increasing working hours to 16 or 24, this time can be reduced considerably. On the other hand, if there are not at least five (5) trucks, or if their load capacity is lower, then this time can be extended.

VII. ESTIMATED COSTS

The budget that appears in the table below has been prepared based on experience in similar work carried out in Cuba and in the Caribbean area, so the calculations are estimated, reflecting the items that are commonly taken into account in the cost sheets prepared by the executing companies, which allows to have an order of the magnitude of the cost of the work for the short and medium term. The rates used were taken from the Price Generator for Construction in Panama (CYPES), in addition to consulting the Regulations of Fees of the College of Civil Engineers (COICI).

Table 21. Estimated cost for the dumping of sand on the beach of Viento Frío

Concept	Unit	Unit price	Quantity	Final price
Direct costs				
Topography brigade (Staking out and marking)	Day	$500.00	7	$3,500.00
Excavation with front loader	m^3	$6.65	11750	$78,137.50
Sand filling and compacting (Includes transportation)	m^3	$51.03	11750	$599,602.50
Subtotal Direct Expenses				**$681,240.00**
General expenses				
Utilities			10%	$68,124.00
Administrative expenses			3%	$20,437.20
Insurance and sureties			two%	$13,624.80
Workers Liquidation			1.5%	$10,218.60
Pension and retirement			1.5%	$10,218.60
Author's control and supervision			10%	$68,124.00
Contingencies and other expenses			5%	$34,062.00
Overhead Subtotal				**$224,809.20**
TOTAL				**$906,049.20**

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IX. MONITORING PROGRAM PROPOSAL

The objective of a Monitoring Program is to develop measurements and field studies that ensure that the magnitude, extension and trend of the erosion process in the coastal fronts of the beaches are kept updated. For the specific case of Viento Frío, once the project has been executed, it will also have the purpose of assessing the effectiveness of the actions carried out, allowing the introduction of corrective measures, or the making of new decisions in the medium and long term management plans.

Tasks of the Monitoring Program.

Task 1. Establishment of the methodology and procedure for the development of field and office work.

Objective: Establish a material base and qualified personnel in Panama to ensure the execution of the Program's tasks.

Description:

The work protocol for the monitoring network development is drawn up, taking as a reference the one used in the project “Impact Assessment of climate change on the sandy shorelines of the Caribbean: Alternatives for its control and resilience”, currently being implemented by the Association of Caribbean States (ACS). It includes training and qualification actions for the personnel.

Output: Work protocol and trained personnel for the development of the monitoring network.

Task 2. Topographic leveling of the beach profile.

Objective: Spatial-temporal evaluation of the changes in the shoreline and the morphology of the beach profile.

Description:

The topographical leveling of the beach profile will be repeated at the points of the established baseline, with measurements at least twice a year and after the occurrence of extreme erosive events. Monitoring techniques using high-resolution satellite images will also be introduced.

Output: Annual reports with topographic records of changes in the shoreline and beach profiles, with calculations of the erosion rate, expressed in m/year, and the volume of material removed from the coast.

Task 3. Sedimentological sampling.

Objective: Spatial-temporal assessment of variations in sediment composition.

Description:

The sedimentological sampling will be repeated to detect the variations in grain size and mineralogical composition of the material, at the same stations established in the baseline, at least twice a year and after the occurrence of extreme erosive events.

Output: Annual reports with records of the space-time changes in grain size and mineralogical composition of sediments.

Task 4. Meteorological study

Objective: Evaluate the spatial-temporal variations of the characteristics of wind and atmospheric pressure, for a better understanding and interpretation of hydrodynamic and morphodynamic processes.

Description:

Maintain a detailed control of the hourly variations of wind direction and speed, through recording equipment located in safe places and with access to specialists, as well as the recording of barometric pressure.

Output: Annual report with hourly records of wind speed and direction, as well as barometric pressure, useful for applying mathematical modeling in the interpretation of hydrodynamic and morphodynamic processes.

In the framework of a project for the monitoring of the evolution of Bonasse shoreline, it is essential to establish a high-precision tide gauge, which should be incorporated into the Caribbean Program to study sea level rise in response to climate change. The information provided by this tide gauge would also be especially useful for regional seismic studies.

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In this Monitoring Program, the tasks that have been identified directly guarantee the information required to evaluate the effectiveness of measures to be executed, as well as to have adequate information available in case other protection measures are required.

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X. ENVIRONMENTAL CONSIDERATIONS

As part of this study, it is carried out the assessment of environmental impacts that may occur, if the project is executed as proposed. For this purpose, the methodology for Environmental Impact Assessment (EIA) was followed, with the aim of gaining clarity and facilitating decision-making.

First, some concepts are pointed out:

Sand mining can be defined as an artificially induced erosion process, which also involves sediment transport and deposition. The different phases have the potential to directly or indirectly produce negative and/or positive impacts on the environment in the borrow areas and material discharge areas, as well as on their surroundings (Landaeta, CJ 2001).

For the assessment and prioritization of environmental impacts associated with the process of mining and deposition of the resulting material on the beach area, the RIAM method (Rapid Impact Assessment Matrix; DHI, Water & Environment, (2000)) was used, which foresees three sequential technical stages. This requires a multidisciplinary assessment team with a high knowledge of the process and the environment, which makes it possible to identify potential impacts and, to assess and prioritize them according to their environmental significance. The stages of the method are the following:

1. Study and identification of environmental factors
2. Identification of potential impacts
3. Assessment and prioritization of impacts

The detailed analysis of the assessments of each impact makes it possible to rank them according to their positive/negative nature, their magnitude and importance, and their severity.

The environmental impacts generated by each action are distinguished according to their magnitude. To assess the impacts derived from environmental problems, the Rapid Impact Assessment Matrix (RIAM) was used, which applies a scoring system that allows subjective judgments to be quantified, through the assessment of impacts according to predefined criteria and their location according to the environmental component involved, so that, in future analyses, each component can be consulted and compared, as well as the way in which the assessment was carried out. At the end of the chapter the prepared matrices are presented.

Other aspects that are normally described as part of the EIA, such as the description of the project to be assessed, the physical environment, biological-ecological environment, perceptual environment and socioeconomic environment, with their different categories, are ignored in this chapter, since most of them are described in other parts of this report and it is not considered necessary to repeat them. Therefore, the analysis goes directly to the environmental assessment.

In terms of management, the ecosystem approach recognizes those changes that are inevitable and seeks an appropriate balance between conservation and use of natural resources. This criterion is appropriate to analyze the environmental impacts in the assessment of socioeconomic development in Viento Frío town, for which having a stable and high-quality beach constitutes an important element for its development, for what it can represent in the dynamism of its economy, as well as in the defense against extreme erosive events.

Environmental impacts are assessed based on their nature according to pre-established environmental components consistent with four different types: physical/chemical, biological/ecological, sociological/cultural, and economic/operational, which were determined from the three phases of the project (Sand Mining, Transport and Discharge on the beach).

The assessment of the criteria is carried out according to the scale shown in Table 22.

The weighting of each variable is done by calculating the Score (ES), as follows:

$$ES = (A_1 x A_2) x (B_1 + B_2 + B_3)$$

Meanwhile, the raking by ranges is done based on the scale shown in Table 23.

Table 22. Assessment criteria of the RIAM method

RIAM ASSESSMENT CRITERIA				
CLUSTER	**CRITERION**	**WEIGHT**		**QUALITATIVE SCALE**
A	Importance of the condition (A1)	4	=	Of National Importance / International Interest
		3	=	Of Regional Importance / National Interest
		2	=	Important for immediate outer area
		1	=	Important only for local condition
		0	=	Without importance
	Magnitude of change or effect (A2)	3	=	Highest positive benefit
		2	=	Significant improvement
		1	=	Improvement
		0	=	Without changes
		-1	=	Negative change
		-2	=	Significant Deterioration or Negative Change
		-3	=	Major Deterioration or Negative Change
B.	Permanence (B1)	1	=	No Changes / Does not apply
		2	=	Temporary
		3	=	Permanent
	Reversibility (B2)	1	=	No Changes / Does not apply
		2	=	Reversible
		3	=	Irreversible
	Accumulation / Synergy (B3)	1	=	No Changes / Does not apply
		2	=	Non-cumulative / Simple
		3	=	Cumulative / Synergistic

Table 23. Ranges to rank the assessed impacts

Ranges to rank the assessed impacts		
Score (ES)	**Class**	**Interpretation**
72 to 108	+E	Change / Major Positive Impacts
36 to 71	+D	Change / Significant Positive Impacts
19 to 35	+C	Change / Moderate Positive Impacts
10 to 18	+B	Change / Positive Impact
1 to 9	+A	Change / Slightly Positive Impact
0	N	No change or importance
-1 to -9	-A	Change / Slightly negative impact
-10 to -18	-B	Change / Negative impact
-19 to -35	-C	Change / Moderate negative impact
-36 to -71	-D	Change / Significant negative impact
-72 to -108	-E	Change / Major Negative Impacts

Additionally, it is possible to analyze the environmental impacts by stages, beginning with those derived from the incidence of natural factors and processes in the current situation, whose effect would extend indefinitely in the event of choosing the No Action option, allowing the continuity of the erosive process in the beach; and concluding with the impacts derived from the abandonment or non-implementation of a management program that gives continuity to the actions necessary to control the effects of erosion in the medium and long term.

This way, the analysis of environmental impacts was carried out for the current situation and the stages of execution, operation and eventual abandonment of the project:

- Current Situation (No Action decision).
- Execution (of actions defined for the short term).
- Operation (exploitation of the beach).
- Eventual Abandonment (abandonment or non-implementation of an integrated beach management program, in the medium and long term).

Tables 24 and 25 show the impacts identified and assessed for each stage and components, based on the weightings that appear in tables 26 to 29.

From this analysis, the matrices corresponding to the current situation and to each of the stages analyzed (Tables 30 to 33) were obtained, as well as their graphic outputs (Fig. 33 to 36).

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Table 24. List of identified environmental impacts. Physical-Chemical and Biological-Ecological Components. The impacts derived from not acting are highlighted; as well as those resulting from not implementing or abandoning the management program in the long term.

No.	Comp.	Stage	Action	Activity	Environmental Impact	Character	Assessment	Permanence
1	PHYSICAL - CHEMICAL	CURRENT - ABANDONMENT	No Action - Non Implementation of Management	Erosive Process	Gradual shoreline retreat	Negative	Moderate	Permanent and irreversible
2					Loss of beach resilience capacity	Negative	Moderate	
3		EXECUTION	Artificial Beach Nourishment (ABN)	Mining	Alteration of the terrain in the borrow area	Negative	Very Low	Temporary and Reversible
4				Mining	Changes in the dynamics of Cuango River estuary	Negative	Very Low	Temporary and Reversible
5				All tasks	Risk of oil spill	Negative	Very Low	Temporary and Reversible
6				Discharge	Increased turbidity in beach water	Negative	Very Low	
7				All tasks	Pollution by emission of combustion gases	Negative	Very Low	Temporary and Non-cumulative
8				Mining	Noise Pollution	Negative	Very Low	
9		EXEC - OPERATION	ABN and Complementary Actions (CA)	Discharge - Profiling - Other tasks	Recovery of natural beach conditions	Positive	Moderate	Temporary and Reversible
10					Increased beach resilience capacity	Positive	Moderate	Temporary, Reversible and Non-cumulative
11	BIOLOGICAL - ECOLOGICAL			Erosive Process	Impacts on Coastal Vegetation due to the effect of erosion	Negative	Low	Permanent
12		Execution	Artificial Beach Nourishment	Mining	Damage To Biodiversity In The Loan Area	Negative	Low	Temporary, Reversible And Non-Cumulative
13				Mining - Discharge	Water eutrophication in the beach area	Negative	Very Low	
14			CA	Dune Reforestation	Rehabilitation of coastal vegetation	Positive	Very Low	Permanent
15			ABN and CA	Discharge - Profiling - Other tasks	Rehabilitated beach as a protective barrier for coastal vegetation	Positive	Low	Temporary and Reversible

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Table 25. List of identified environmental impacts. Sociological-Cultural and Economic-Operational Components. The impacts derived from not acting are highlighted; as well as those resulting from not implementing or abandoning the management program in the long term.

No.	Comp.	Stage	Action	Activity	Environmental Impact	Character	Assessment	Permanence
16	SOCIOLOGICAL - CULTURAL	CURRENT - ABANDONMENT	No Action - Non Implementation of Management	Erosive Process	Loss of beach recreational use value	Negative	Low	Permanent, Reversible and Cumulative
17					Damage to buildings in the coastal zone	Negative	Low	
18					Loss of beach natural aesthetic values	Negative	Low	
19		EXECUTION	ABN and Complementary Actions	All tasks	Employment generation during execution	Positive	Very Low	Temporary
20					Risk to the health of workers due to contaminants	Negative	Very Low	
21					Safety risk to workers due to the use of machinery	Negative	Very Low	
22		EXEC - OPERATION		Discharge - Profiling - Other tasks	Recovery of beach recreational use value	Positive	Low	Temporary, Reversible and Non-cumulative
23					Beach as coastal defense for Viento Frío town	Positive	Low	
24					Beach aesthetic-environmental improvement	Positive	Low	
25		OPERATION	Use and Management	Management Program	Generation of employment during Management	Positive	Low	Temporary
26	ECONOMIC - OPERATIONAL	CURRENT - ABANDONMENT	No Action - Non Implementation of Management	Erosive Process	Impact on the beach recreational potential	Negative	High	Permanent, Reversible and Cumulative
27					Depreciation of properties in the beach area	Negative	High	
28					Unfavorable environment for tourism-related services	Negative	High	
29					Increased cost of infrastructure maintenance	Negative	Low	
30		EXECUTION	ABN and Complementary Actions	Investment	High investment cost	Negative	Low	Permanent
31		EXEC - OPERATION		Discharge - Profiling - Other tasks	Increase in beach use potential	Positive	High	Temporary, Reversible and Non-cumulative
32					Appraisal of properties in the beach area	Positive	High	
33					Creation of a favorable environment for tourism-related services	Positive	High	
34					Reduction of infrastructure maintenance costs	Positive	Moderate	

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Table 26. Physical-Chemical Component. Impact assessment by stage.

Code	Physical-Chemical Component	Score / Stage				Classification / Stage				ASSESSMENT				
		Ac.	Ex.	Op.	Ab.	Ac.	Ex.	Op.	Ab.	A1	A2	B1	B2	B3
PC1	Gradual shoreline retreat	-27			-27	-C			-C	3	-1	3	3	3
PC2	Loss of beach resilience capacity	-27			-27	-C			-C	3	-1	3	3	3
PC3	Alteration of the terrain in the borrow area		-6				-A			1	-1	2	2	2
PC4	Change in the dynamics of Cuango River estuary		-6				-A			1	-1	2	2	2
PC5	Oil spill risk		-6				-A			1	-1	2	2	2
PC6	Increased turbidity in beach water		-6				-A			1	-1	2	2	2
PC7	Pollution by emission of combustion gases		-6				-A			1	-1	2	2	2
PC8	Noise pollution		-6				-A			1	-1	2	2	2
PC9	Recovery of natural beach conditions		36	36			D	D		3	2	2	2	2
PC10	Increased beach resilience capacity		36	36			D	D		3	2	2	2	2

Table 27. Biological-Ecological Component. Impact assessment by stage.

Code	Biological-Ecological Component	Score / Stage				Classification / Stage				ASSESSMENT				
		Ac.	Ex.	Op.	Ab.	Ac.	Ex.	Op.	Ab.	A1	A2	B1	B2	B3
BE1	Impacts on the vegetation due to erosion	-18			-18	-B			-B	1	-2	3	3	3
BE2	Damage to biodiversity in the borrow area		-12				-B			1	-2	2	2	2
BE3	Water eutrophication in the beach area		-6				-A			1	-1	2	2	2
BE4	Rehabilitation of coastal vegetation		9	9			A	A		1	1	3	3	3
BE5	Beach rehabilitated as a protective barrier for the ecosystem		12	12			B	B		1	2	2	2	2

Table 28. Socio-Cultural Component. Impact assessment by stage.

Code	Socio-Cultural Component	Score / Stage				Classification / Stage				ASSESSMENT				
		Ac.	Ex.	Op.	Ab.	Ac.	Ex.	Op.	Ab.	A1	A2	B1	B2	B3
SC1	Loss of beach tourist and recreational use value	-18			-18	-B			-B	1	-2	3	3	3
SC2	Damage to buildings in the coastal zone	-18			-18	-B			-B	1	-2	3	3	3
SC3	Loss of beach natural aesthetic values	-18			-18	-B			-B	1	-2	3	3	3
SC4	Employment generation during execution		6				A			1	1	2	2	2
SC5	Risk to the health of workers due to contaminants		6				A			1	1	2	2	2
SC6	Safety risk to workers due to the use of machinery		6				A			1	1	2	2	2
SC7	Recovery of beach tourist and recreational use value		18	18			B	B		1	2	3	3	3
SC8	Beach as coastal defense for building protection		12	12			B	B		1	2	2	2	2
SC9	Beach aesthetic-environmental improvement		12	12			B	B		1	2	2	2	2
SC10	Generation of employment during Management			18				B		1	2	3	3	3

Table 29. Economic-Operational Component. Impact assessment by stage.

Code	Economic-Operational Component	Score / Stage				Classification / Stage				ASSESSMENT				
		Ac.	Ex.	Op.	Ab.	Ac.	Ex.	Op.	Ab.	A1	A2	B1	B2	B3
EO1	Impacts on the beach tourist potential	-36			-36	-D			-D	2	-2	3	3	3
EO2	Depreciation of properties in the beach area	-36			-36	-D			-D	2	-2	3	3	3
EO3	Unfavorable environment for tourism-related services	-36			-36	-D			-D	2	-2	3	3	3
EO4	Increased cost of infrastructure maintenance	-18			-18	-B			-B	1	-2	3	3	3
EO5	High investment cost		-18				-B			3	-1	2	2	2
EO6	Increase in tourist potential of the beach		36	36			D	D		2	2	3	3	3
EO7	Appraisal of properties in the beach area		36	36			D	D		2	2	3	3	3
EO8	Creation of a favorable environment for services related to tourism		36	36			D	D		2	2	3	3	3
EO9	Reduction of infrastructure maintenance costs		24	24			C	C		2	2	2	2	2

During the application of RIAM methodology, a total of 34 environmental impacts were identified. From them:

- By components: Physical-Chemical 10; Biological-Ecological 5; Socio-Cultural 10; and Economic-Operational 9.
- Negative impacts: 21. However, 10 of them are typical of the current condition, being present as long as no action is taken, or after the execution of the proposed actions in the short term; 9 of them could occur again in the future, due to the non-implementation of a management program or its eventual abandonment.
- Positive impacts: 13. The concentration of positive impacts in the Operation stage (Use or exploitation of the beach) is remarkable. These impacts are achieved through the Execution of the proposed actions in the short term and last in the medium and long term, requiring a Management Program to guarantee their preservation.

Analysis by Stage:

Current Situation (No Action Option)

The option of not acting leads to the continuity and advance of erosion on the beach, so that it can only be expected the manifestation and exacerbation of mostly high or moderate negative impacts (Class D and C), in correspondence with the intensity of the erosive process.

It should be noted that Viento Frío Beach does not have a national significance, since it is currently not used for tourism or other activities that reach this level. That is why, the positive or negative impacts do not reach a higher categorization. However, for the local population, it is highly significant to have a more robust beach that allows its use as a source of income for the locality, in addition to becoming an element of natural defense against sea level rise and climate change effects.

This analysis expresses the need to act and implement the proposed strategy and actions defined in the short, medium and long term.

Table 30. Matrix of Impacts by Class. Current Situation (No Action Option).

CURRENT SITUATION / NO ACTION											
Class	-E	-D	-C	-B	-A	N	A	B	C	D	E
PC	0	0	two	0	0	0	0	0	0	0	0
BE	0	0	0	1	0	0	0	0	0	0	0
SC	0	0	0	3	0	0	0	0	0	0	0
EO	0	3	0	1	0	0	0	0	0	0	0
Total	**0**	**3**	**2**	**5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

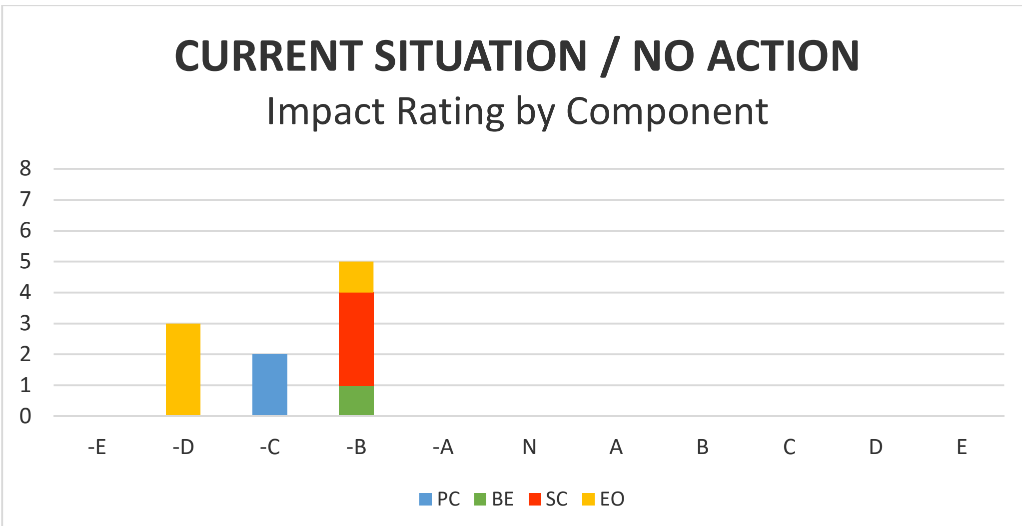

Figure 33. Graphic output of RIAM Matrix. Impacts by Class. Current Situation (No Action Option).

<u>Execution Stage</u>

This is the Stage with the highest number of impacts, 23, as it is the project's own execution.

However, the benefits derived from an improvement in the morphological, aesthetic and functional conditions of the beach contribute 5 positive impacts of class D (High) and 1 of class C (Moderate), expression of the desired reversal of the current state of the beach. In addition, among the positive impacts there are 4 class B (Low) and 4 class A (Very low), for a total of 14 positive impacts.

The foreseeable negative impacts of this type of actions amount to 9, all of them classifying as Low or Very Low (Classes A and B), several of them are small impacts that can be avoided with good technological practices.

Table 31. Matrix of Impacts by Class. Execution Stage.

EXECUTION STAGE											
Class	**-E**	**-D**	**-C**	**-B**	**-A**	**N**	**A**	**B**	**C**	**D**	**E**
PC	0	0	0	0	6	0	0	0	0	2	0
BE	0	0	0	1	1	0	1	1	0	0	0
SC	0	0	0	0	0	0	3	3	0	0	0
EO	0	0	0	1	0	0	0	0	1	3	0
T	**0**	**0**	**0**	**2**	**7**	**0**	**4**	**4**	**1**	**5**	**0**

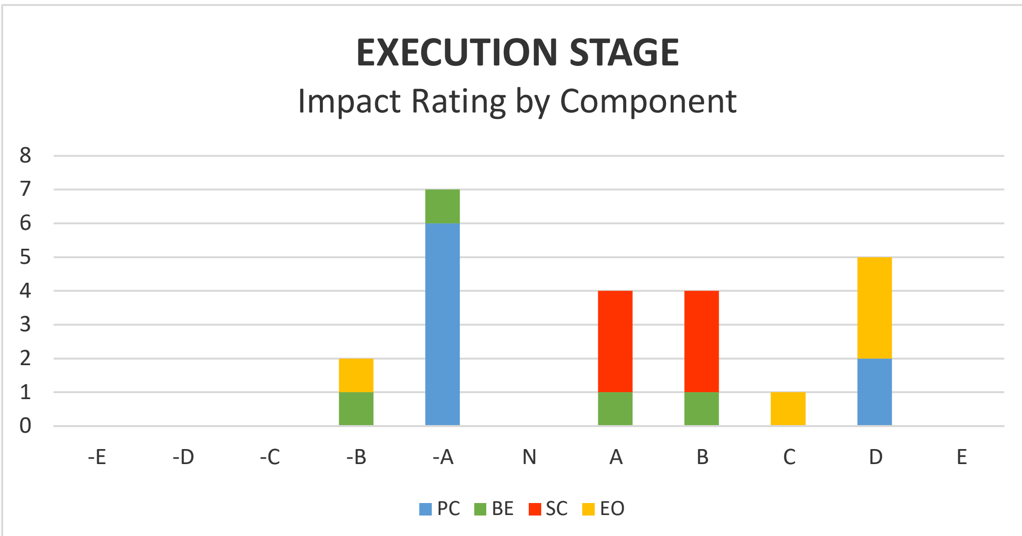

Figure 34. Graphic output of RIAM Matrix. Impacts by Class. Execution Stage.

<u>Operation Stage (Use or Exploitation)</u>

The objectives that will be achieved from the execution of beach restoration and other proposed complementary actions will allow that, once completed, the foreseeable impacts that will last on the beach will be positive in their entirety.

However, it should be noted that most are considered reversible, their sustainability depending on the implementation of a beach management program in the medium and long term.

Table 32. Matrix of Impacts by Class. Operation Situation (Use of the beach).

OPERATION STAGE (USE)											
Class	**-E**	**-D**	**-C**	**-B**	**-A**	**N**	**A**	**B**	**C**	**D**	**E**
PC	0	0	0	0	0	0	0	0	0	2	0
BE	0	0	0	0	0	0	1	1	0	0	0
SC	0	0	0	0	0	0	0	4	0	0	0
EO	0	0	0	0	0	0	0	0	1	3	0
T	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**5**	**1**	**5**	**0**

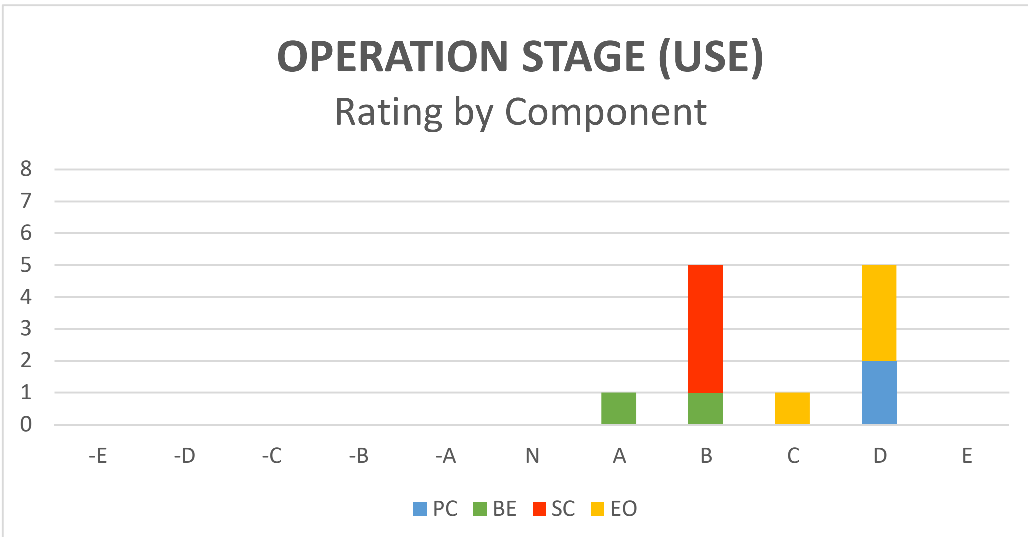

Figure 35. Graphic output of RIAM Matrix. Impacts by Class. Preparation Stage (Use of the beach).

Eventual Abandonment (Non-implementation or Abandonment of Management Program)

Once the recommended actions have been carried out, if the beach management strategy is not continued in the medium and long term, the beach situation could be reversed once again, returning to a condition very similar to the current one, which may then continue to deteriorate. Therefore, the 10 impacts identified in such a scenario are negative, half of them (5) in classifying classes D (High) and C (Moderate).

Table 33. Matrix of Impacts by Class. Abandonment (Non-implementation or abandonment of the Beach Management Plan in the medium and long term)

ABANDONMENT (WITHOUT MANAGEMENT PLAN)											
Class	-E	-D	-C	-B	-A	N	A	B	C	D	E
PC	0	0	2	0	0	0	0	0	0	0	0
BE	0	0	0	1	0	0	0	0	0	0	0
SC	0	0	0	3	0	0	0	0	0	0	0
EO	0	3	0	1	0	0	0	0	0	0	0
T	**0**	**3**	**2**	**5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

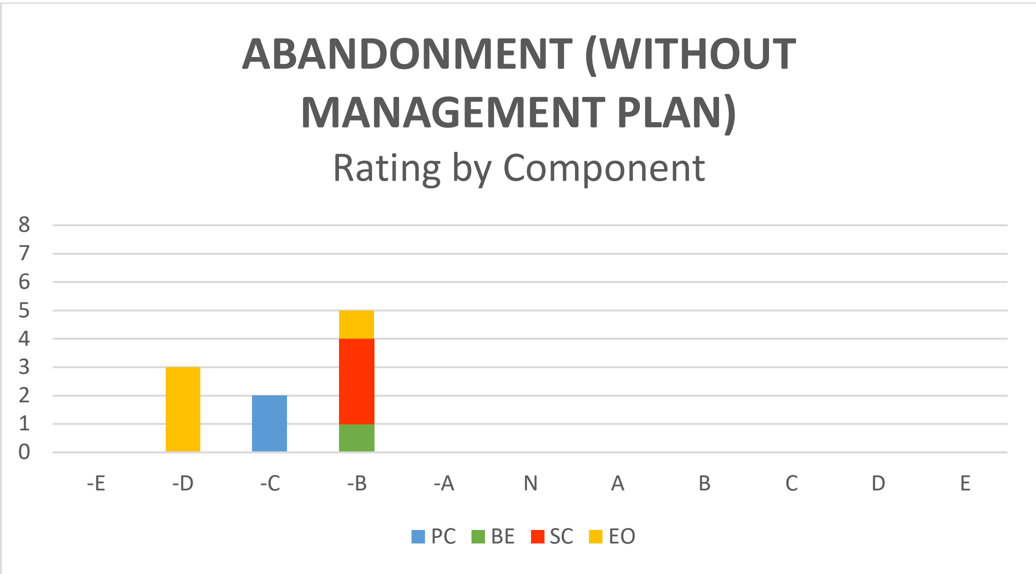

Figure 36. Graphic output of RIAM Matrix. Impacts by Class. Eventual Abandonment (Non-implementation or abandonment of the Beach Management Plan in the medium and long term).

Conclusions from the application of RIAM Method

From the preliminary assessment of environmental impacts of the actions proposed for the rehabilitation of Viento Frío Beach, it can be concluded that:

- The benefits of the project, in all the components, justify advancing in its execution and the implementation of a beach management strategy in the short, medium and long term.
- If no action is taken, it will imply greater damage to the beach due to the continuity of the erosive process and its effects.

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- After the execution of the actions foreseen in the short term, the non-implementation of a Management Program, once the foreseen period of effectiveness has elapsed, will return the beach to a condition similar to the current one and its deterioration will continue, progressively increasing the damages in all the components, and consequently, the costs of a possible new intervention for beach rehabilitation.

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ANNEXES

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Annex 1

Results of grain size analysis

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Result of the analyzes carried out on the beach of Viento Frío

Sample	Sieve Range								M		Standard deviation (Ø)	Wentworth Clasification
	>4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.062	< 0.062	(mm)	(Ø)		
M1	0	0.3	0.5	6.4	82.1	10.4	0	0	0.35	1.521	0.46	Medium sand
M2	0.6	2.1	2.6	6.8	57.4	29.6	0.2	0	0.31	1.609	0.82	Medium sand
M3	22.5	23.5	9.7	4.2	29.7	9.9	0	0	1.53	-0.613	1.33	Very coarse sand
M4	42.3	31.1	12.0	3.9	7.4	3.3	0	0	3.37	-1.752	1.01	Very fine sand and gravel
M5	35.4	14.2	5.5	2.3	20.0	21.9	0.7	0	0.56	0.643	1.353	Gross sand
M6	0.5	0.6	1.8	3.3	30.5	60.3	2.7	0	0.23	2.064	0.752	Fine sand
M7	0	0	0.3	1.4	62.5	34.8	0.4	0	0.28	1.838	0.527	Medium sand
M8	0	0	0	0.5	30.6	66.6	2.1	0	0.22	2.204	0.510	Fine sand
M9	0.9	0.2	0.9	3.8	45.6	43.4	4.2	0	0.24	1.947	0.722	Medium sand
M10	3.4	5.9	6.7	26.2	48.2	8.9	0.7	0	0.40	0.979	0.991	Medium sand
M11	1.3	4.2	4.3	9.9	40.6	35.9	3.3	0	0.30	1.595	1.080	Medium sand
M12	0	0.2	0	0	4.5	78.0	17.0	0.2	0.16	2.620	0.489	Fine sand
M13	0.7	1.8	0.9	3.1	20.8	62.0	10.5	0.2	0.21	2.222	0.883	Fine sand
M14	0.4	1.3	1.9	3.9	12.0	53.4	25.5	1.5	0.18	2.467	0.996	Fine sand
M15	0	0	0.1	0.7	3.5	55.7	38.5	1.5	0.14	2.861	0.618	Fine sand
S. Type	**7.2**	**5.7**	**3.1**	**5.1**	**33.0**	**38.3**	**7.1**	**0.2**	**0.19**	**1.639**	**1.232**	**Fine sand**

SAMPLE STATISTICS

SIEVING ERROR: 0.3%

SAMPLE IDENTITY: **M-1**   ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Well Sorted   TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

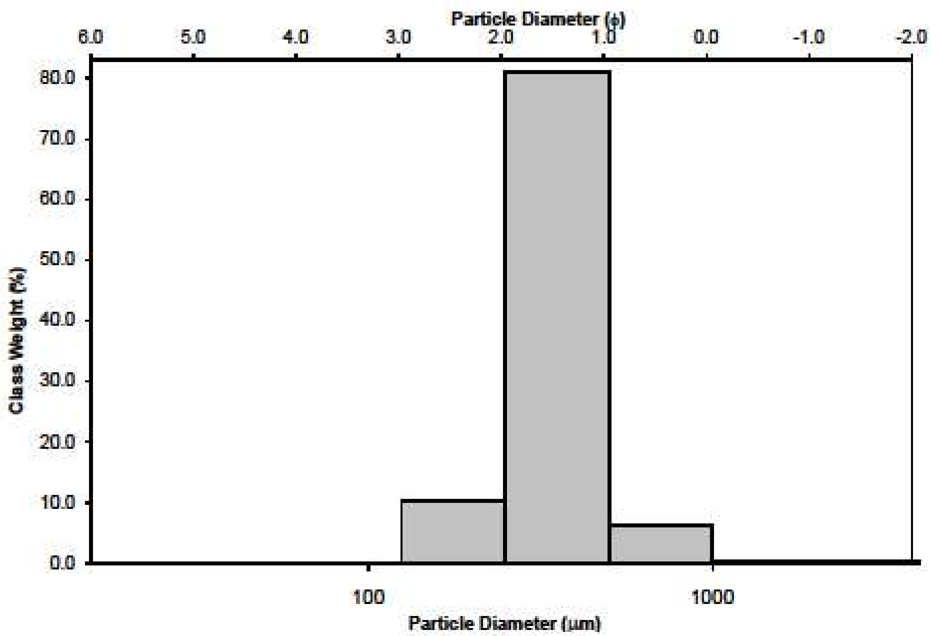
	μm	ϕ
MODE 1:	375.0	1.500
MODE 2:		
MODE 3:		
D_{10}:	242.9	1.034
MEDIAN or D_{50}:	348.8	1.519
D_{90}:	488.4	2.041
(D_{90} / D_{10}):	2.011	1.975
$(D_{90} - D_{10})$:	245.5	1.008
(D_{75} / D_{25}):	1.523	1.499
$(D_{75} - D_{25})$:	147.9	0.607

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.3%	COARSE SAND:	6.4%
SAND:	99.7%	MEDIUM SAND:	82.3%
MUD:	0.0%	FINE SAND:	10.4%
		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:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.3%	V FINE SILT:	0.0%
V COARSE SAND:	0.5%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	393.1	348.4	1.521	348.8	1.519	Medium Sand
SORTING (σ):	198.6	1.379	0.464	1.404	0.489	Well Sorted
SKEWNESS (Sk):	7.928	0.950	-0.950	-0.036	0.036	Symmetrical
KURTOSIS (K):	94.93	10.79	10.79	1.260	1.260	Leptokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.5%

SAMPLE IDENTITY: **M-11** ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Poorly Sorted TEXTURAL GROUP: Gravelly Sand

SEDIMENT NAME: Very Fine Gravelly Medium Sand

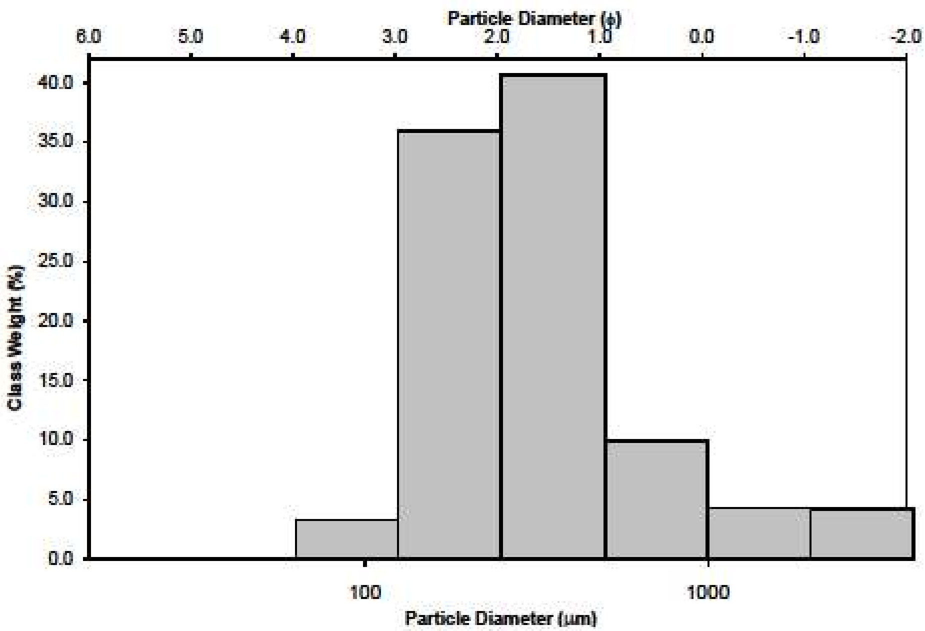
	μm	ϕ
MODE 1:	375.0	1.500
MODE 2:		
MODE 3:		
D_{10}:	142.1	0.015
MEDIAN or D_{50}:	299.3	1.740
D_{90}:	989.6	2.815
(D_{90} / D_{10}):	6.963	185.8
$(D_{90} - D_{10})$:	847.4	2.800
(D_{75} / D_{25}):	2.414	2.128
$(D_{75} - D_{25})$:	268.1	1.272

GRAIN SIZE DISTRIBUTION

GRAVEL:	5.5%	COARSE SAND:	9.9%
SAND:	94.5%	MEDIUM SAND:	40.8%
MUD:	0.0%	FINE SAND:	36.1%
		V FINE SAND:	3.3%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	5.5%	V FINE SILT:	0.0%
V COARSE SAND:	4.3%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	489.9	302.5	1.595	314.5	1.669	Medium Sand
SORTING (σ):	602.9	2.685	1.080	2.182	1.126	Poorly Sorted
SKEWNESS (Sk):	3.193	-1.930	-1.063	0.255	-0.255	Coarse Skewed
KURTOSIS (K):	13.06	16.14	4.128	1.314	1.314	Leptokurtic

GRAIN SIZE DISTRIBUTION



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SAMPLE STATISTICS

SIEVING ERROR: 0.1%

SAMPLE IDENTITY: **M-12**

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Fine Sand

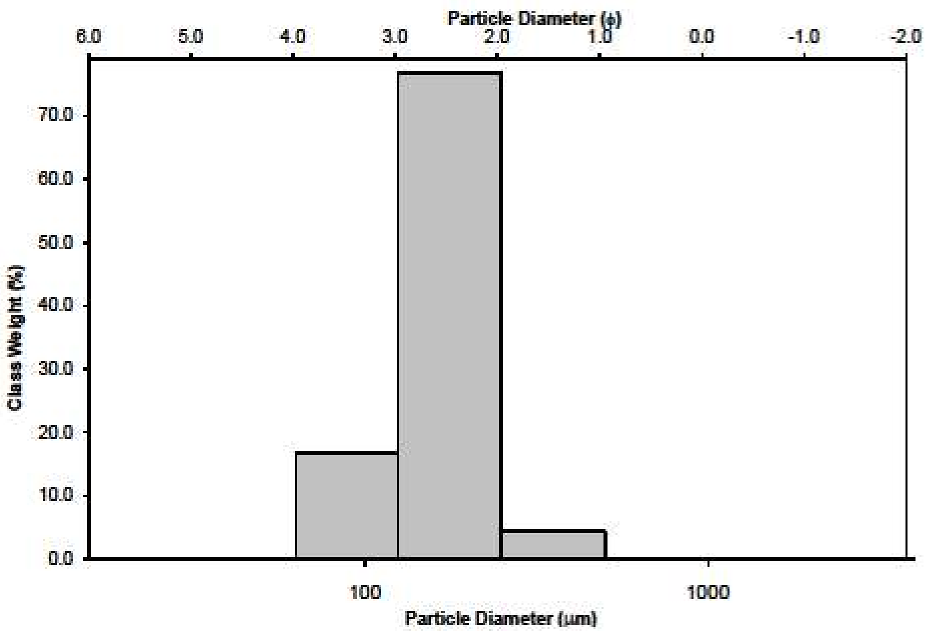
	μm	ϕ
MODE 1:	187.5	2.500
MODE 2:		
MODE 3:		
D_{10}:	93.48	2.068
MEDIAN or D_{50}:	167.2	2.580
D_{90}:	238.5	3.419
(D_{90} / D_{10}):	2.552	1.654
$(D_{90} - D_{10})$:	145.0	1.351
(D_{75} / D_{25}):	1.559	1.283
$(D_{75} - D_{25})$:	74.84	0.640

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.2%	COARSE SAND:	0.0%
SAND:	99.6%	MEDIUM SAND:	4.5%
MUD:	0.2%	FINE SAND:	78.1%
		V FINE SAND:	17.0%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.2%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.2%	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 ($\bar{x}$):	185.4	162.7	2.620	165.1	2.599	Fine Sand
SORTING (σ):	137.6	1.403	0.489	1.404	0.490	Well Sorted
SKEWNESS (Sk):	17.19	0.666	-0.666	-0.192	0.192	Fine Skewed
KURTOSIS (K):	350.4	13.54	13.54	1.092	1.092	Mesokurtic

GRAIN SIZE DISTRIBUTION



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SAMPLE STATISTICS

SIEVING ERROR: 0.0%

SAMPLE IDENTITY: **M-13**

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Sorted

TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Fine Sand

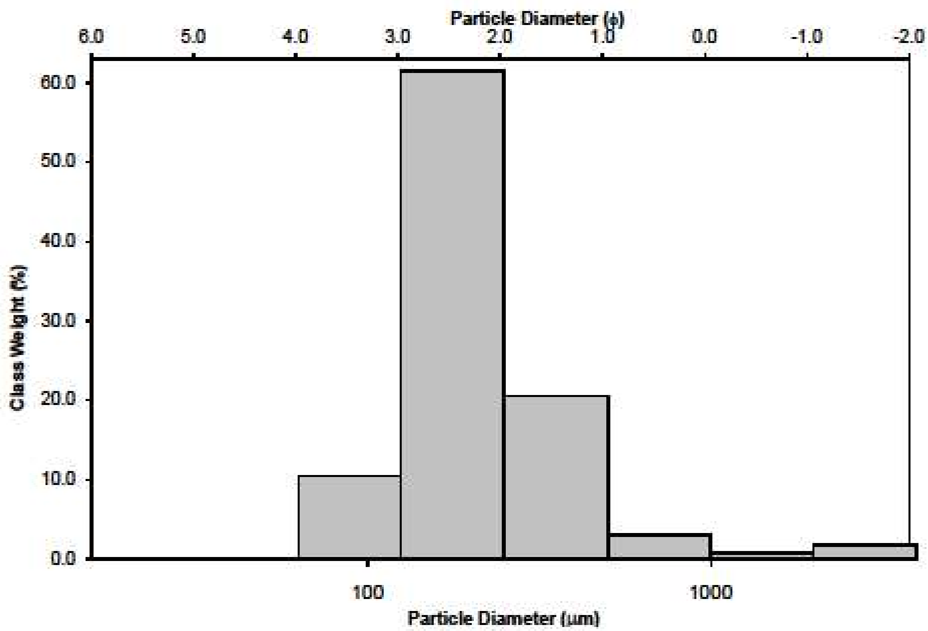
	μm	ϕ
MODE 1:	187.5	2.500
MODE 2:		
MODE 3:		
D_{10}:	119.4	1.168
MEDIAN or D_{50}:	194.0	2.366
D_{90}:	445.0	3.066
(D_{90} / D_{10}):	3.726	2.624
$(D_{90} - D_{10})$:	325.5	1.898
(D_{75} / D_{25}):	1.840	1.466
$(D_{75} - D_{25})$:	123.2	0.880

GRAIN SIZE DISTRIBUTION

GRAVEL:	2.5%	COARSE SAND:	3.1%
SAND:	97.3%	MEDIUM SAND:	20.8%
MUD:	0.2%	FINE SAND:	62.0%
		V FINE SAND:	10.5%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.2%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	2.5%	V FINE SILT:	0.0%
V COARSE SAND:	0.9%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	295.0	204.2	2.222	210.8	2.246	Fine Sand
SORTING (σ):	405.8	2.109	0.883	1.768	0.822	Moderately Sorted
SKEWNESS (Sk):	5.586	-1.534	-1.700	0.236	-0.236	Coarse Skewed
KURTOSIS (K):	36.31	21.73	7.873	1.407	1.407	Leptokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.1%

SAMPLE IDENTITY: **M-14**

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Sorted

TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Fine Sand

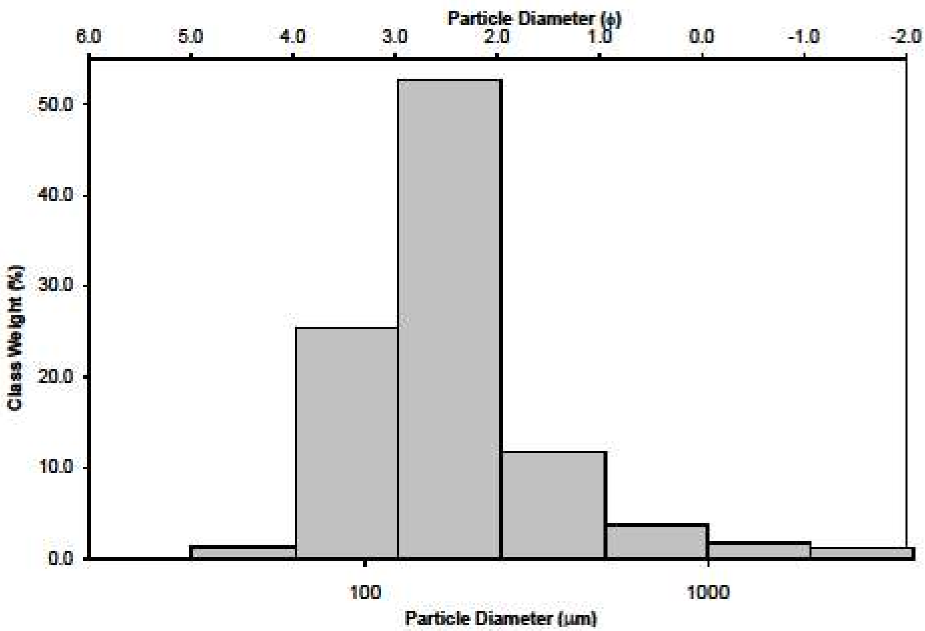
	μm	ϕ
MODE 1:	187.5	2.500
MODE 2:		
MODE 3:		
D_{10}:	79.14	1.208
MEDIAN or D_{50}:	168.4	2.570
D_{90}:	433.0	3.659
(D_{90} / D_{10}):	5.471	3.031
$(D_{90} - D_{10})$:	353.9	2.452
(D_{75} / D_{25}):	1.967	1.464
$(D_{75} - D_{25})$:	114.5	0.976

GRAIN SIZE DISTRIBUTION

GRAVEL:	1.7%	COARSE SAND:	3.9%
SAND:	96.8%	MEDIUM SAND:	12.0%
MUD:	1.5%	FINE SAND:	53.5%
		V FINE SAND:	25.5%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	1.5%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	1.7%	V FINE SILT:	0.0%
V COARSE SAND:	1.9%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	266.8	176.0	2.467	168.6	2.568	Fine Sand
SORTING (σ):	385.6	2.131	0.996	1.945	0.960	Moderately Sorted
SKEWNESS (Sk):	5.306	-0.181	-1.387	0.135	-0.135	Coarse Skewed
KURTOSIS (K):	34.97	13.07	6.171	1.468	1.468	Leptokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.0%

SAMPLE IDENTITY: **M-15**

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand

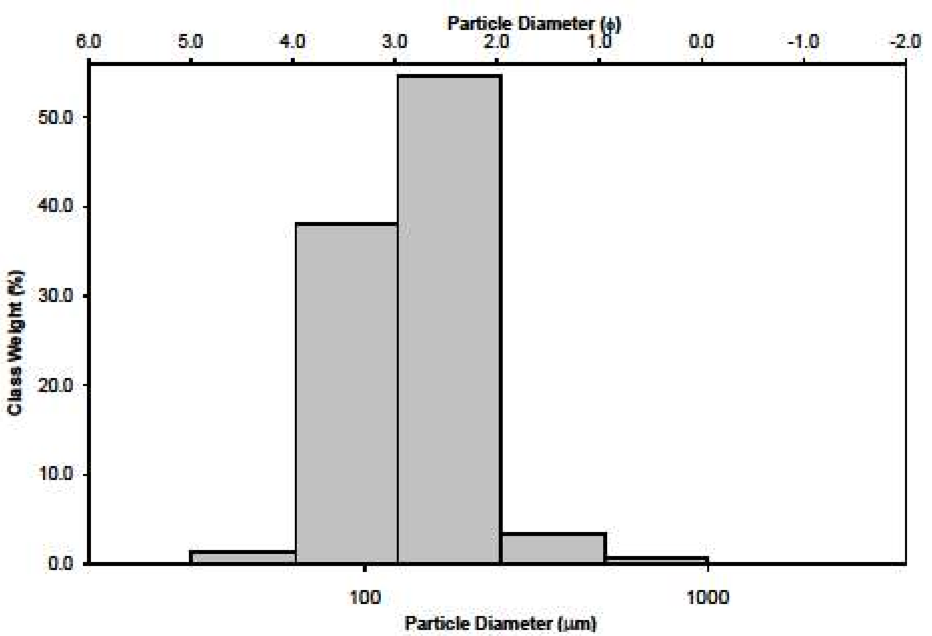
	μm	ϕ
MODE 1:	187.5	2.500
MODE 2:		
MODE 3:		
D_{10}:	73.29	2.102
MEDIAN or D_{50}:	141.6	2.820
D_{90}:	232.9	3.770
(D_{90} / D_{10}):	3.178	1.793
$(D_{90} - D_{10})$:	159.6	1.668
(D_{75} / D_{25}):	2.019	1.427
$(D_{75} - D_{25})$:	97.51	1.013

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.0%	COARSE SAND:	0.7%
SAND:	98.5%	MEDIUM SAND:	3.5%
MUD:	1.5%	FINE SAND:	55.7%
		V FINE SAND:	38.5%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	1.5%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	0.1%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	161.2	137.7	2.861	135.6	2.882	Fine Sand
SORTING (σ):	90.21	1.535	0.618	1.555	0.637	Moderately Well Sorted
SKEWNESS (Sk):	5.504	0.340	-0.340	-0.138	0.138	Fine Skewed
KURTOSIS (K):	62.47	4.409	4.409	0.763	0.763	Platykurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.7%

SAMPLE IDENTITY: **M-2** ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Sorted TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

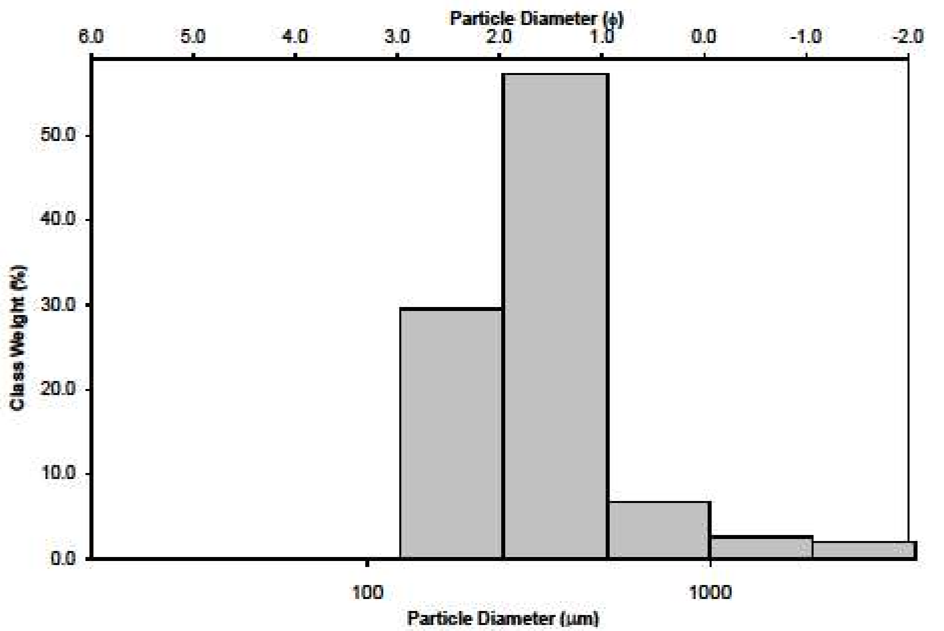
	μm	φ
MODE 1:	375.0	1.500
MODE 2:		
MODE 3:		
D_{10}:	157.0	0.681
MEDIAN or D_{50}:	317.7	1.654
D_{90}:	623.8	2.671
(D_{90} / D_{10}):	3.973	3.923
$(D_{90} - D_{10})$:	466.8	1.990
(D_{75} / D_{25}):	1.927	1.775
$(D_{75} - D_{25})$:	206.3	0.946

GRAIN SIZE DISTRIBUTION

GRAVEL:	2.7%	COARSE SAND:	6.8%
SAND:	97.3%	MEDIUM SAND:	57.8%
MUD:	0.0%	FINE SAND:	29.8%
		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:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	2.7%	V FINE SILT:	0.0%
V COARSE SAND:	2.6%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	426.9	314.5	1.609	301.4	1.730	Medium Sand
SORTING (σ):	444.2	2.051	0.819	1.742	0.801	Moderately Sorted
SKEWNESS (Sk):	4.453	-2.319	-1.410	0.020	-0.020	Symmetrical
KURTOSIS (K):	24.76	27.42	6.323	1.285	1.285	Leptokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.5%

SAMPLE IDENTITY: **M-3**

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Bimodal, Poorly Sorted

TEXTURAL GROUP: Sandy Gravel

SEDIMENT NAME: Sandy Very Fine Gravel

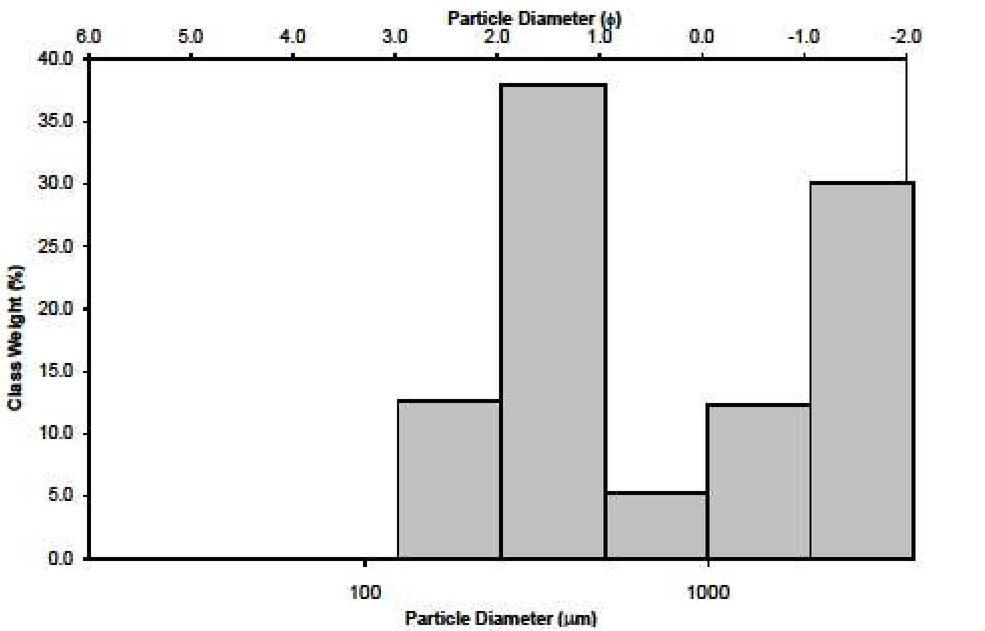
	μm	φ
MODE 1:	375.0	1.500
MODE 2:	3000.0	-1.500
MODE 3:		
D_{10}:	250.3	-2.748
MEDIAN or D_{50}:	1529.9	-0.613
D_{90}:	6718.5	1.998
(D_{90} / D_{10}):	26.84	-0.727
$(D_{90} - D_{10})$:	6468.2	4.746
(D_{75} / D_{25}):	10.52	-0.788
$(D_{75} - D_{25})$:	3374.8	3.395

GRAIN SIZE DISTRIBUTION

GRAVEL:	46.2%	COARSE SAND:	4.2%
SAND:	53.8%	MEDIUM SAND:	29.8%
MUD:	0.0%	FINE SAND:	9.9%
		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:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	46.2%	V FINE SILT:	0.0%
V COARSE SAND:	9.7%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	1017.0	168.6	0.315	1054.9	-0.077	Very Coarse Sand
SORTING (σ):	1174.7	18.51	1.327	2.376	1.249	Poorly Sorted
SKEWNESS (Sk):	0.912	-0.966	0.028	-0.809	0.809	Very Fine Skewed
KURTOSIS (K):	2.099	2.393	1.763	0.355	0.355	Very Platykurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.0%

SAMPLE IDENTITY: **M-4**

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Bimodal, Well Sorted

TEXTURAL GROUP: Sandy Gravel

SEDIMENT NAME: Sandy Very Fine Gravel

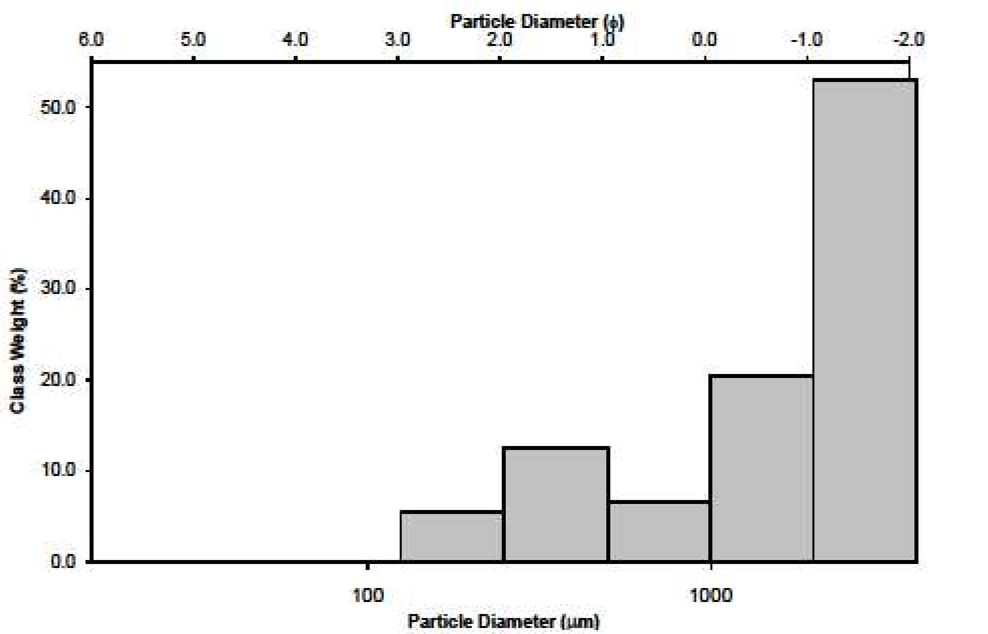
	μm	φ
MODE 1:	3000.0	-1.500
MODE 2:	375.0	1.500
MODE 3:		
D_{10}:	468.3	-4.062
MEDIAN or D_{50}:	3369.2	-1.752
D_{90}:	16699.1	1.095
(D_{90} / D_{10}):	35.66	-0.269
$(D_{90} - D_{10})$:	16230.9	5.156
(D_{75} / D_{25}):	1.244	0.733
$(D_{75} - D_{25})$:	445.5	0.315

GRAIN SIZE DISTRIBUTION

GRAVEL:	73.4%	COARSE SAND:	3.9%
SAND:	26.6%	MEDIUM SAND:	7.4%
MUD:	0.0%	FINE SAND:	3.3%
		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:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	73.4%	V FINE SILT:	0.0%
V COARSE SAND:	12.0%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	1176.2	66.89	-0.314	1834.3	-0.875	Very Coarse Sand
SORTING (σ):	1311.1	38.90	1.007	1.379	0.464	Well Sorted
SKEWNESS (Sk):	0.501	-0.220	0.676	-3.312	3.312	Very Fine Skewed
KURTOSIS (K):	1.460	1.143	3.410	2.608	2.608	Very Leptokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.0%

SAMPLE IDENTITY: **M-5** ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Bimodal, Poorly Sorted TEXTURAL GROUP: Sandy Gravel

SEDIMENT NAME: Sandy Very Fine Gravel

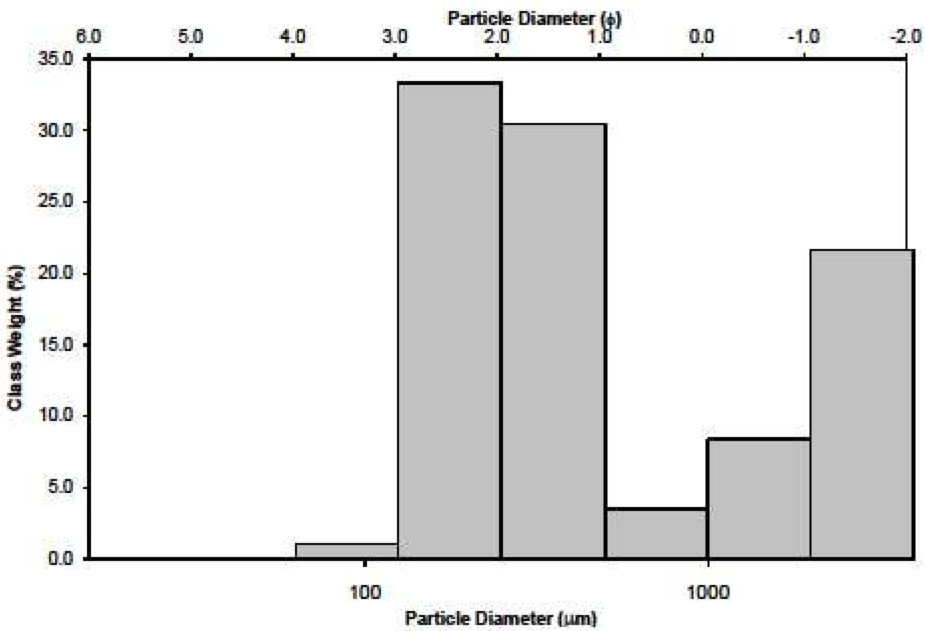
	µm	ϕ
MODE 1:	187.5	2.500
MODE 2:	3000.0	-1.500
MODE 3:		
D_{10}:	167.8	-4.419
MEDIAN or D_{50}:	1901.7	-0.927
D_{90}:	21392.7	2.575
(D_{90} / D_{10}):	127.5	-0.583
$(D_{90} - D_{10})$:	21224.9	6.994
(D_{75} / D_{25}):	9.798	-1.331
$(D_{75} - D_{25})$:	2390.2	3.292

GRAIN SIZE DISTRIBUTION

GRAVEL:	49.6%	COARSE SAND:	2.3%
SAND:	50.4%	MEDIUM SAND:	20.0%
MUD:	0.0%	FINE SAND:	21.9%
		V FINE SAND:	0.7%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	49.6%	V FINE SILT:	0.0%
V COARSE SAND:	5.5%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic µm	Geometric µm	Logarithmic ϕ	Geometric µm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	642.5	55.52	0.643	897.1	0.157	Coarse Sand
SORTING (σ):	1018.7	22.20	1.353	2.410	1.269	Poorly Sorted
SKEWNESS (Sk):	1.680	-0.351	0.047	-1.216	1.216	Very Fine Skewed
KURTOSIS (K):	4.167	1.470	1.889	0.384	0.384	Very Platykurtic

GRAIN SIZE DISTRIBUTION



SIEVING ERROR: 0.3%

SAMPLE STATISTICS

SAMPLE IDENTITY: **M-6**

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Sorted

TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Fine Sand

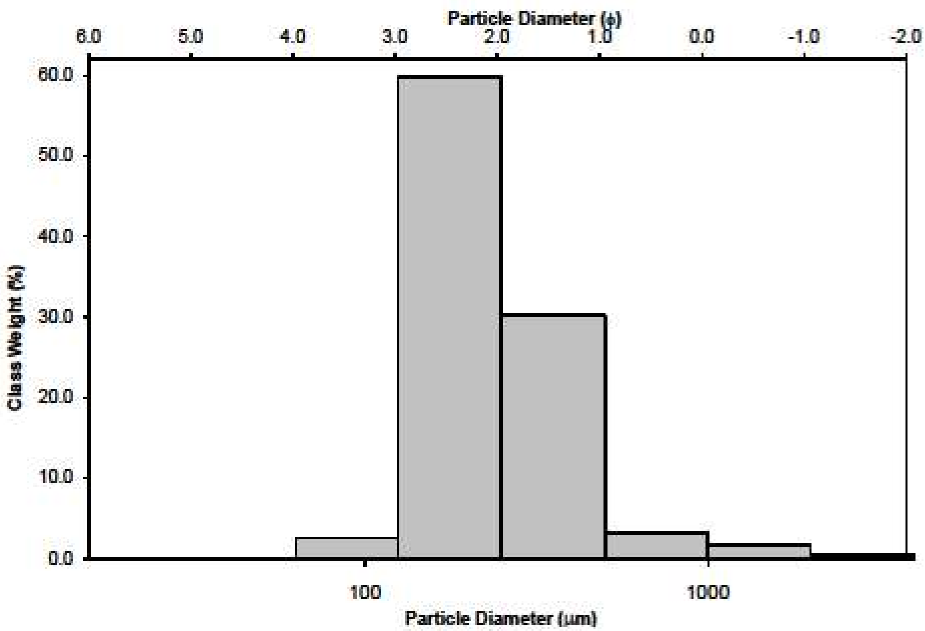
	μm	φ
MODE 1:	187.5	2.500
MODE 2:		
MODE 3:		
D_{10}:	135.9	1.124
MEDIAN or D_{50}:	214.9	2.218
D_{90}:	458.9	2.879
(D_{90} / D_{10}):	3.377	2.563
(D_{90} - D_{10}):	323.1	1.756
(D_{75} / D_{25}):	2.024	1.630
(D_{75} - D_{25}):	165.3	1.017

GRAIN SIZE DISTRIBUTION

GRAVEL:	1.1%	COARSE SAND:	3.3%
SAND:	98.9%	MEDIUM SAND:	30.6%
MUD:	0.0%	FINE SAND:	60.5%
		V FINE SAND:	2.7%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	1.1%	V FINE SILT:	0.0%
V COARSE SAND:	1.8%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	300.6	231.0	2.064	232.3	2.106	Fine Sand
SORTING (σ):	295.9	1.898	0.752	1.645	0.718	Moderately Sorted
SKEWNESS (Sk):	5.845	-2.174	-1.584	0.296	-0.296	Coarse Skewed
KURTOSIS (K):	46.76	29.19	6.909	0.939	0.939	Mesokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.6%

SAMPLE IDENTITY: **M-7** ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Medium Sand

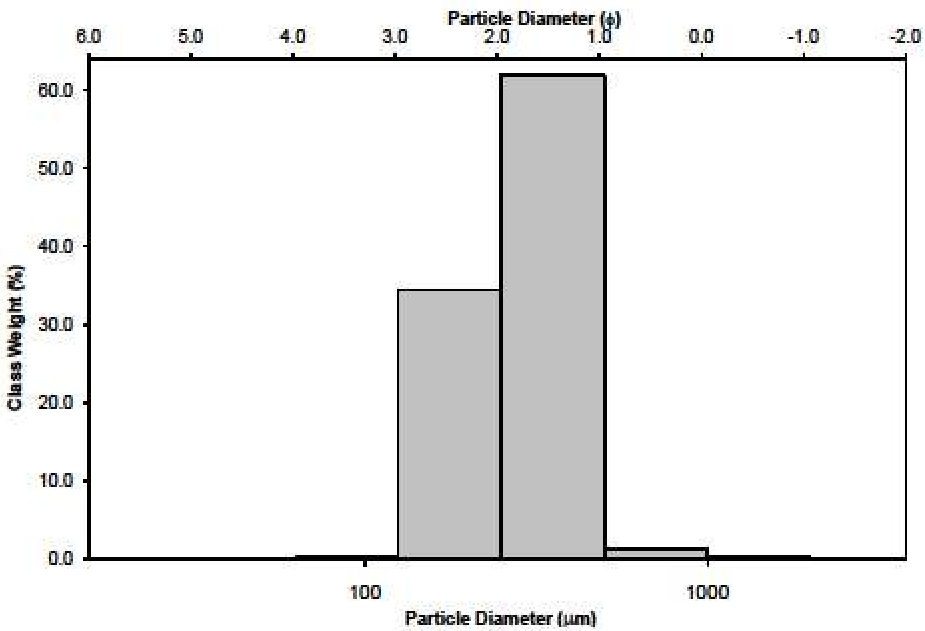
	μm	φ
MODE 1:	375.0	1.500
MODE 2:		
MODE 3:		
D_{10}:	151.2	1.132
MEDIAN or D_{50}:	293.6	1.768
D_{90}:	456.3	2.726
(D_{90} / D_{10}):	3.019	2.408
$(D_{90} - D_{10})$:	305.2	1.594
(D_{75} / D_{25}):	1.901	1.676
$(D_{75} - D_{25})$:	183.4	0.927

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.0%	COARSE SAND:	1.4%
SAND:	100.0%	MEDIUM SAND:	62.9%
MUD:	0.0%	FINE SAND:	35.0%
		V FINE SAND:	0.4%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	0.3%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	316.9	279.7	1.838	277.4	1.850	Medium Sand
SORTING (σ):	122.7	1.441	0.527	1.523	0.607	Moderately Well Sorted
SKEWNESS (Sk):	2.958	-0.159	0.159	-0.199	0.199	Fine Skewed
KURTOSIS (K):	28.80	3.119	3.119	0.803	0.803	Platykurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.2%

SAMPLE IDENTITY: **M-8**

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand

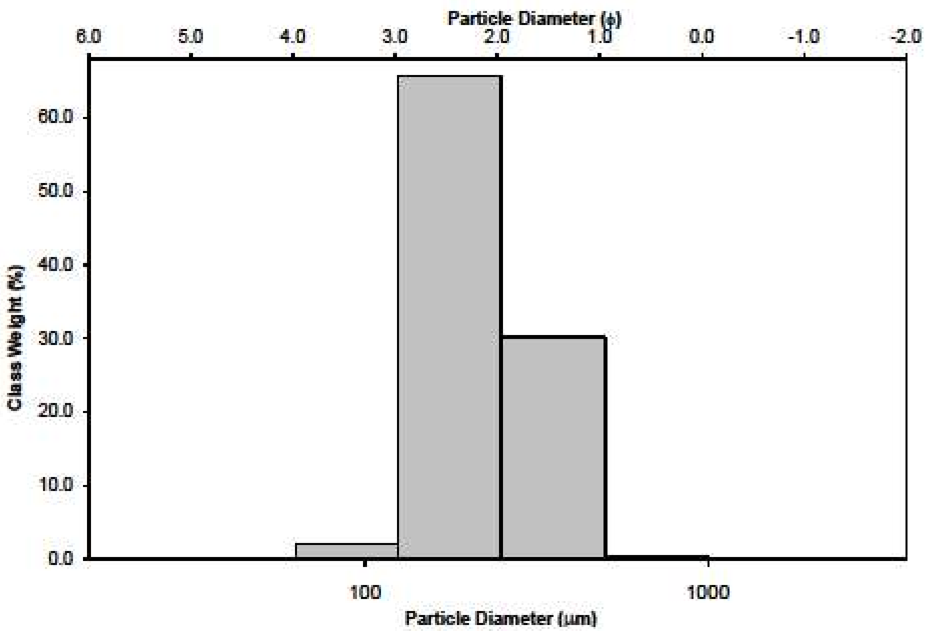
	μm	ϕ
MODE 1:	187.5	2.500
MODE 2:		
MODE 3:		
D_{10}:	135.7	1.310
MEDIAN or D_{50}:	205.6	2.282
D_{90}:	403.4	2.882
(D_{90} / D_{10}):	2.973	2.200
$(D_{90} - D_{10})$:	267.7	1.572
(D_{75} / D_{25}):	1.812	1.477
$(D_{75} - D_{25})$:	128.8	0.858

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.0%	COARSE SAND:	0.5%
SAND:	100.0%	MEDIUM SAND:	30.7%
MUD:	0.0%	FINE SAND:	66.7%
		V FINE SAND:	2.1%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	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 ($\bar{x}$):	245.8	217.0	2.204	218.7	2.193	Fine Sand
SORTING (σ):	95.63	1.424	0.510	1.511	0.596	Moderately Well Sorted
SKEWNESS (Sk):	1.254	0.524	-0.524	0.231	-0.231	Coarse Skewed
KURTOSIS (K):	5.117	2.678	2.678	0.865	0.865	Platykurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 1.0%

SAMPLE IDENTITY: **M-9** ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Sorted TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

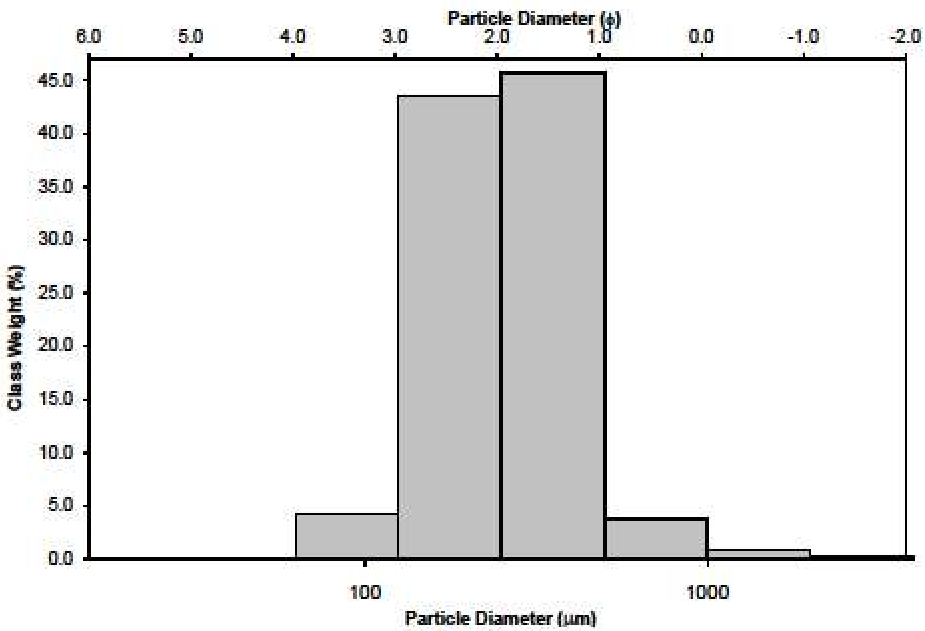
	μm	φ
MODE 1:	375.0	1.500
MODE 2:		
MODE 3:		
D_{10}:	136.9	1.090
MEDIAN or D_{50}:	257.3	1.958
D_{90}:	469.8	2.869
(D_{90} / D_{10}):	3.431	2.632
$(D_{90} - D_{10})$:	332.9	1.779
(D_{75} / D_{25}):	2.160	1.785
$(D_{75} - D_{25})$:	201.3	1.111

GRAIN SIZE DISTRIBUTION

GRAVEL:	1.1%	COARSE SAND:	3.8%
SAND:	98.9%	MEDIUM SAND:	46.1%
MUD:	0.0%	FINE SAND:	43.8%
		V FINE SAND:	4.2%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	1.1%	V FINE SILT:	0.0%
V COARSE SAND:	0.9%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	307.4	243.6	1.947	255.2	1.970	Medium Sand
SORTING (σ):	215.2	2.043	0.722	1.638	0.712	Moderately Sorted
SKEWNESS (Sk):	5.712	-3.885	-0.555	0.024	-0.024	Symmetrical
KURTOSIS (K):	58.94	32.82	4.468	0.814	0.814	Platykurtic

GRAIN SIZE DISTRIBUTION



Inversiones GAMMA S.A.
No. 308, 14 Street between 3rd and 5th Ave. Miramar, Playa, Havana, Cuba
gamma@gamma.com.cu www.gamma.com.cu/en

SAMPLE STATISTICS

SIEVING ERROR: 0.0%

SAMPLE IDENTITY: **M-10**

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Poorly Sorted

TEXTURAL GROUP: Gravelly Sand

SEDIMENT NAME: Very Fine Gravelly Medium Sand

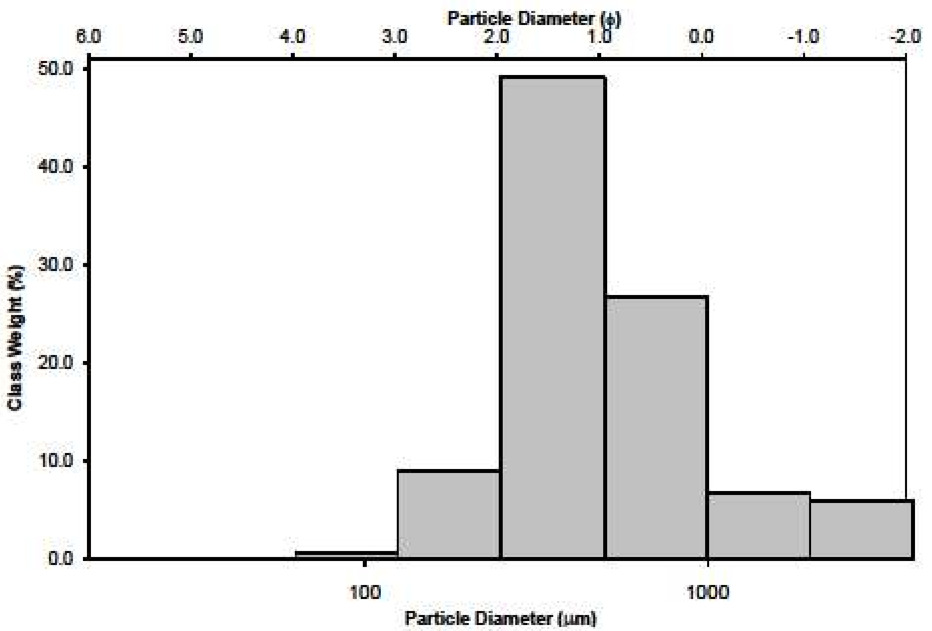
	μm	φ
MODE 1:	375.0	1.500
MODE 2:		
MODE 3:		
D_{10}:	251.4	-0.896
MEDIAN or D_{50}:	446.9	1.162
D_{90}:	1860.3	1.992
(D_{90} / D_{10}):	7.398	-2.224
$(D_{90} - D_{10})$:	1608.8	2.887
(D_{75} / D_{25}):	2.526	4.892
$(D_{75} - D_{25})$:	476.1	1.337

GRAIN SIZE DISTRIBUTION

GRAVEL:	9.3%	COARSE SAND:	26.2%
SAND:	90.7%	MEDIUM SAND:	48.2%
MUD:	0.0%	FINE SAND:	8.9%
		V FINE SAND:	0.7%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	9.3%	V FINE SILT:	0.0%
V COARSE SAND:	6.7%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	672.1	401.1	0.979	496.7	1.010	Medium Sand
SORTING (σ):	669.6	3.713	0.991	2.159	1.110	Poorly Sorted
SKEWNESS (Sk):	2.491	-3.002	-0.701	0.303	-0.303	Very Coarse Skewed
KURTOSIS (K):	8.856	15.21	3.505	1.301	1.301	Leptokurtic

GRAIN SIZE DISTRIBUTION



Result of the analyzes carried out for the selection of the borrow area Zone 1

Sample	Sieve Range								M		Stand. Desv. (Ø)	Wentworth Clasification
	>4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.062	< 0.062	(mm)	(Ø)		
M1	0.0	0.1	0.0	0.5	4.8	29.9	49.9	14.1	0.107	3.221	0.793	Very fine sand
M2	Analysis was not performed. (Remains of shells and gravel)											

Result of the analyzes carried out for the selection of the borrow area Zone 2

Sample	Sieve Range								M		Stand. Desv. (Ø)	Wentworth Clasification
	>4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.062	< 0.062	(mm)	(Ø)		
M3	0.0	0.0	0.6	0.9	3.5	20.8	54.7	19.2	0.124	3.359	0.836	Very fine sand
M4	0.0	0.0	1.5	7.0	4.3	50.7	30.5	6.0	0.154	2.695	0.981	Fine sand
M5	0.0	1.0	0.5	2.5	3.9	37.6	42.5	11.6	0.124	3.013	0.985	Very fine sand
S. Type	**0.0**	**0.33**	**0.87**	**3.47**	**3.9**	**36.37**	**42.57**	**12.27**	**0.123**	**3.022**	**0.975**	**Very fine sand**

Result of the analyzes carried out for the selection of the borrow area Zone 3

Sample	Sieve Range								M		Stand. Desv. (Ø)	Wentworth Clasification
	>4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.062	< 0.062	(mm)	(Ø)		
M6	0.0	0.9	5.3	41.3	47.8	2.9	1.4	0.0	0.497	1.009	0.743	Medium sand
M7	0.0	1.7	1.2	1.5	51.4	41.3	2.5	0.0	0.273	1.874	0.769	Medium sand
M8	0.4	0.9	0.6	3.6	5.3	55.4	29.4	4.2	0.151	2.688	0.919	Fine sand
M9	0.0	0.0	0.6	3.7	5.9	30.4	51.5	7.5	0.124	3.013	0.901	Very fine sand
M10	0.0	0.6	1.3	5.5	4.9	37.7	41.8	7.7	0.139	2.849	1.043	Fine sand
S. Type	**0.08**	**0.82**	**1.8**	**11.1**	**23.1**	**33.54**	**25.32**	**3.88**	**0.204**	**2.287**	**1.157**	**Fine sand**

Mouth of the Cuango River

Sample	Sieve Range								M		Stand. Desv. (Ø)	Wentworth Clasification
	>4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.062	< 0.062	(mm)	(Ø)		
DC 1	0.0	1.3	4.8	18.4	47.3	25.5	2.5	0.0	0.36	1.486	0.921	Medium sand
DC 2	1.2	8.5	38.6	26.6	17.1	7.1	0.7	0.0	0.76	0.272	1.094	Gross sand
DC 3	1.3	9.6	42.2	24.1	16.2	6.0	0.5	0.0	0.80	0.176	1.074	Gross sand
DC 4	12.5	16.0	39.0	21.0	9.1	1.9	0.3	0.0	1.46	-0.13	0.924	Very gross sand
DC 5	0.0	1.5	4.5	19.2	46.0	25.8	2.8	0.0	0.36	1.487	0.937	Medium sand
DC 6	0.0	3.4	7.8	30.8	45.8	10.9	1.1	0.0	0.48	1.064	0.944	Medium sand
S. Type	**2.5**	**6.7**	**22.7**	**23.3**	**30.2**	**12.8**	**1.3**	**0.0**	**0.51**	**0.725**	**1.178**	**Gross sand**

SAMPLE STATISTICS

SIEVING ERROR: 0.0%
SAMPLE IDENTITY: VF-4B
ANALYST & DATE: Trista, 10/4/2021
SAMPLE TYPE: Unimodal, Moderately Sorted
TEXTURAL GROUP: Sand
SEDIMENT NAME: Moderately Sorted Fine Sand

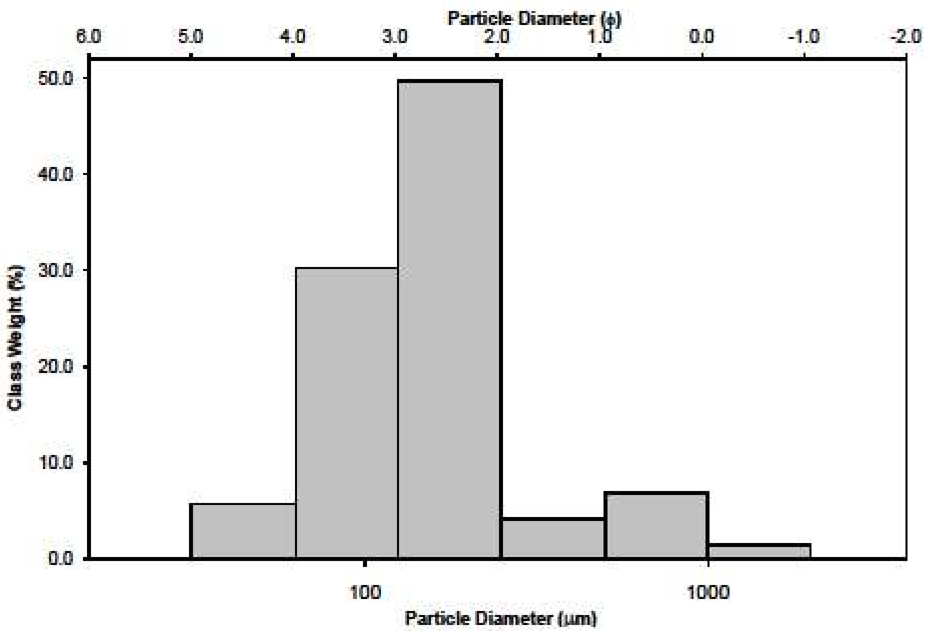
	μm	φ
MODE 1:	187.5	2.500
MODE 2:		
MODE 3:		
D_{10}:	68.92	1.349
MEDIAN or D_{50}:	150.3	2.734
D_{90}:	392.6	3.859
(D_{90} / D_{10}):	5.696	2.861
$(D_{90} - D_{10})$:	323.7	2.510
(D_{75} / D_{25}):	2.192	1.505
$(D_{75} - D_{25})$:	115.1	1.132

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.0%	COARSE SAND:	7.0%
SAND:	94.1%	MEDIUM SAND:	4.3%
MUD:	5.9%	FINE SAND:	50.7%
		V FINE SAND:	30.6%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	5.9%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.1%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	1.5%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	217.7	154.4	2.695	141.6	2.820	Fine Sand
SORTING (σ):	229.0	1.973	0.981	1.938	0.955	Moderately Sorted
SKEWNESS (Sk):	3.453	0.847	-0.847	0.029	-0.029	Symmetrical
KURTOSIS (K):	16.85	4.369	4.369	1.325	1.325	Leptokurtic

GRAIN SIZE DISTRIBUTION



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SAMPLE STATISTICS

SIEVING ERROR: 0.4%

SAMPLE IDENTITY: VF-4C

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Sorted

TEXTURAL GROUP: Slightly Gravelly Muddy Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Very Coarse Silty Very Fine Sand

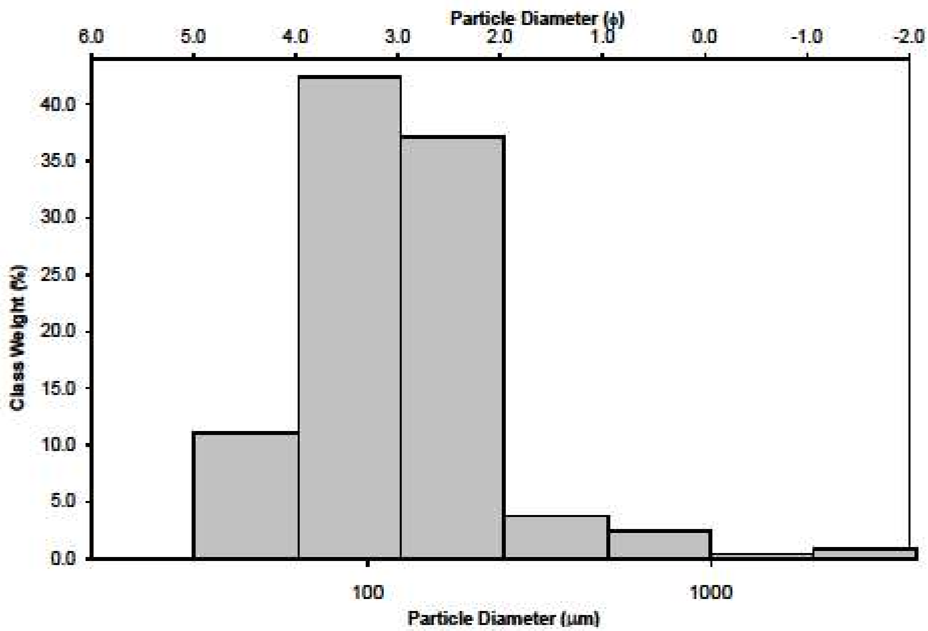
	μm	ϕ
MODE 1:	94.00	3.494
MODE 2:		
MODE 3:		
D_{10}:	56.99	2.055
MEDIAN or D_{50}:	116.6	3.100
D_{90}:	240.7	4.133
(D_{90} / D_{10}):	4.223	2.011
$(D_{90} - D_{10})$:	183.7	2.078
(D_{75} / D_{25}):	2.341	1.500
$(D_{75} - D_{25})$:	104.7	1.227

GRAIN SIZE DISTRIBUTION

GRAVEL:	1.0%	COARSE SAND:	2.5%
SAND:	87.5%	MEDIUM SAND:	3.9%
MUD:	11.5%	FINE SAND:	37.8%
		V FINE SAND:	42.8%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	11.4%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.1%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	1.0%	V FINE SILT:	0.0%
V COARSE SAND:	0.5%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	187.5	123.9	3.013	119.3	3.067	Very Fine Sand
SORTING (σ):	321.6	1.979	0.985	1.894	0.922	Moderately Sorted
SKEWNESS (Sk):	7.179	1.354	-1.354	0.086	-0.086	Symmetrical
KURTOSIS (K):	60.38	7.172	7.172	1.109	1.109	Mesokurtic

GRAIN SIZE DISTRIBUTION



SIEVING ERROR: 0.7%

SAMPLE STATISTICS

SAMPLE IDENTITY: **VF-1**

ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Sorted

TEXTURAL GROUP: Slightly Gravelly Muddy Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Very Coarse Silty Very Fine Sand

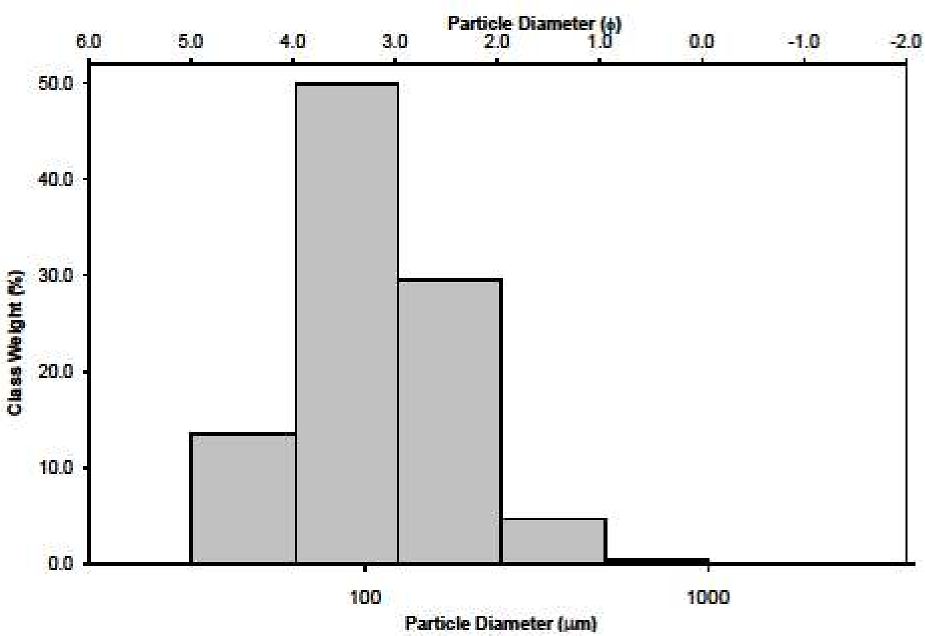
	μm	φ
MODE 1:	94.00	3.494
MODE 2:		
MODE 3:		
D_{10}:	51.08	2.152
MEDIAN or D_{50}:	102.6	3.284
D_{90}:	225.1	4.291
(D_{90} / D_{10}):	4.406	1.994
$(D_{90} - D_{10})$:	174.0	2.140
(D_{75} / D_{25}):	2.183	1.425
$(D_{75} - D_{25})$:	86.36	1.126

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.1%	COARSE SAND:	0.5%
SAND:	85.9%	MEDIUM SAND:	4.8%
MUD:	14.0%	FINE SAND:	30.1%
		V FINE SAND:	50.4%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	13.9%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.2%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.1%	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 ($\bar{x}$):	135.3	107.2	3.221	109.1	3.196	Very Fine Sand
SORTING (σ):	125.4	1.733	0.793	1.761	0.816	Moderately Sorted
SKEWNESS (Sk):	12.89	0.520	-0.520	0.084	-0.084	Symmetrical
KURTOSIS (K):	277.7	4.204	4.204	0.998	0.998	Mesokurtic

GRAIN SIZE DISTRIBUTION



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SAMPLE STATISTICS

SIEVING ERROR: 0.5%

SAMPLE IDENTITY: VF-4 — ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Bimodal, Poorly Sorted — TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Fine Sand

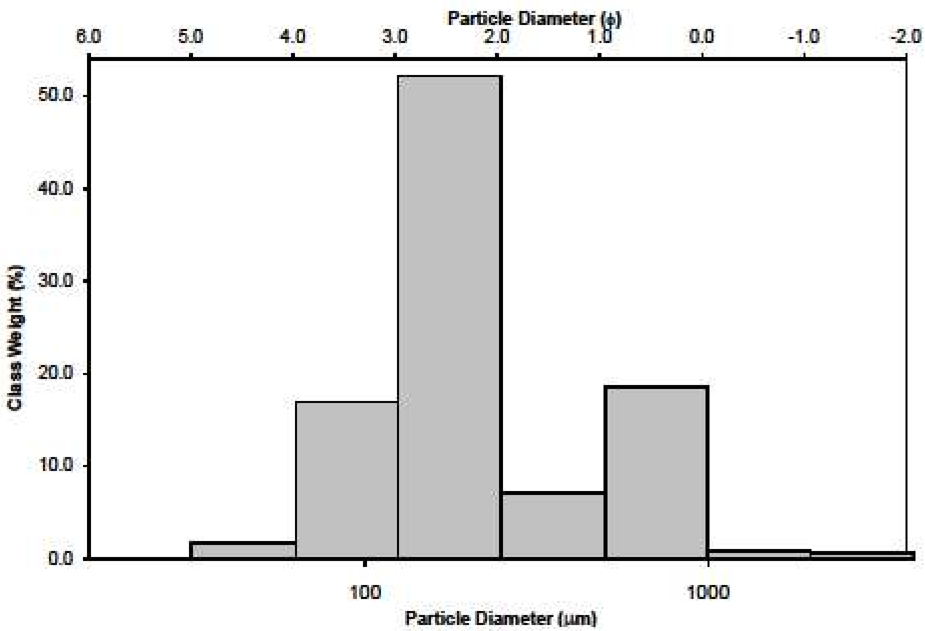
	μm	ϕ
MODE 1:	187.5	2.500
MODE 2:	750.0	0.500
MODE 3:		
D_{10}:	87.15	0.439
MEDIAN or D_{50}:	187.4	2.416
D_{90}:	737.7	3.520
(D_{90} / D_{10}):	8.465	8.022
(D_{90} - D_{10}):	650.6	3.082
(D_{75} / D_{25}):	2.441	1.805
(D_{75} - D_{25}):	194.8	1.288

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.7%	COARSE SAND:	18.9%
SAND:	97.4%	MEDIUM SAND:	7.3%
MUD:	1.9%	FINE SAND:	53.1%
		V FINE SAND:	17.1%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	1.9%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.7%	V FINE SILT:	0.0%
V COARSE SAND:	1.0%	CLAY:	0.0%

	METHOD OF MOMENTS Arithmetic μm	Geometric μm	Logarithmic ϕ	FOLK & WARD METHOD Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	321.9	217.9	2.199	230.8	2.115	Fine Sand
SORTING (σ):	345.2	2.128	1.089	2.227	1.155	Poorly Sorted
SKEWNESS (Sk):	3.956	0.685	-0.685	0.303	-0.303	Very Coarse Skewed
KURTOSIS (K):	27.36	3.169	3.169	1.157	1.157	Leptokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.3%
SAMPLE IDENTITY: **VF-4A**
ANALYST & DATE: Trista, 10/4/2021
SAMPLE TYPE: Unimodal, Moderately Sorted
TEXTURAL GROUP: Muddy Sand
SEDIMENT NAME: Very Coarse Silty Very Fine Sand

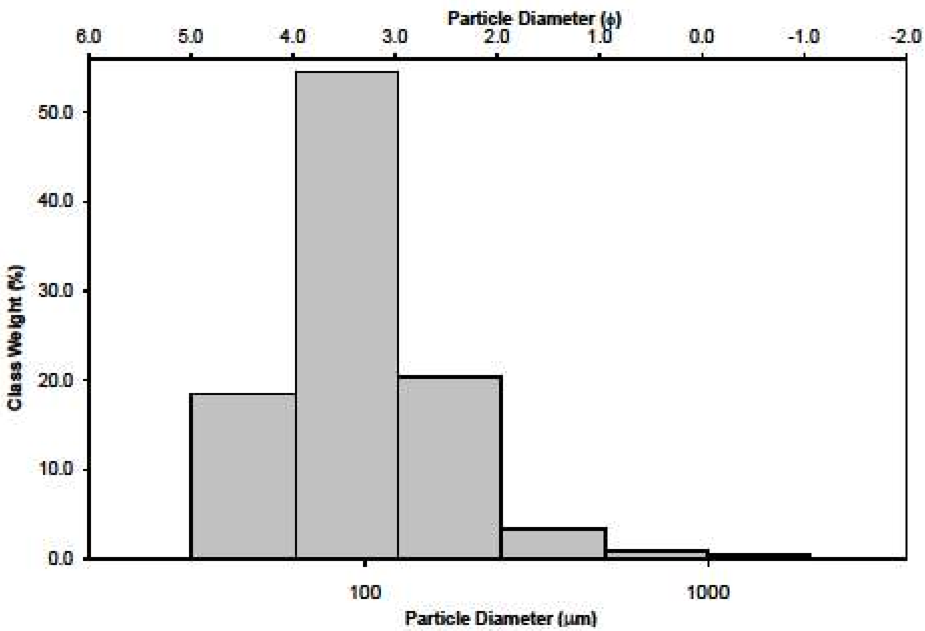
	μm	φ
MODE 1:	94.00	3.494
MODE 2:		
MODE 3:		
D_{10}:	44.80	2.239
MEDIAN or D_{50}:	92.49	3.435
D_{90}:	211.8	4.480
(D_{90} / D_{10}):	4.729	2.001
$(D_{90} - D_{10})$:	167.0	2.241
(D_{75} / D_{25}):	1.901	1.313
$(D_{75} - D_{25})$:	61.01	0.927

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.0%	COARSE SAND:	0.9%
SAND:	81.0%	MEDIUM SAND:	3.5%
MUD:	19.0%	FINE SAND:	20.9%
		V FINE SAND:	55.1%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	18.8%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.2%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	0.6%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	128.7	97.43	3.359	96.44	3.374	Very Fine Sand
SORTING (σ):	140.0	1.785	0.836	1.772	0.825	Moderately Sorted
SKEWNESS (Sk):	6.605	1.074	-1.074	0.079	-0.079	Symmetrical
KURTOSIS (K):	59.27	5.720	5.720	1.216	1.216	Leptokurtic

GRAIN SIZE DISTRIBUTION



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SAMPLE STATISTICS

SIEVING ERROR: 0.4%

SAMPLE IDENTITY: **MIR-5** ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Very Fine Sand

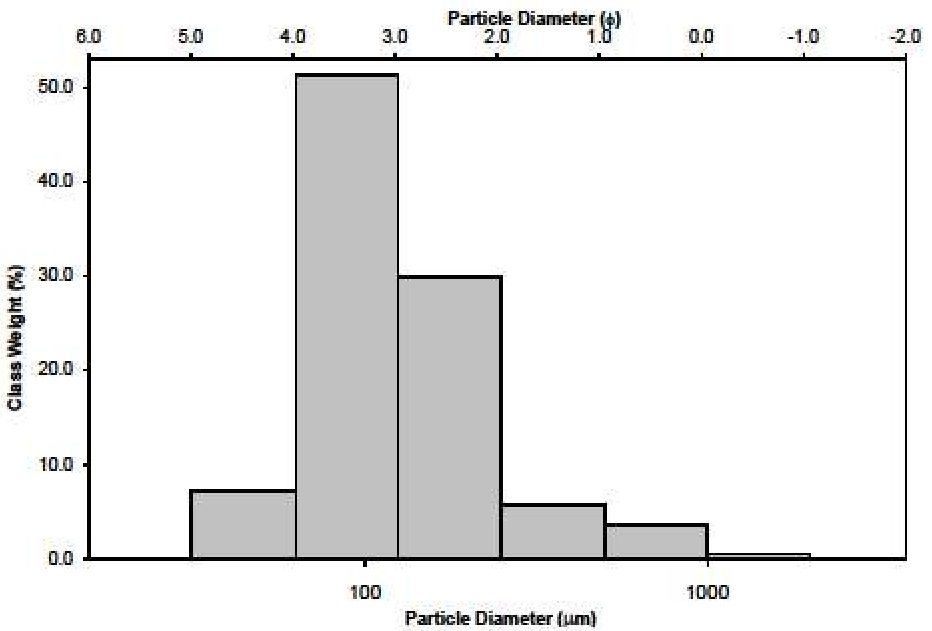
	μm	φ
MODE 1:	94.00	3.494
MODE 2:		
MODE 3:		
D_{10}:	65.10	1.959
MEDIAN or D_{50}:	110.6	3.177
D_{90}:	257.1	3.941
(D_{90} / D_{10}):	3.950	2.012
$(D_{90} - D_{10})$:	192.1	1.982
(D_{75} / D_{25}):	2.252	1.471
$(D_{75} - D_{25})$:	99.39	1.171

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.0%	COARSE SAND:	3.7%
SAND:	92.6%	MEDIUM SAND:	5.9%
MUD:	7.4%	FINE SAND:	30.5%
		V FINE SAND:	51.8%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	7.4%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.1%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	0.6%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	168.5	123.9	3.013	119.6	3.064	Very Fine Sand
SORTING (σ):	172.8	1.867	0.901	1.862	0.897	Moderately Sorted
SKEWNESS (Sk):	4.206	1.084	-1.084	0.244	-0.244	Coarse Skewed
KURTOSIS (K):	26.16	4.752	4.752	1.126	1.126	Leptokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.5%
SAMPLE IDENTITY: **MIR-6**
ANALYST & DATE: Trista, 10/4/2021
SAMPLE TYPE: Unimodal, Moderately Sorted
TEXTURAL GROUP: Slightly Gravelly Sand
SEDIMENT NAME: Slightly Very Fine Gravelly Very Fine Sand

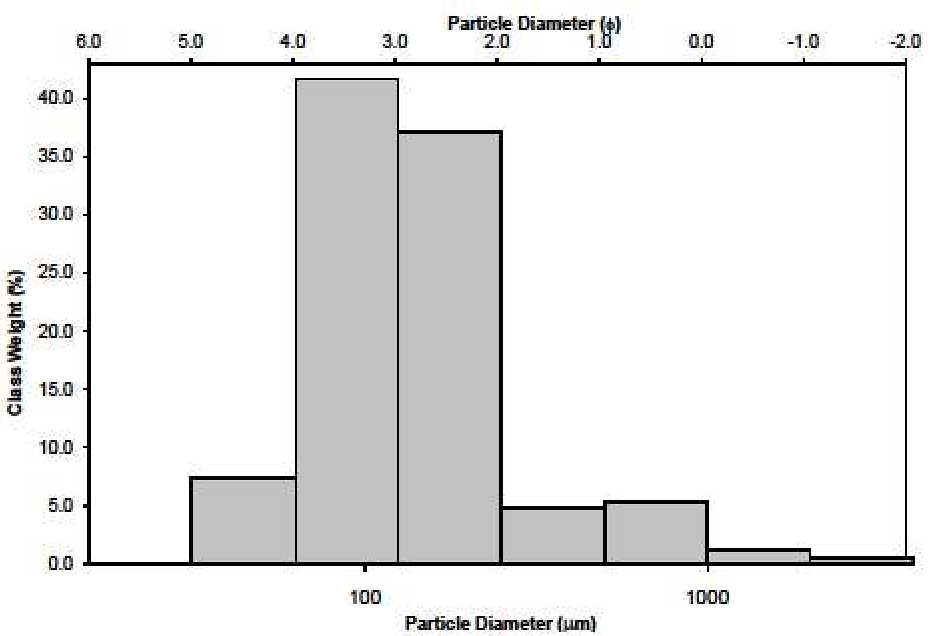
	μm	ϕ
MODE 1:	94.00	3.494
MODE 2:		
MODE 3:		
D_{10}:	65.37	1.520
MEDIAN or D_{50}:	125.6	2.993
D_{90}:	348.6	3.935
(D_{90} / D_{10}):	5.333	2.588
(D_{90} - D_{10}):	283.2	2.415
(D_{75} / D_{25}):	2.376	1.535
(D_{75} - D_{25}):	114.9	1.249

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.6%	COARSE SAND:	5.5%
SAND:	91.7%	MEDIUM SAND:	4.9%
MUD:	7.7%	FINE SAND:	37.9%
		V FINE SAND:	42.1%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	7.6%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.1%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.6%	V FINE SILT:	0.0%
V COARSE SAND:	1.3%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	211.8	138.8	2.849	128.4	2.961	Fine Sand
SORTING (σ):	306.7	2.060	1.043	1.999	0.999	Moderately Sorted
SKEWNESS (Sk):	5.771	1.217	-1.217	0.170	-0.170	Coarse Skewed
KURTOSIS (K):	45.83	5.332	5.332	1.244	1.244	Leptokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.4%

SAMPLE IDENTITY: **MIR-1** ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Sorted TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

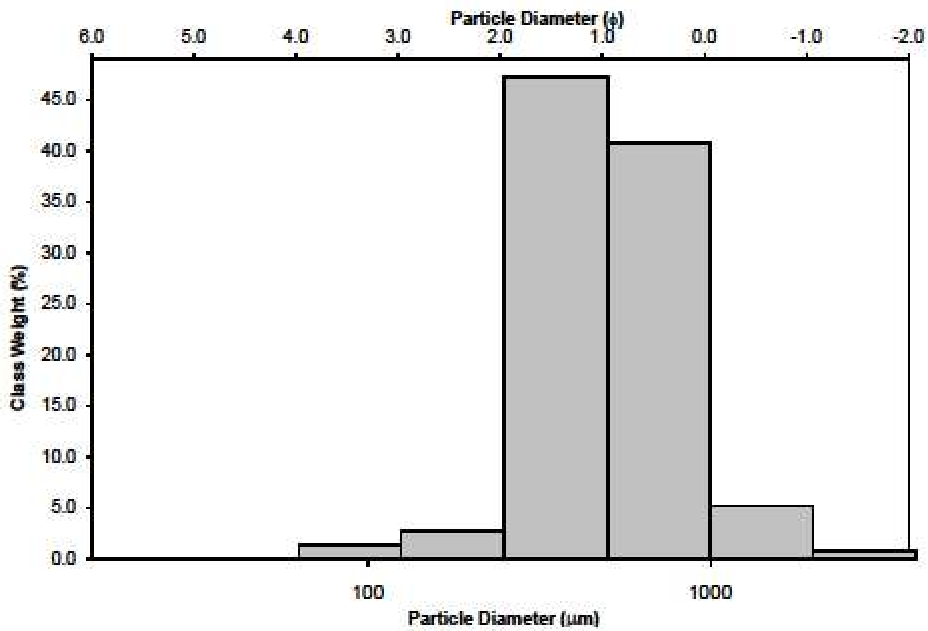
	μm	ϕ
MODE 1:	375.0	1.500
MODE 2:		
MODE 3:		
D_{10}:	271.4	0.091
MEDIAN or D_{50}:	483.6	1.048
D_{90}:	938.8	1.882
(D_{90} / D_{10}):	3.459	20.67
$(D_{90} - D_{10})$:	667.5	1.791
(D_{75} / D_{25}):	2.168	3.465
$(D_{75} - D_{25})$:	393.6	1.116

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.9%	COARSE SAND:	41.5%
SAND:	99.1%	MEDIUM SAND:	48.0%
MUD:	0.0%	FINE SAND:	2.9%
		V FINE SAND:	1.4%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.9%	V FINE SILT:	0.0%
V COARSE SAND:	5.3%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	604.7	496.9	1.009	495.4	1.013	Medium Sand
SORTING (σ):	370.6	1.674	0.743	1.643	0.716	Moderately Sorted
SKEWNESS (Sk):	3.024	0.027	-0.027	0.111	-0.111	Coarse Skewed
KURTOSIS (K):	17.77	4.484	4.484	0.814	0.814	Platykurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.2%

SAMPLE IDENTITY: **MIR-4** — ANALYST & DATE: Trista, 10/4/2021

SAMPLE TYPE: Unimodal, Moderately Sorted — TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Fine Sand

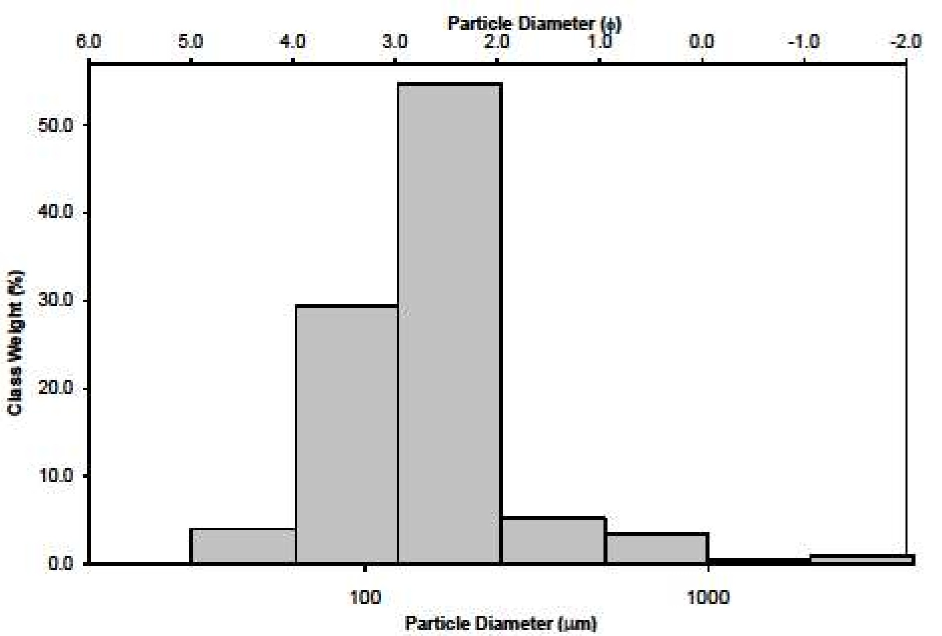
	μm	φ
MODE 1:	187.5	2.500
MODE 2:		
MODE 3:		
D_{10}:	72.08	1.845
MEDIAN or D_{50}:	153.3	2.706
D_{90}:	278.3	3.794
(D_{90} / D_{10}):	3.861	2.056
$(D_{90} - D_{10})$:	206.2	1.949
(D_{75} / D_{25}):	2.050	1.459
$(D_{75} - D_{25})$:	107.3	1.035

GRAIN SIZE DISTRIBUTION

GRAVEL:	1.3%	COARSE SAND:	3.6%
SAND:	94.5%	MEDIUM SAND:	5.3%
MUD:	4.2%	FINE SAND:	55.5%
		V FINE SAND:	29.5%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	4.1%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	1.3%	V FINE SILT:	0.0%
V COARSE SAND:	0.6%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	216.8	151.0	2.688	143.9	2.797	Fine Sand
SORTING (σ):	312.5	2.019	0.919	1.796	0.845	Moderately Sorted
SKEWNESS (Sk):	6.946	-0.480	-1.287	0.004	-0.004	Symmetrical
KURTOSIS (K):	58.77	15.23	7.160	1.228	1.228	Leptokurtic

GRAIN SIZE DISTRIBUTION



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SAMPLE STATISTICS

SIEVING ERROR: 0.1%

SAMPLE IDENTITY: **DC3** | ANALYST & DATE: Trista, 10/7/2021

SAMPLE TYPE: Unimodal, Poorly Sorted | TEXTURAL GROUP: Gravelly Sand

SEDIMENT NAME: Very Fine Gravelly Very Coarse Sand

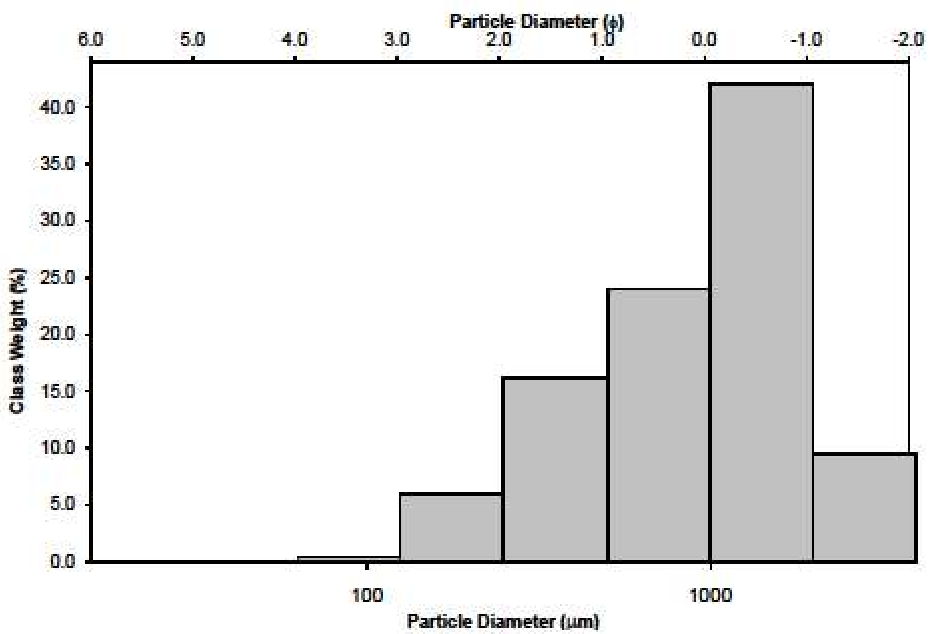
	μm	φ
MODE 1:	1500.0	-0.500
MODE 2:		
MODE 3:		
D_{10}:	290.3	-1.095
MEDIAN or D_{50}:	1053.1	-0.075
D_{90}:	2135.8	1.785
(D_{90} / D_{10}):	7.358	-1.630
$(D_{90} - D_{10})$:	1845.6	2.879
(D_{75} / D_{25}):	2.973	-1.359
$(D_{75} - D_{25})$:	1053.4	1.572

GRAIN SIZE DISTRIBUTION

GRAVEL:	10.9%	COARSE SAND:	24.1%
SAND:	89.1%	MEDIUM SAND:	16.2%
MUD:	0.0%	FINE SAND:	6.0%
		V FINE SAND:	0.5%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	10.9%	V FINE SILT:	0.0%
V COARSE SAND:	42.2%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	1175.4	809.0	0.176	899.1	0.153	Coarse Sand
SORTING (σ):	771.0	2.915	1.074	2.233	1.159	Poorly Sorted
SKEWNESS (Sk):	0.897	-3.268	0.596	-0.251	0.251	Fine Skewed
KURTOSIS (K):	3.490	20.57	2.790	1.008	1.008	Mesokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.2%

SAMPLE IDENTITY: **DC4**

ANALYST & DATE: Trista, 10/7/2021

SAMPLE TYPE: Unimodal, Poorly Sorted

TEXTURAL GROUP: Gravelly Sand

SEDIMENT NAME: Very Fine Gravelly Very Coarse Sand

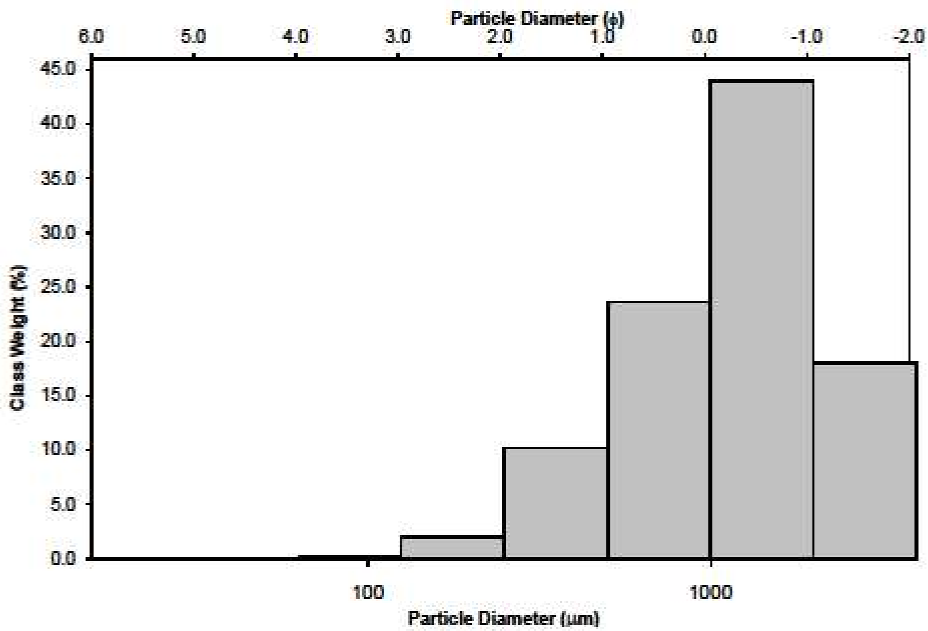
	µm	ϕ
MODE 1:	1500.0	-0.500
MODE 2:		
MODE 3:		
D_{10}:	452.2	-2.099
MEDIAN or D_{50}:	1367.3	-0.451
D_{90}:	4285.5	1.145
(D_{90} / D_{10}):	9.478	-0.545
$(D_{90} - D_{10})$:	3833.4	3.245
(D_{75} / D_{25}):	2.973	-0.286
$(D_{75} - D_{25})$:	1547.9	1.572

GRAIN SIZE DISTRIBUTION

GRAVEL:	28.6%	COARSE SAND:	21.0%
SAND:	71.4%	MEDIUM SAND:	9.1%
MUD:	0.0%	FINE SAND:	1.9%
		V FINE SAND:	0.3%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	28.6%	V FINE SILT:	0.0%
V COARSE SAND:	39.1%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic µm	Geometric µm	Logarithmic ϕ	Geometric µm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	1263.0	462.5	-0.136	1400.2	-0.486	Very Coarse Sand
SORTING (σ):	926.8	11.12	0.924	2.025	1.018	Poorly Sorted
SKEWNESS (Sk):	0.593	-1.966	0.660	-0.341	0.341	Very Fine Skewed
KURTOSIS (K):	2.551	5.349	3.694	0.650	0.650	Very Platykurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.2%

SAMPLE IDENTITY: **DC5**

ANALYST & DATE: Trista, 10/7/2021

SAMPLE TYPE: Unimodal, Moderately Sorted

TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

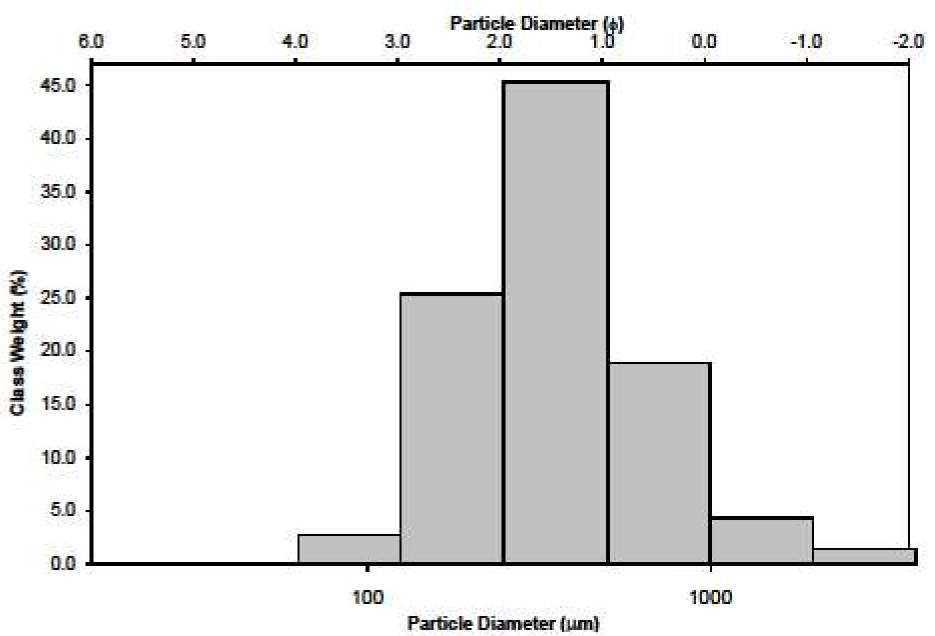
	μm	φ
MODE 1:	375.0	1.500
MODE 2:		
MODE 3:		
D_{10}:	151.6	0.207
MEDIAN or D_{50}:	344.6	1.537
D_{90}:	866.2	2.722
(D_{90} / D_{10}):	5.714	13.13
$(D_{90} - D_{10})$:	714.6	2.514
(D_{75} / D_{25}):	2.226	2.170
$(D_{75} - D_{25})$:	277.9	1.154

GRAIN SIZE DISTRIBUTION

GRAVEL:	1.5%	COARSE SAND:	19.2%
SAND:	98.5%	MEDIUM SAND:	46.1%
MUD:	0.0%	FINE SAND:	25.9%
		V FINE SAND:	2.8%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	1.5%	V FINE SILT:	0.0%
V COARSE SAND:	4.5%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	481.0	356.8	1.487	349.8	1.515	Medium Sand
SORTING (σ):	433.3	1.915	0.937	1.957	0.968	Moderately Sorted
SKEWNESS (Sk):	3.478	0.539	-0.539	0.078	-0.078	Symmetrical
KURTOSIS (K):	18.65	3.645	3.645	1.115	1.115	Leptokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

SIEVING ERROR: 0.2%
SAMPLE IDENTITY: DC6
ANALYST & DATE: Trista, 10/7/2021
SAMPLE TYPE: Unimodal, Moderately Sorted
TEXTURAL GROUP: Slightly Gravelly Sand
SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

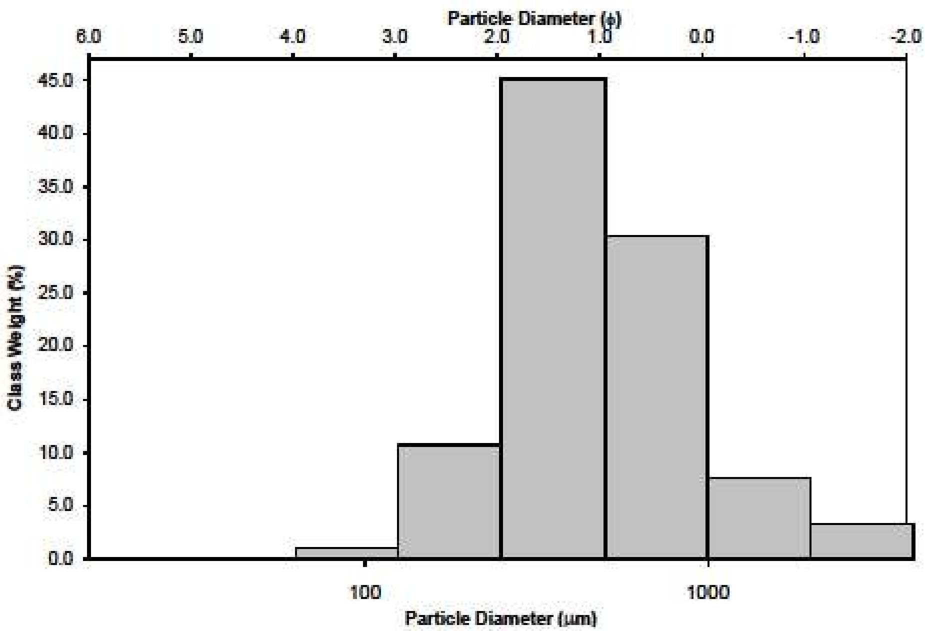
	μm	φ
MODE 1:	375.0	1.500
MODE 2:		
MODE 3:		
D_{10}:	219.9	-0.156
MEDIAN or D_{50}:	443.7	1.172
D_{90}:	1114.5	2.185
(D_{90} / D_{10}):	5.069	-13.972
$(D_{90} - D_{10})$:	894.6	2.342
(D_{75} / D_{25}):	2.413	3.847
$(D_{75} - D_{25})$:	429.7	1.271

GRAIN SIZE DISTRIBUTION

GRAVEL:	3.4%	COARSE SAND:	30.9%
SAND:	96.6%	MEDIUM SAND:	45.9%
MUD:	0.0%	FINE SAND:	10.9%
		V FINE SAND:	1.1%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	3.4%	V FINE SILT:	0.0%
V COARSE SAND:	7.8%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	644.5	478.3	1.064	473.0	1.080	Medium Sand
SORTING (σ):	556.0	1.924	0.944	1.946	0.961	Moderately Sorted
SKEWNESS (Sk):	2.754	0.487	-0.487	0.151	-0.151	Coarse Skewed
KURTOSIS (K):	11.50	3.574	3.574	1.109	1.109	Mesokurtic

GRAIN SIZE DISTRIBUTION



SAMPLE STATISTICS

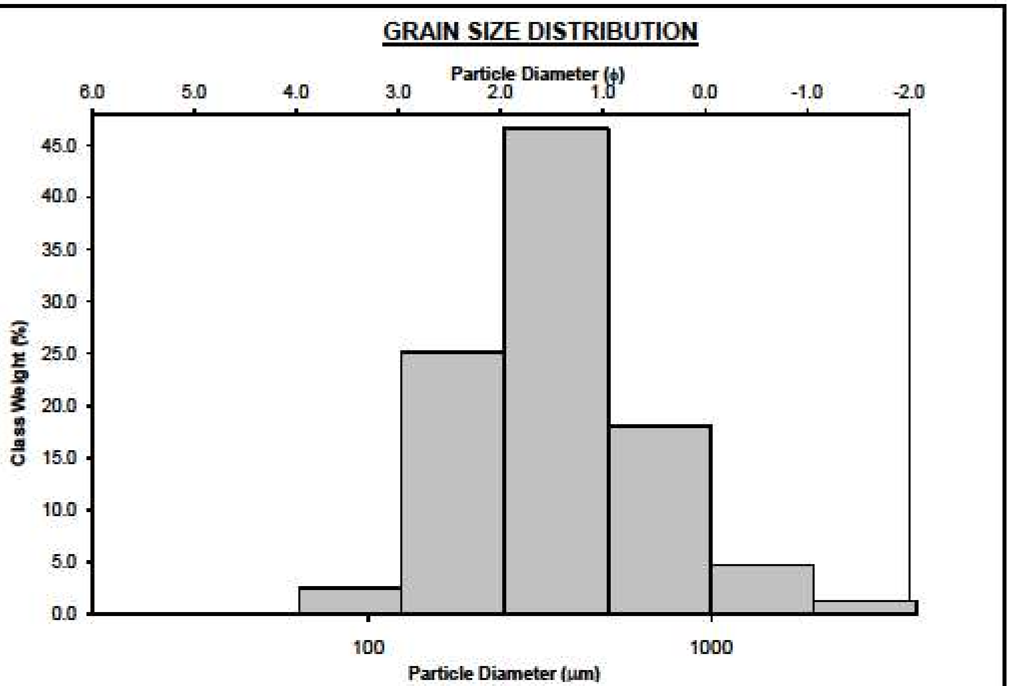
SIEVING ERROR: 0.2%
SAMPLE IDENTITY: **DC1**
ANALYST & DATE: Trista, 10/7/2021
SAMPLE TYPE: Unimodal, Moderately Sorted
TEXTURAL GROUP: Slightly Gravelly Sand
SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

	μm	ϕ
MODE 1:	375.0	1.500
MODE 2:		
MODE 3:		
D_{10}:	153.2	0.211
MEDIAN or D_{50}:	344.6	1.537
D_{90}:	864.0	2.707
(D_{90} / D_{10}):	5.640	12.84
$(D_{90} - D_{10})$:	710.8	2.496
(D_{75} / D_{25}):	2.159	2.100
$(D_{75} - D_{25})$:	266.6	1.110

GRAIN SIZE DISTRIBUTION

GRAVEL:	1.3%	COARSE SAND:	18.4%
SAND:	98.7%	MEDIUM SAND:	47.4%
MUD:	0.0%	FINE SAND:	25.6%
		V FINE SAND:	2.5%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	1.3%	V FINE SILT:	0.0%
V COARSE SAND:	4.8%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	477.5	357.0	1.486	349.9	1.515	Medium Sand
SORTING (σ):	420.7	1.894	0.921	1.944	0.959	Moderately Sorted
SKEWNESS (Sk):	3.438	0.550	-0.550	0.081	-0.081	Symmetrical
KURTOSIS (K):	18.62	3.657	3.657	1.157	1.157	Leptokurtic



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SAMPLE STATISTICS

SIEVING ERROR: 0.2%

SAMPLE IDENTITY: **DC2** ANALYST & DATE: Trista, 10/7/2021

SAMPLE TYPE: Unimodal, Poorly Sorted TEXTURAL GROUP: Gravelly Sand

SEDIMENT NAME: Very Fine Gravelly Very Coarse Sand

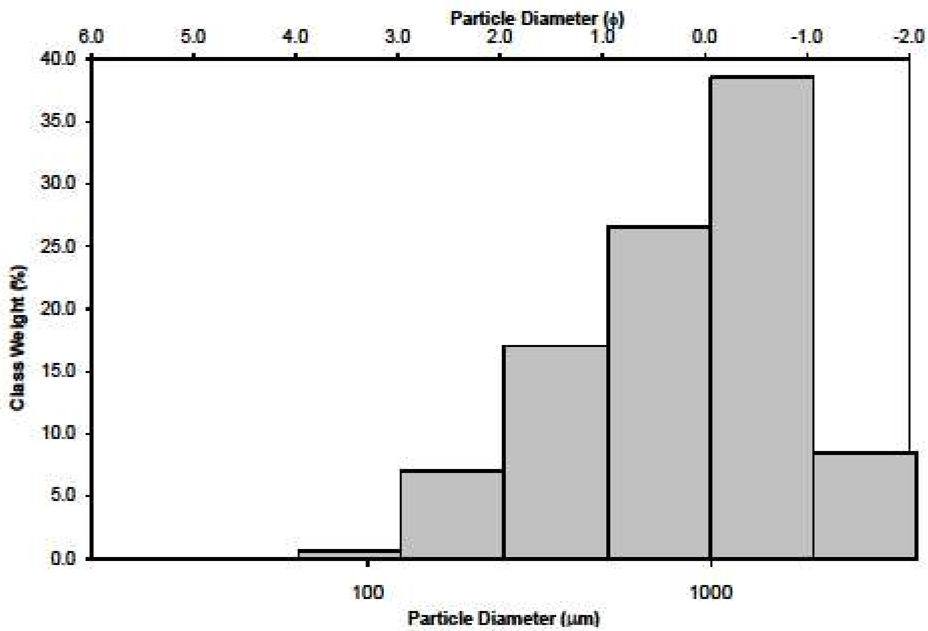
	μm	φ
MODE 1:	1500.0	-0.500
MODE 2:		
MODE 3:		
D_{10}:	273.1	-0.993
MEDIAN or D_{50}:	959.2	0.060
D_{90}:	1990.0	1.873
(D_{90} / D_{10}):	7.287	-1.886
$(D_{90} - D_{10})$:	1716.9	2.865
(D_{75} / D_{25}):	3.038	-1.650
$(D_{75} - D_{25})$:	1020.2	1.603

GRAIN SIZE DISTRIBUTION

GRAVEL:	9.7%	COARSE SAND:	26.7%
SAND:	90.3%	MEDIUM SAND:	17.1%
MUD:	0.0%	FINE SAND:	7.1%
		V FINE SAND:	0.7%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	9.7%	V FINE SILT:	0.0%
V COARSE SAND:	38.7%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic φ	Geometric μm	Logarithmic φ	Description
MEAN ($\bar{x}$):	1113.8	762.4	0.272	841.9	0.248	Coarse Sand
SORTING (σ):	756.8	2.869	1.094	2.279	1.188	Poorly Sorted
SKEWNESS (Sk):	0.995	-3.076	0.528	-0.211	0.211	Fine Skewed
KURTOSIS (K):	3.721	19.59	2.706	1.010	1.010	Mesokurtic

GRAIN SIZE DISTRIBUTION



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Annex 2

Results of the modeling done with the Coastal Modeling System (SMC) for the different directions and scenarios

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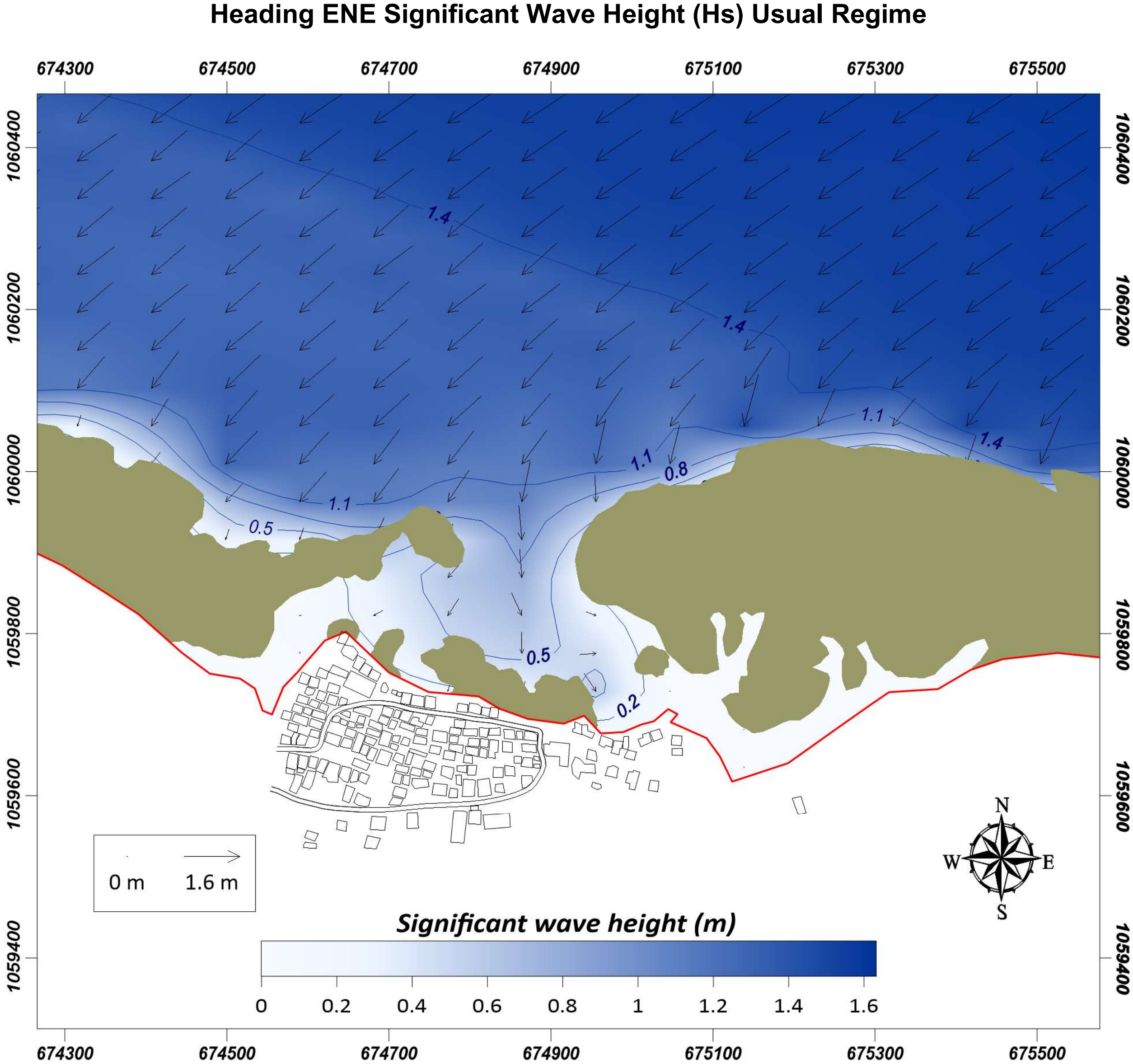
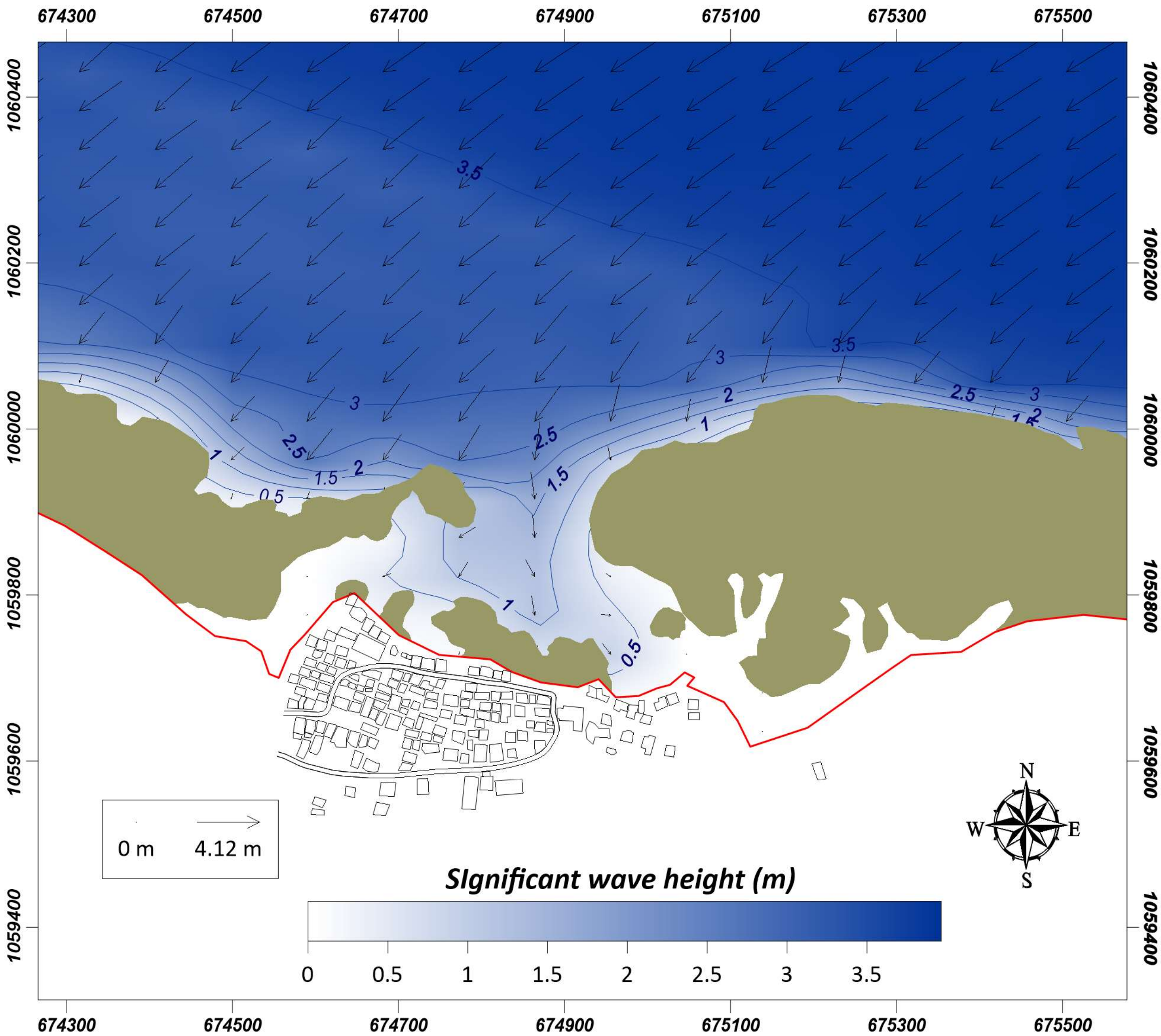
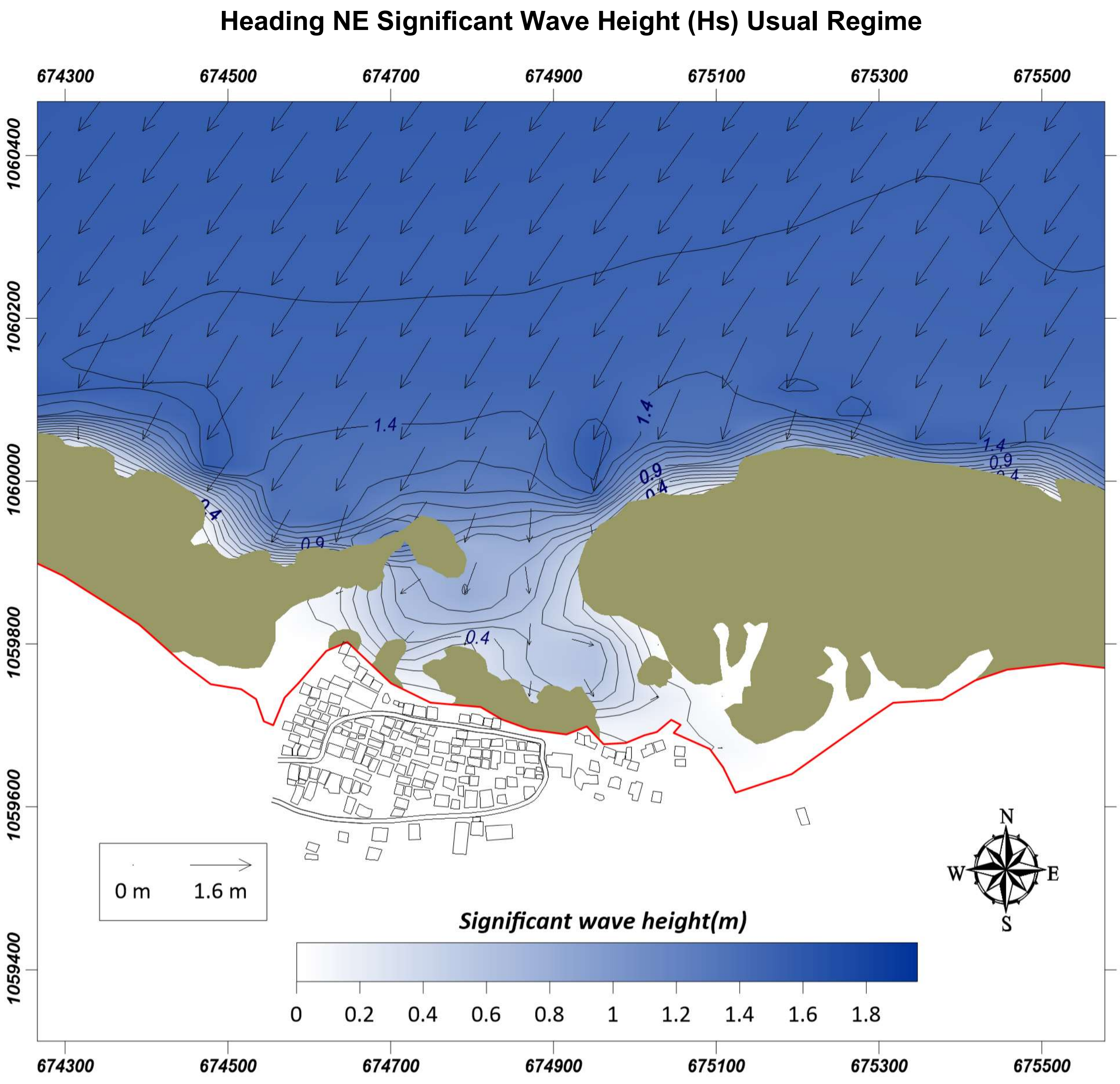

Heading ENE Significant Wave Height (Hs) Usual Regime
674300
674500
674700
674900
675100
675300
675500
1060400
1060200
1060000
1059800
1059600
1059400
1.4
1.1
0.8
0.5
0.2
0 m
1.6 m
Significant wave height (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
N
S
W
E

Heading ENE Wave Height Extreme Regime





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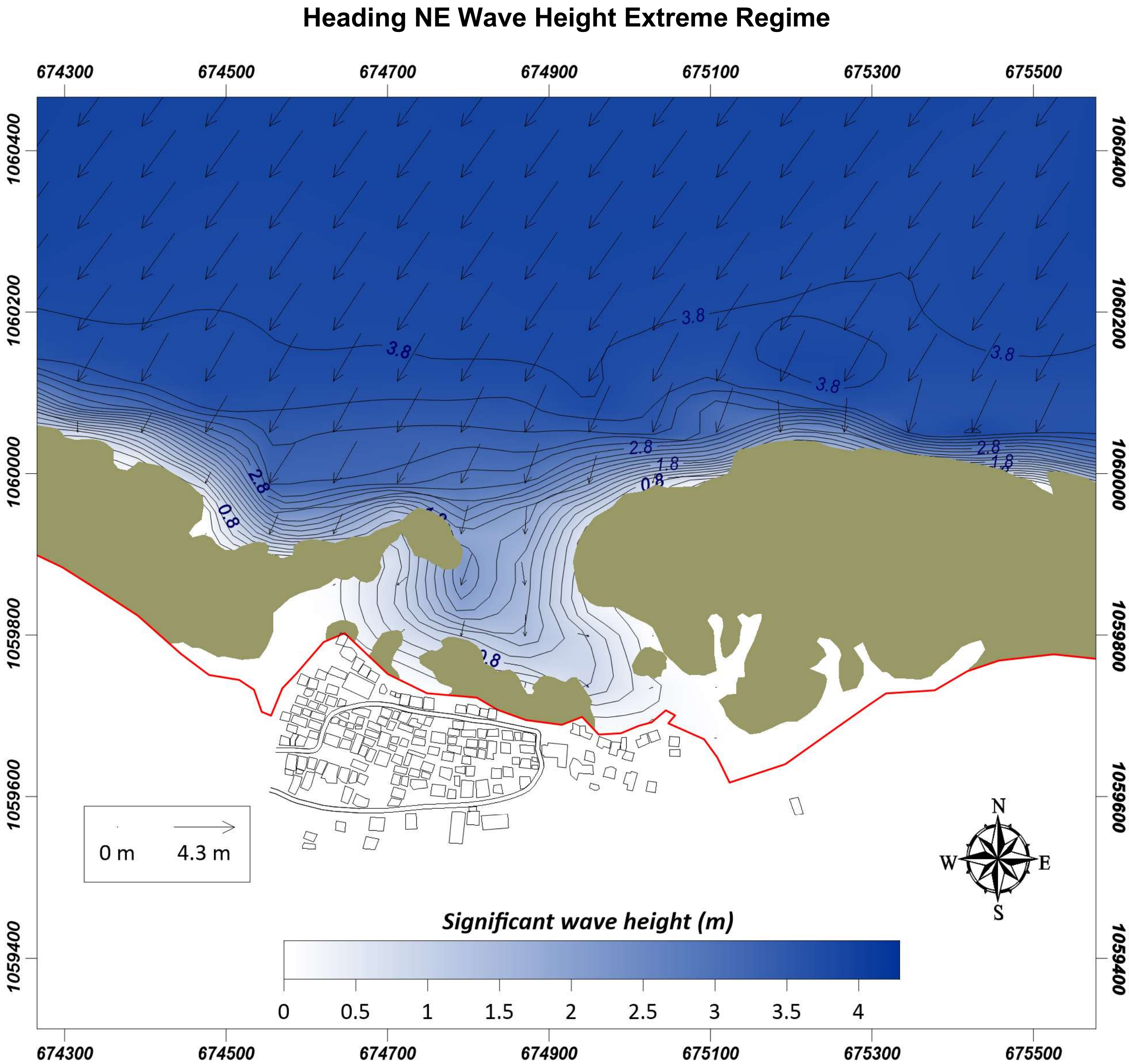
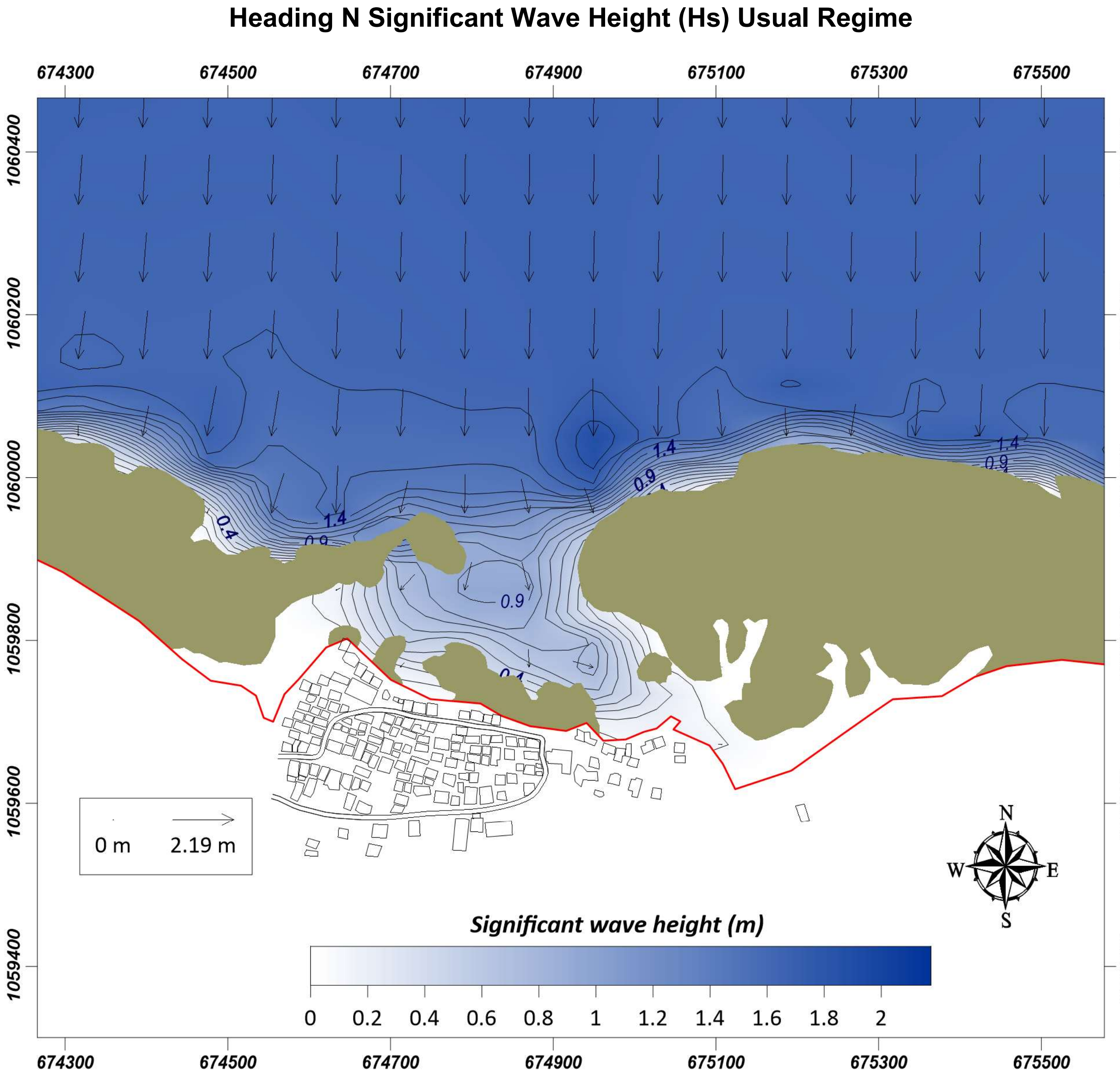

Heading NE Wave Height Extreme Regime
674300
674500
674700
674900
675100
675300
675500
1060400
1060200
1060000
1059800
1059600
1059400
3.8
2.8
1.8
0.8
0 m
4.3 m
N
S
W
E
Significant wave height (m)
0
0.5
1
1.5
2
2.5
3
3.5
4



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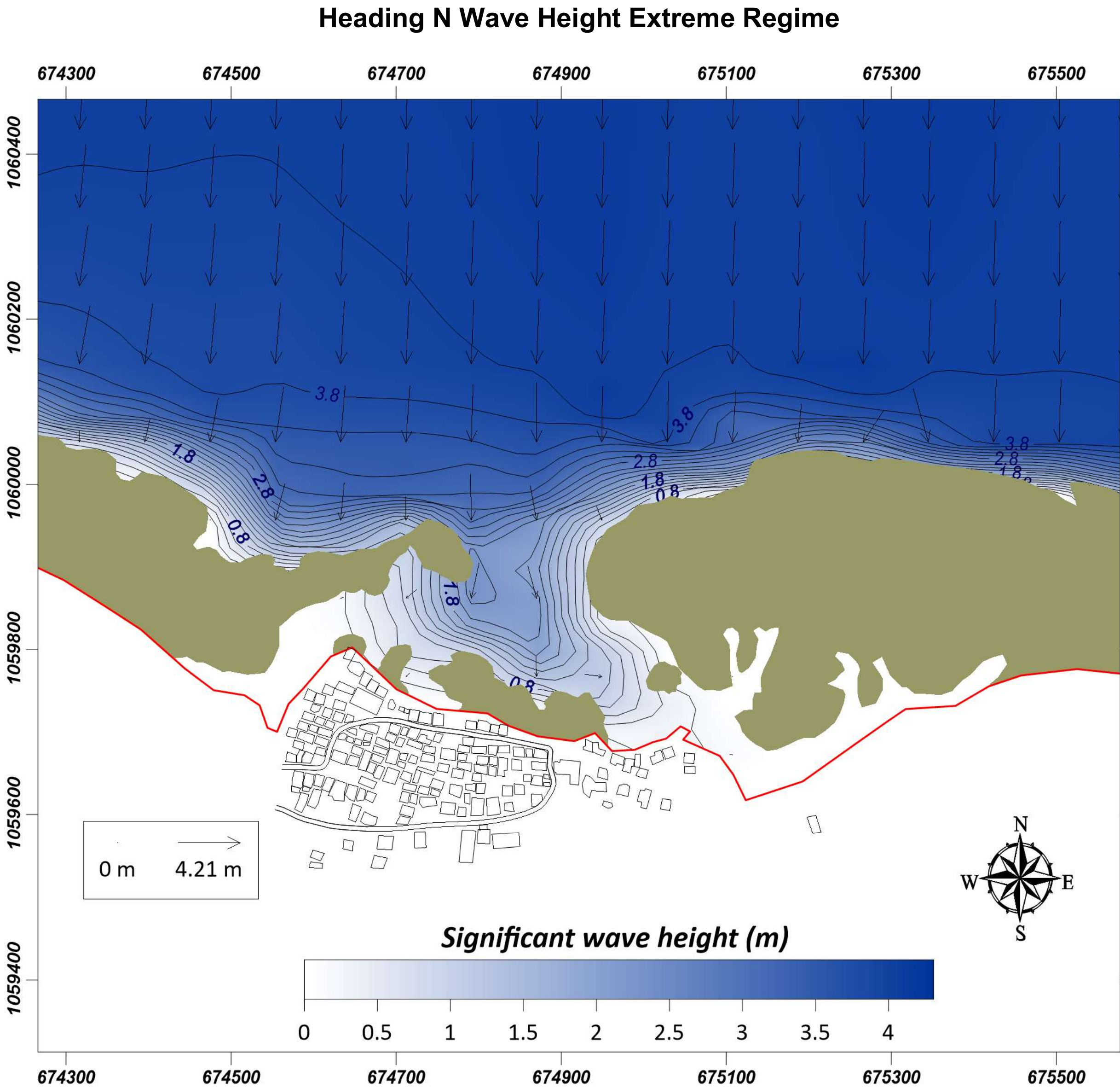
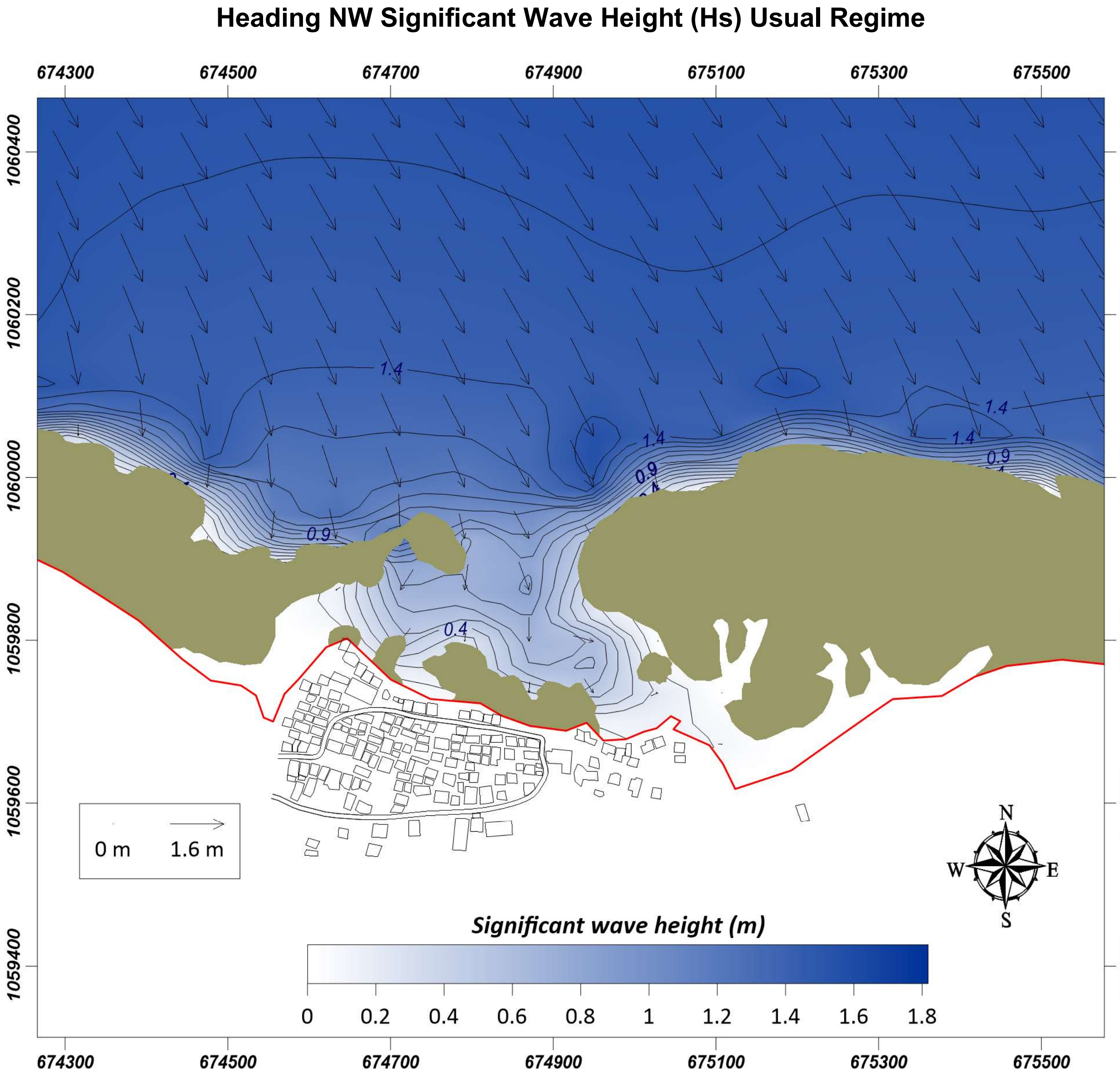
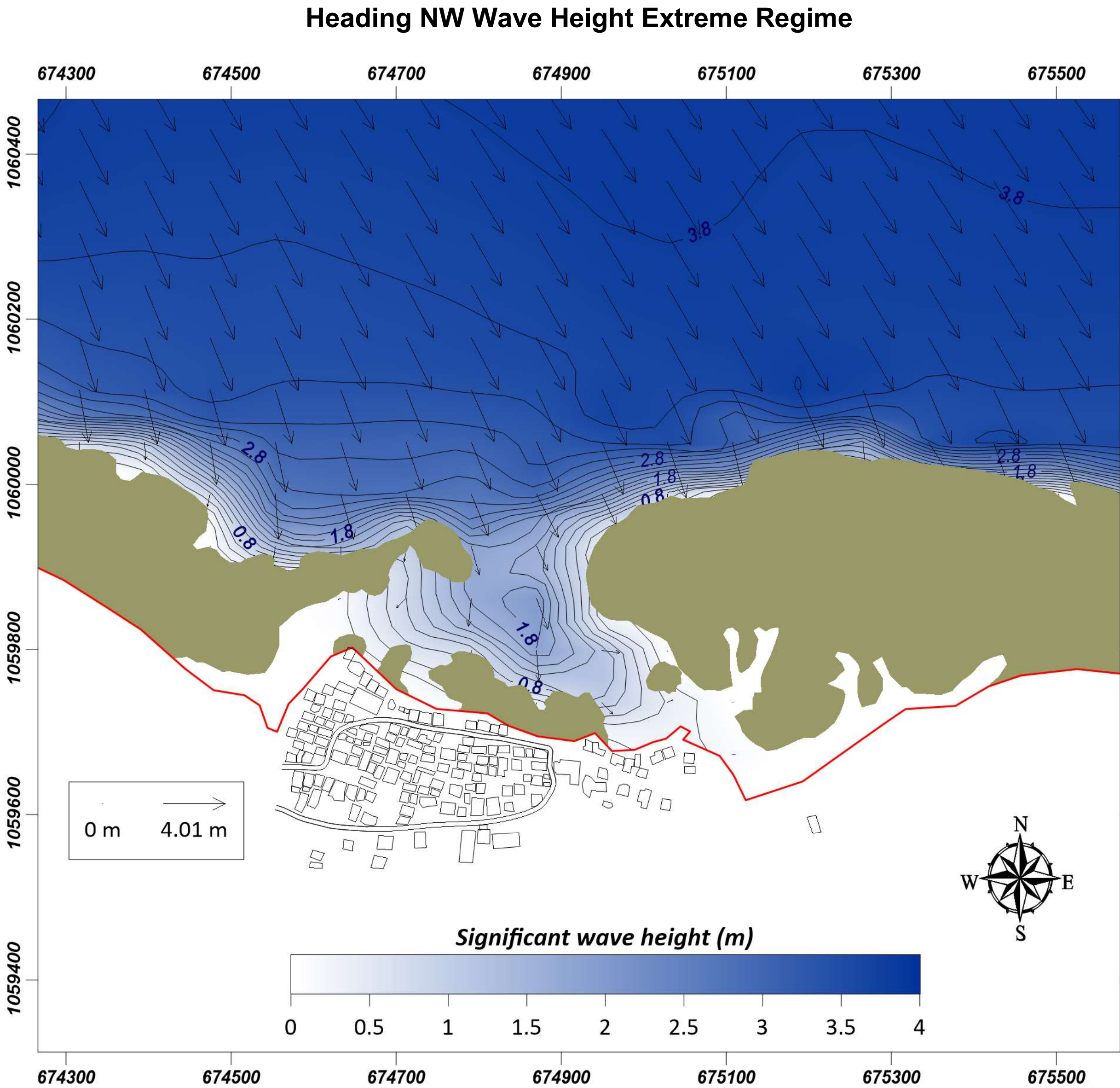
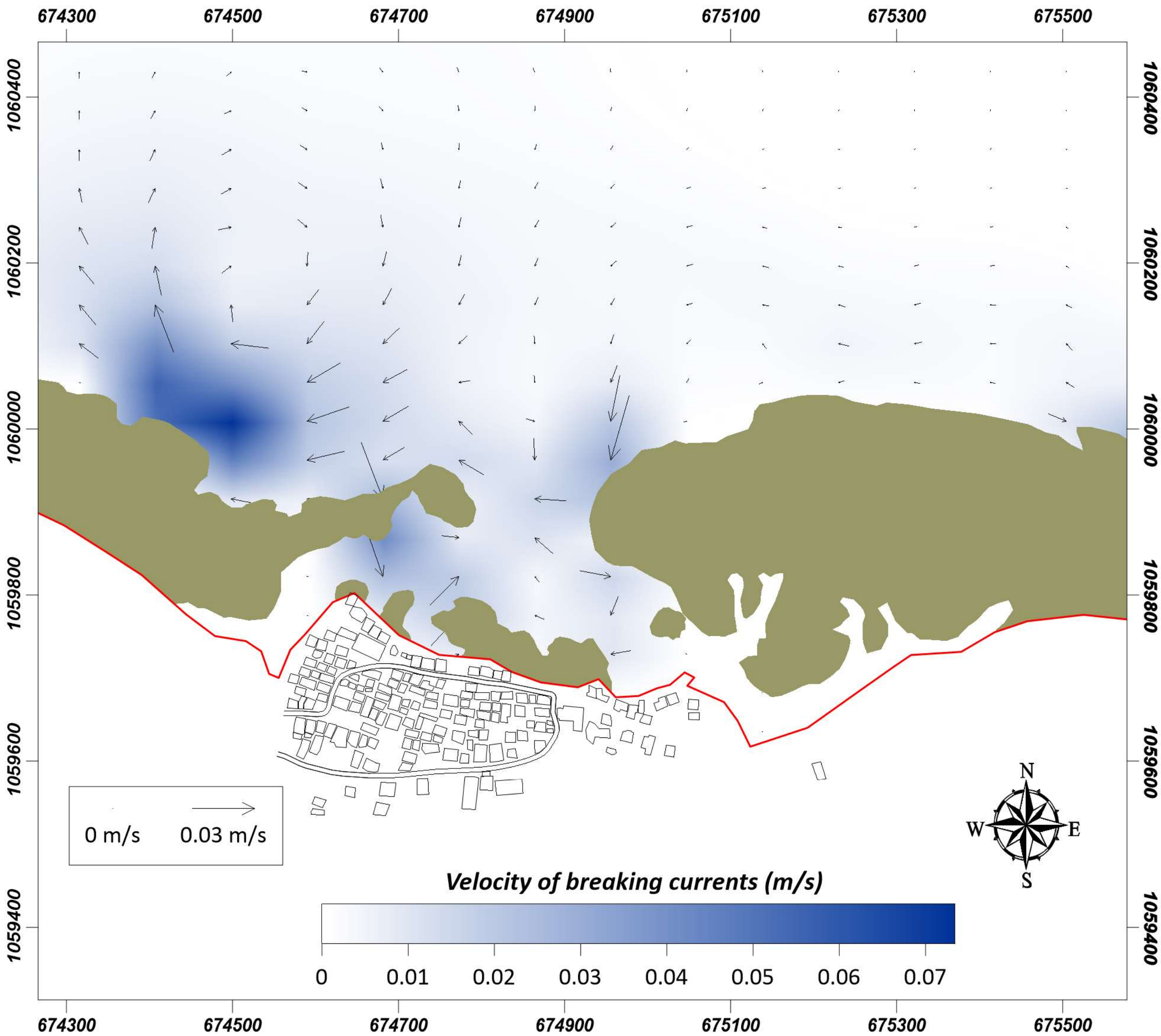

Heading N Wave Height Extreme Regime
674300
674500
674700
674900
675100
675300
675500
1060400
1060200
1060000
1059800
1059600
1059400
3.8
2.8
1.8
0.8
0 m
4.21 m
N
S
W
E
Significant wave height (m)
0
0.5
1
1.5
2
2.5
3
3.5
4


Heading NW Significant Wave Height (Hs) Usual Regime
674300
674500
674700
674900
675100
675300
675500
1060400
1060200
1060000
1059800
1059600
1059400
1.4
0.9
0.4
0 m
1.6 m
N
S
W
E
Significant wave height (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8


Heading NW Wave Height Extreme Regime
674300
674500
674700
674900
675100
675300
675500
1060400
1060200
1060000
1059800
1059600
1059400
3.8
2.8
1.8
0.8
0 m
4.01 m
N
W
E
S
Significant wave height (m)
0
0.5
1
1.5
2
2.5
3
3.5
4

Heading ENE. Currents generated by the usual waves



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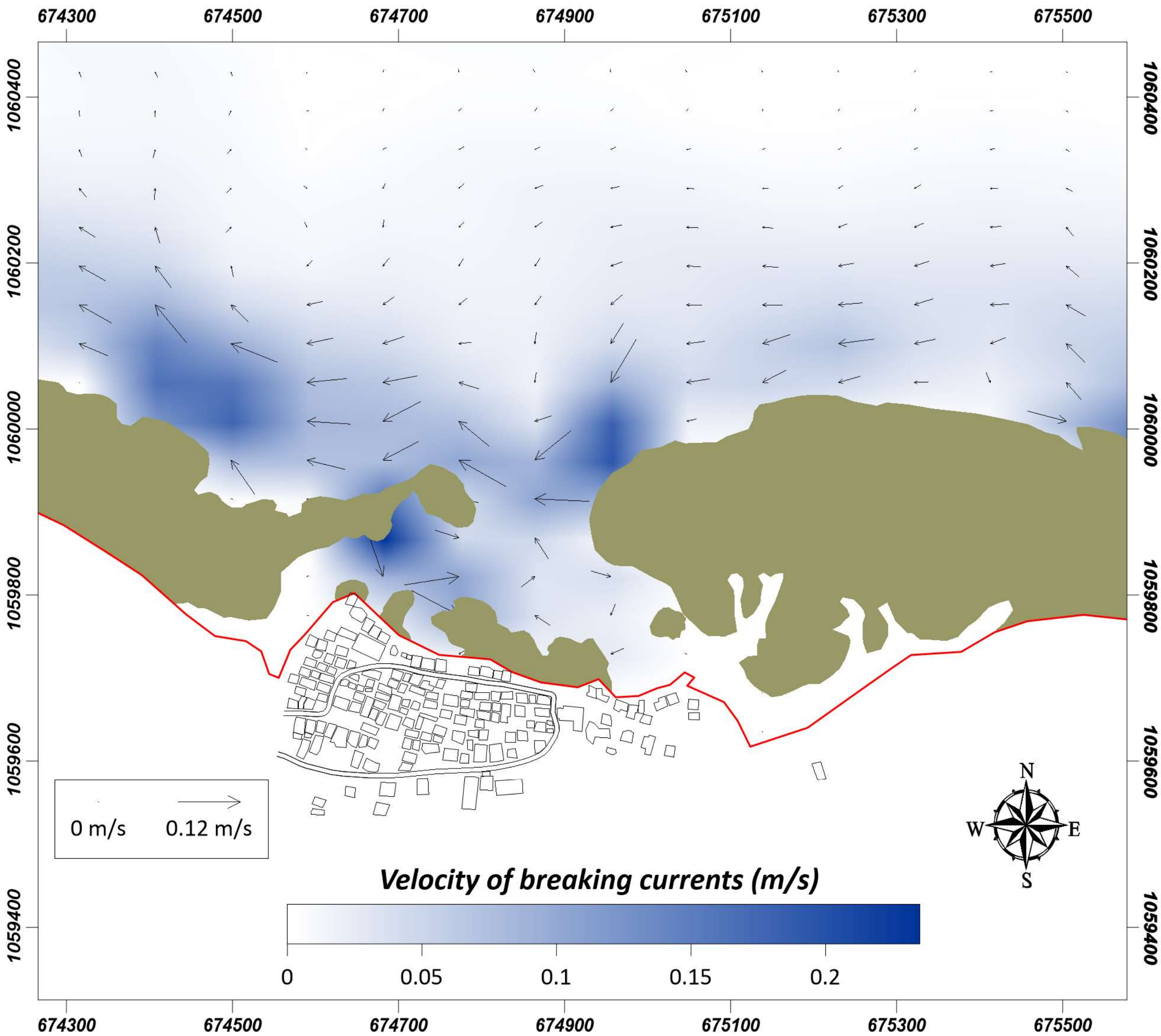
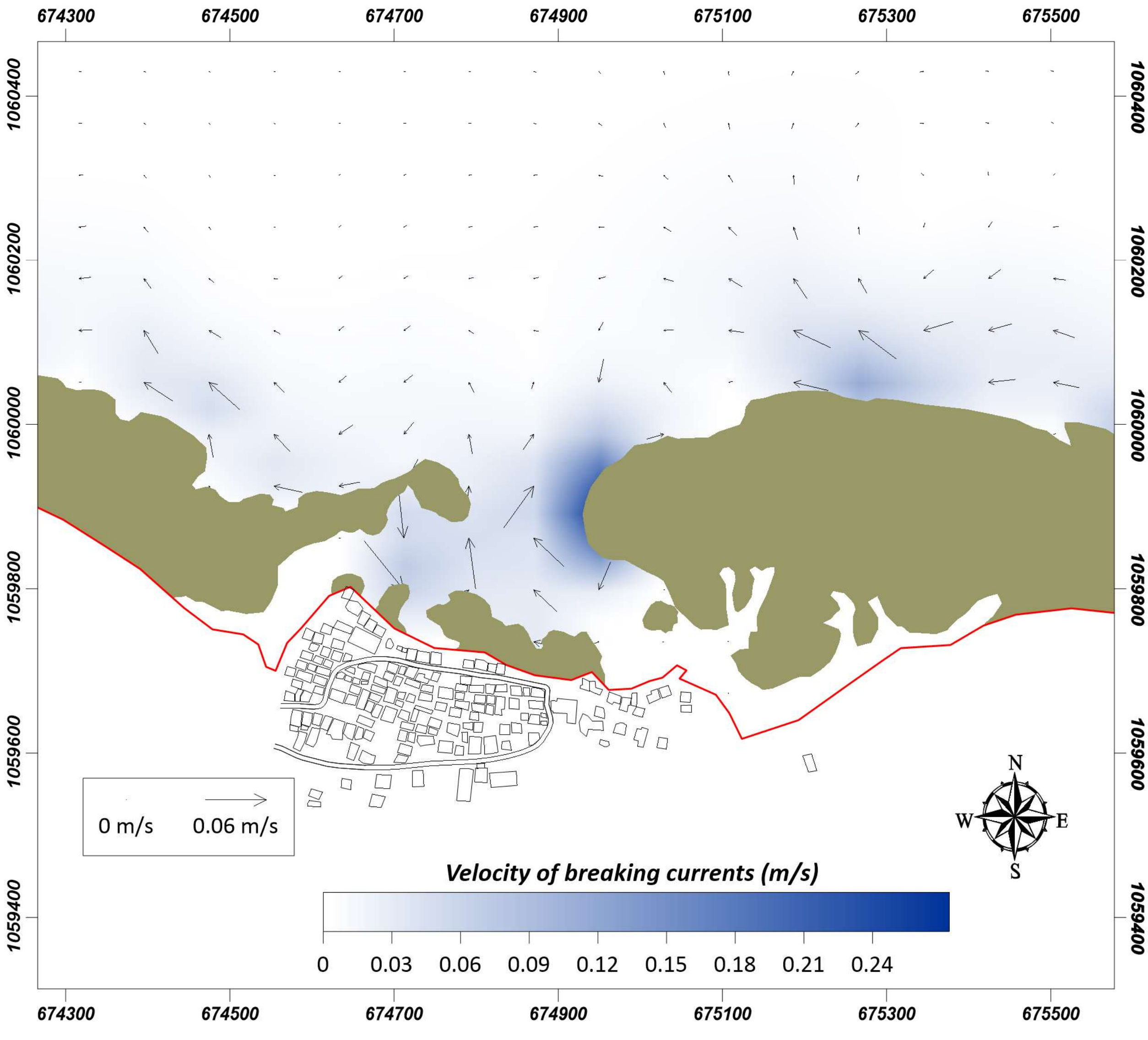
Heading ENE. Currents generated by extreme waves



Heading NE. Currents generated by the usual waves



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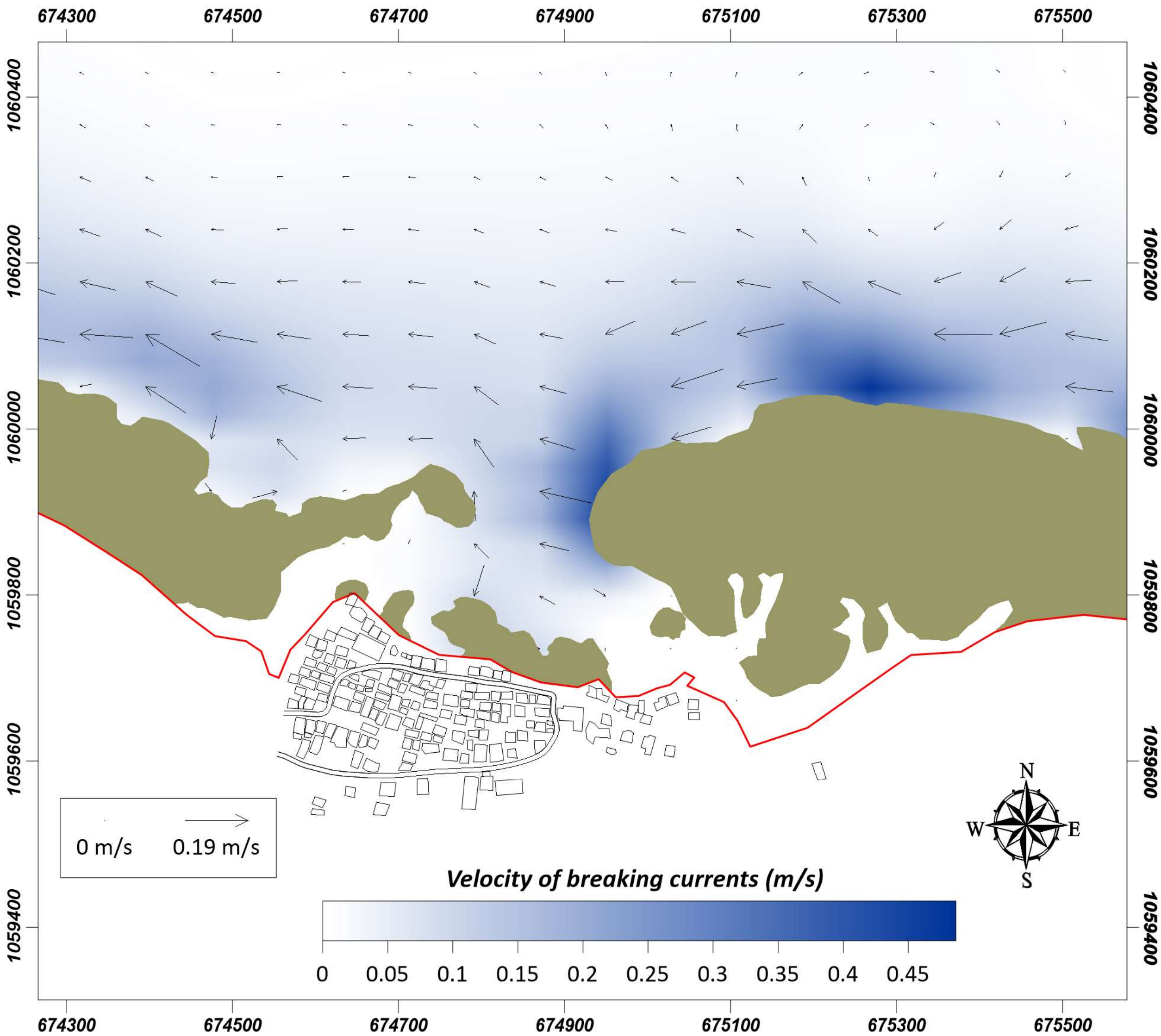
Heading NE. Currents generated by extreme waves



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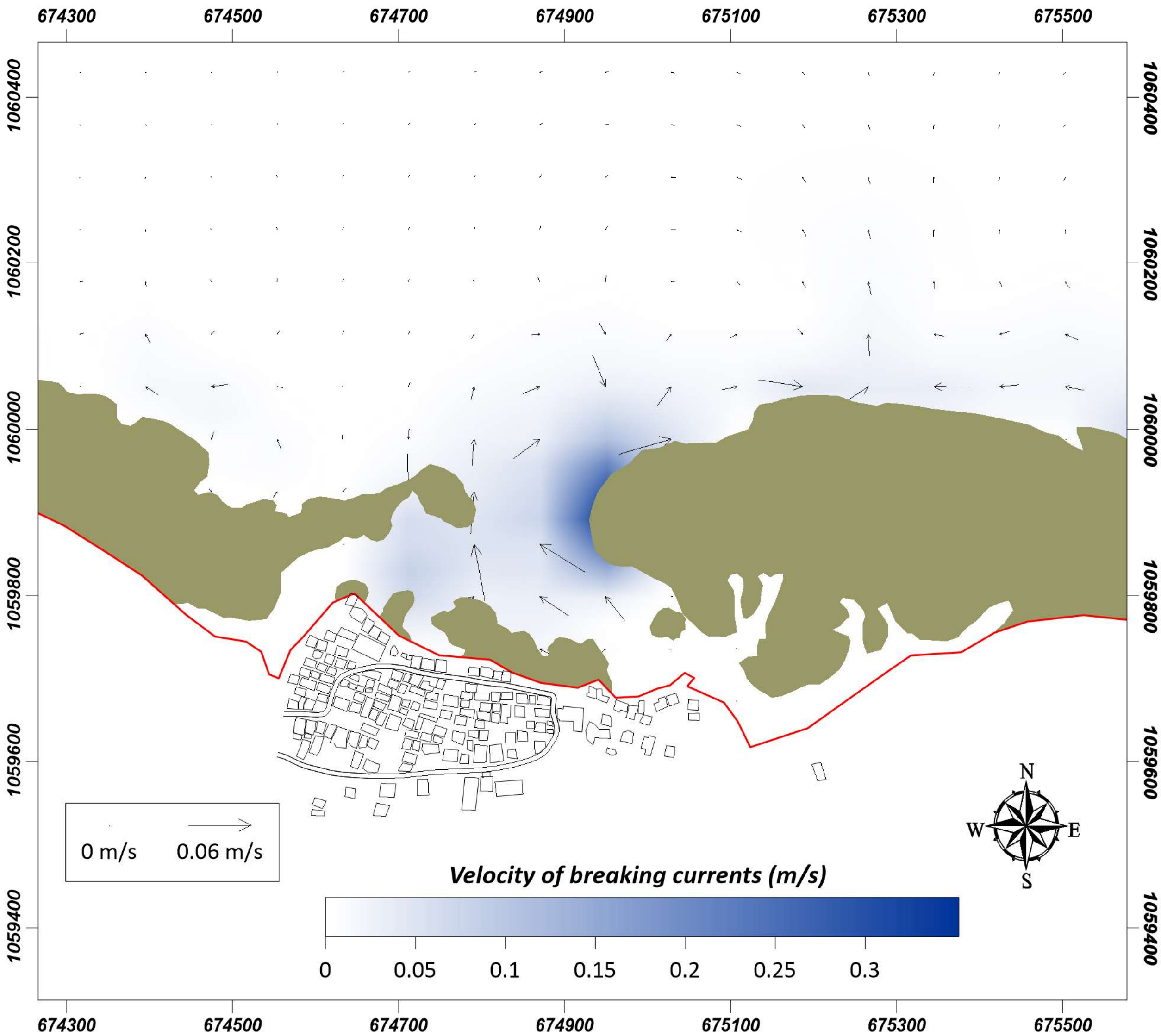
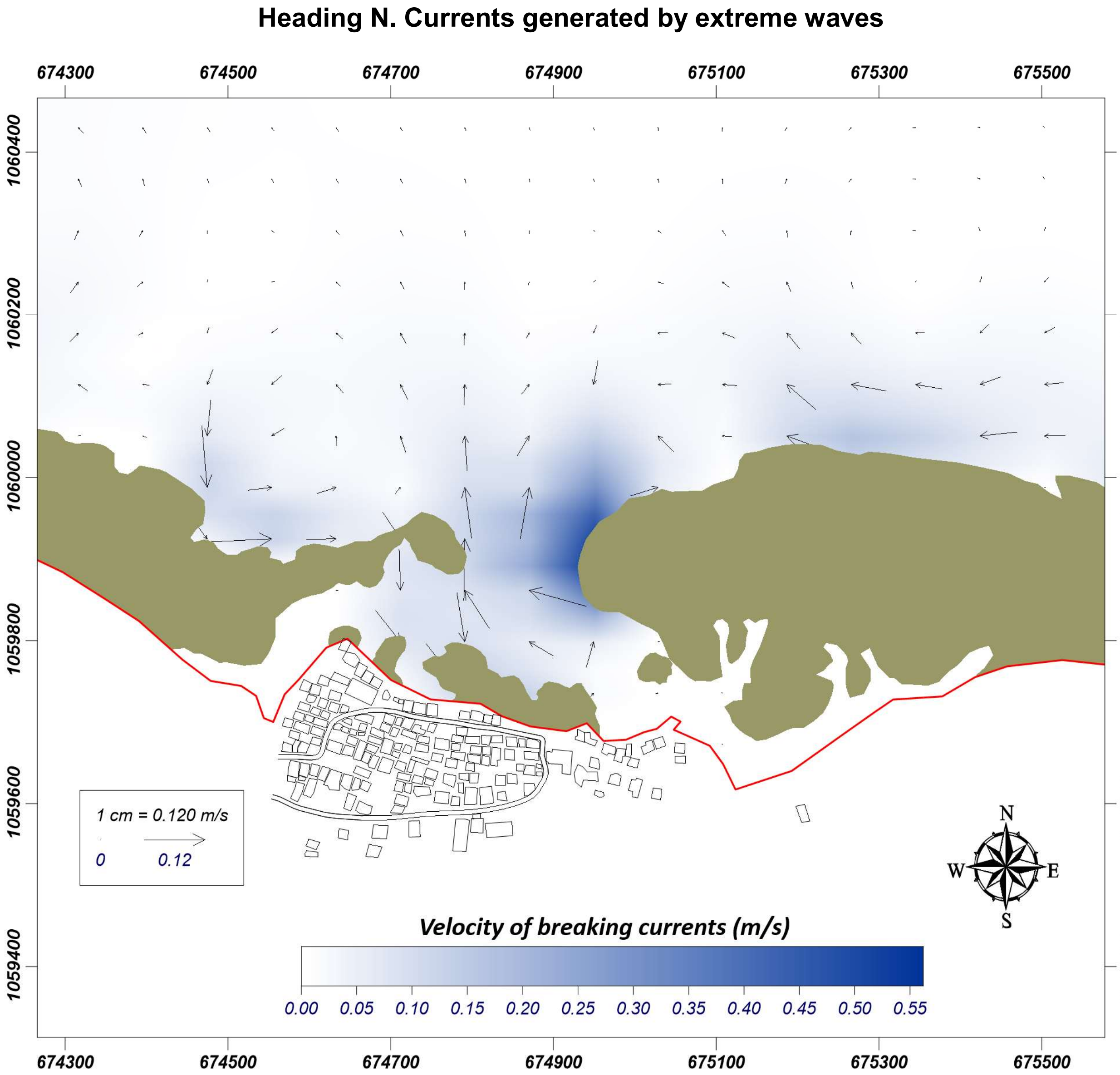
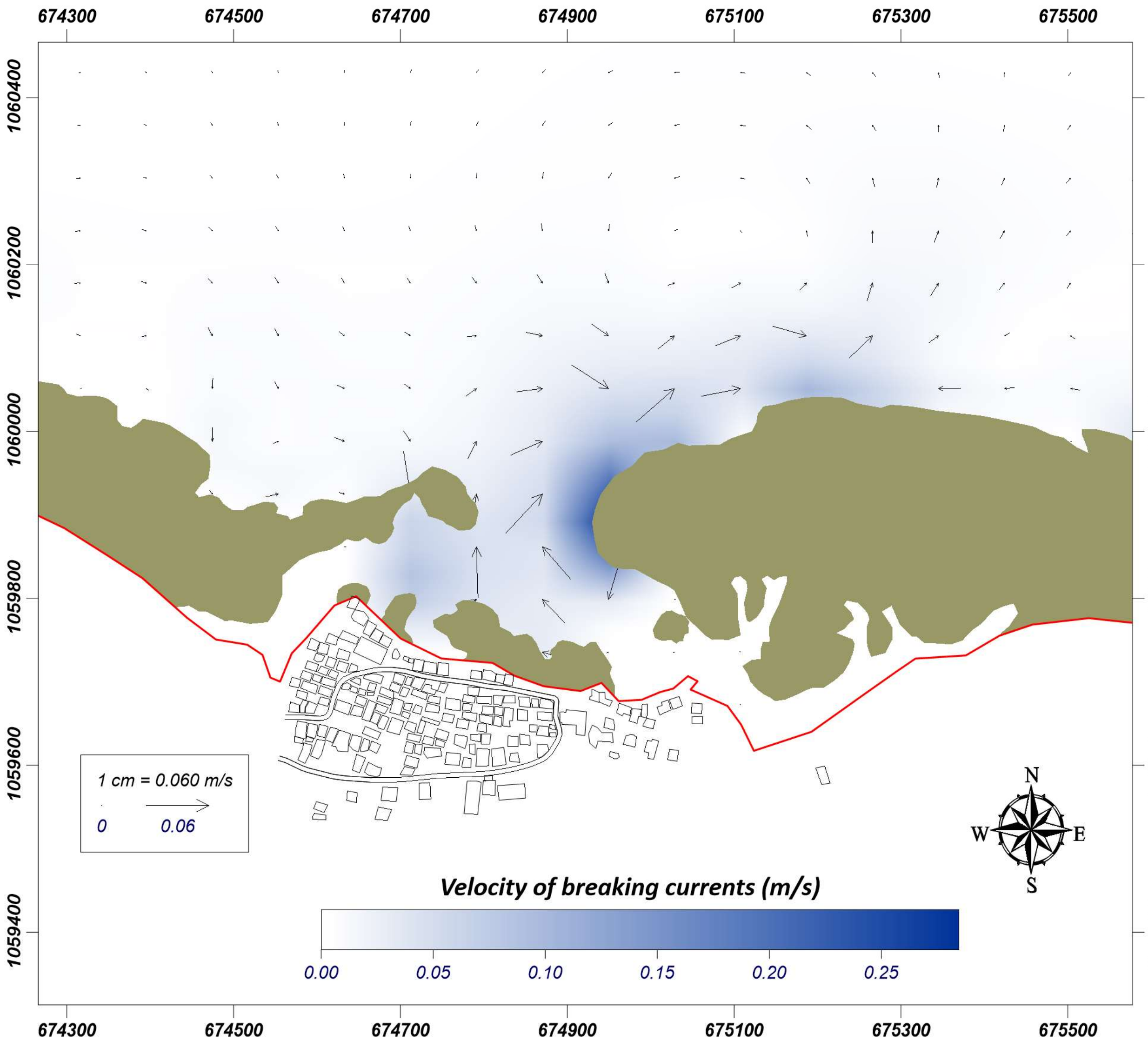
Heading N. Currents generated by the usual waves




Heading N. Currents generated by extreme waves
674300
674500
674700
674900
675100
675300
675500
1060400
1060200
1060000
1059800
1059600
1059400
1 cm = 0.120 m/s
0
0.12
Velocity of breaking currents (m/s)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
N
W
E
S

Heading NW. Currents generated by the usual waves



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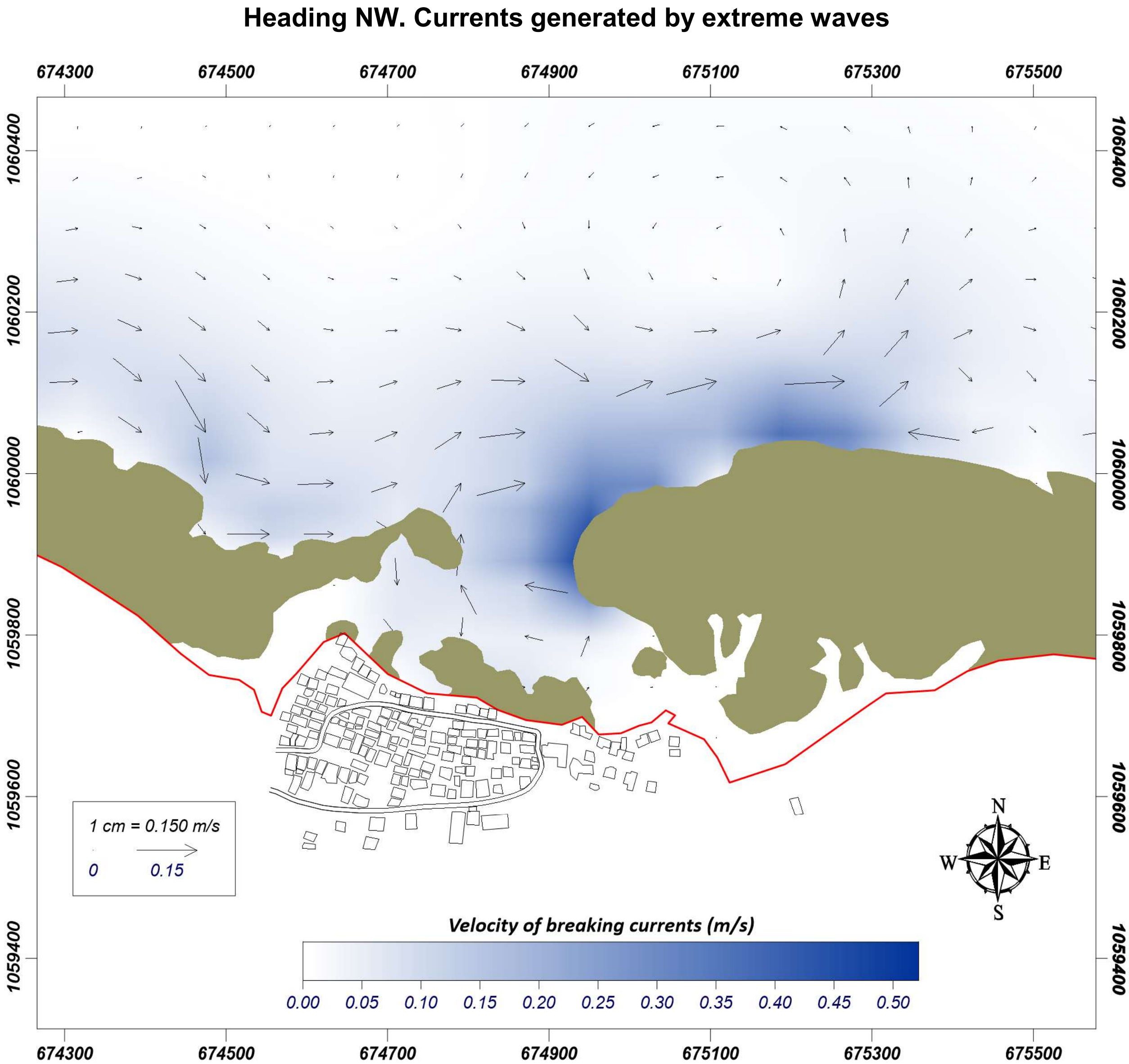
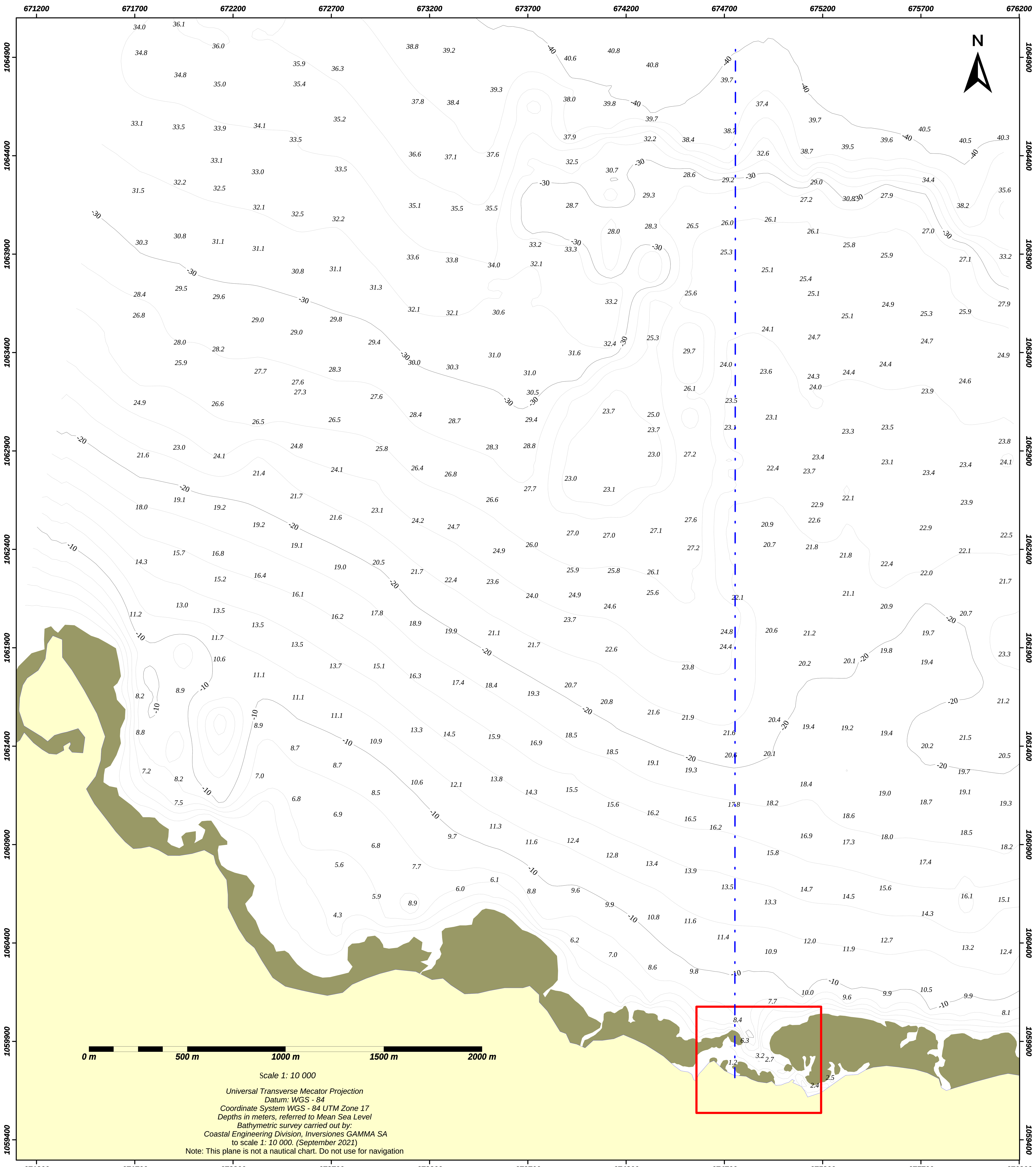
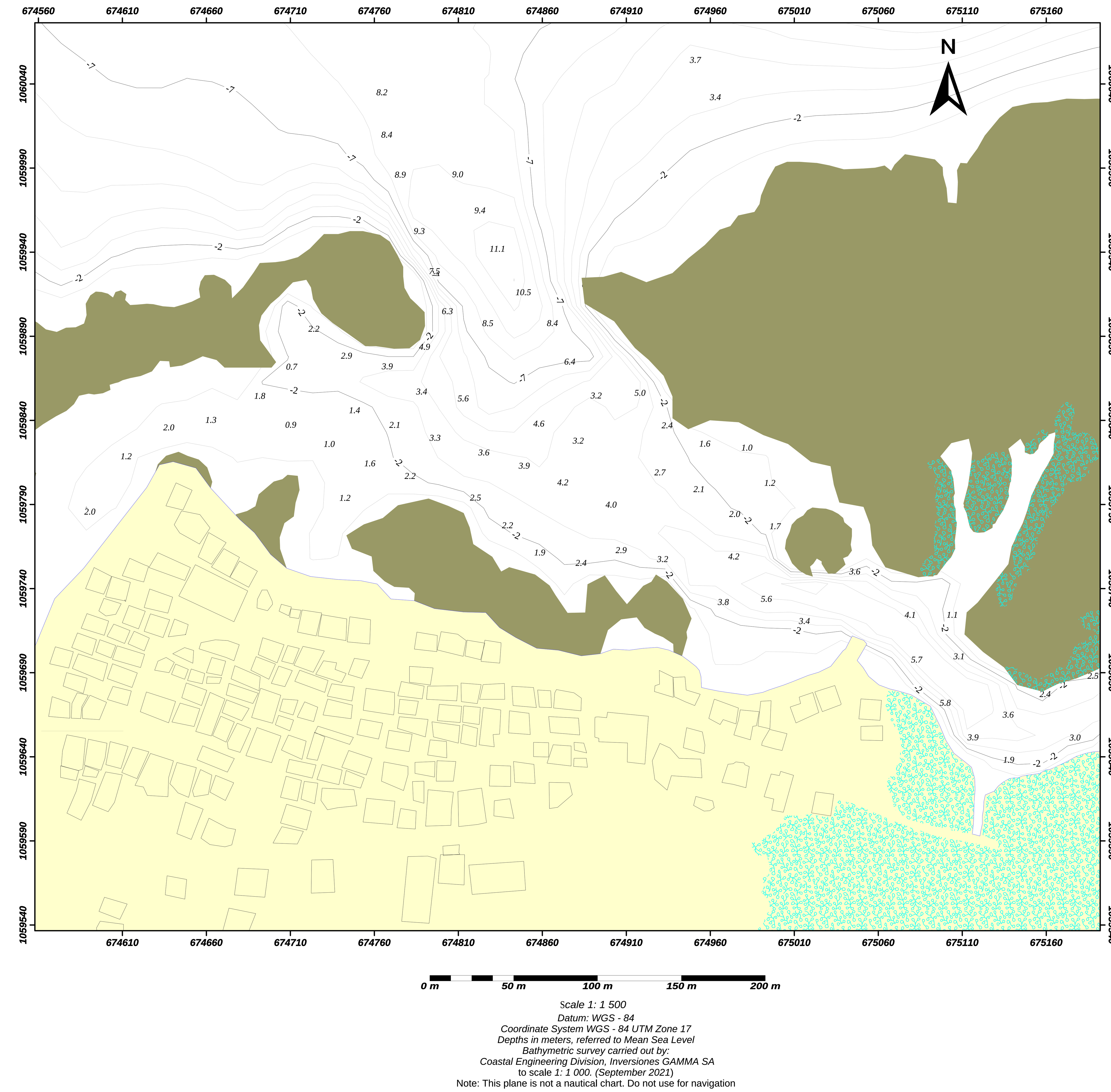
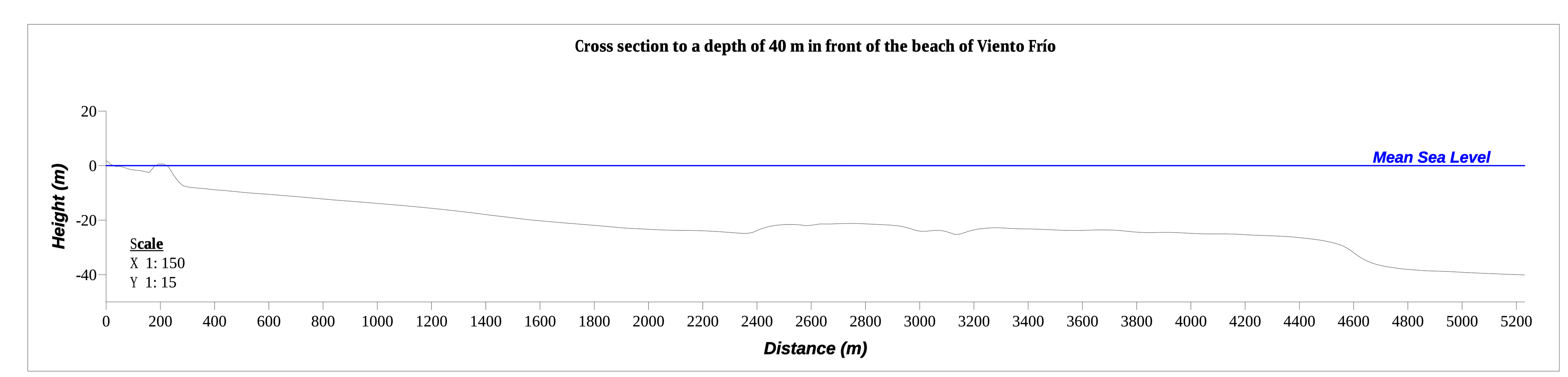


Heading NW. Currents generated by extreme waves
674300
674500
674700
674900
675100
675300
675500
1060400
1060200
1060000
1059800
1059600
1059400
1 cm = 0.150 m/s
0
0.15
N
W
E
S
Velocity of breaking currents (m/s)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

PLANES



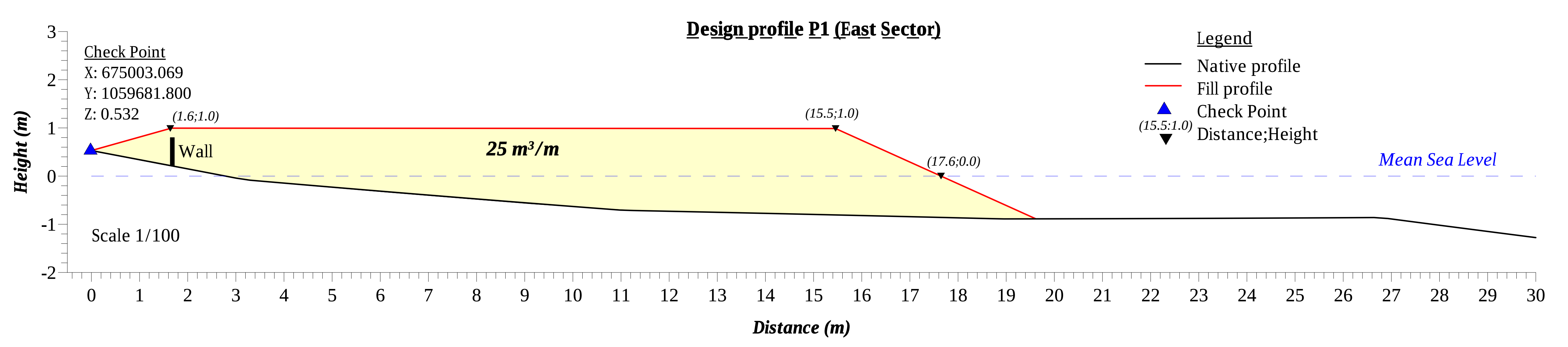


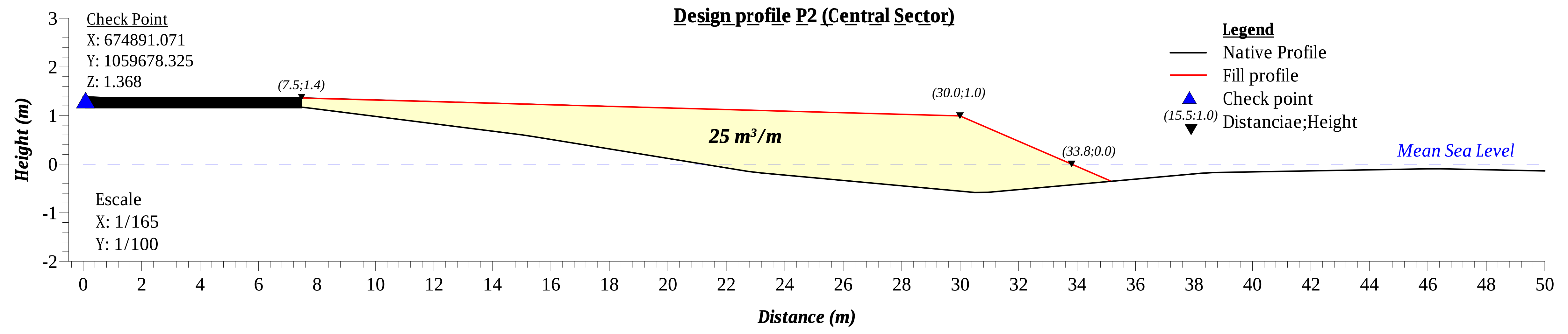


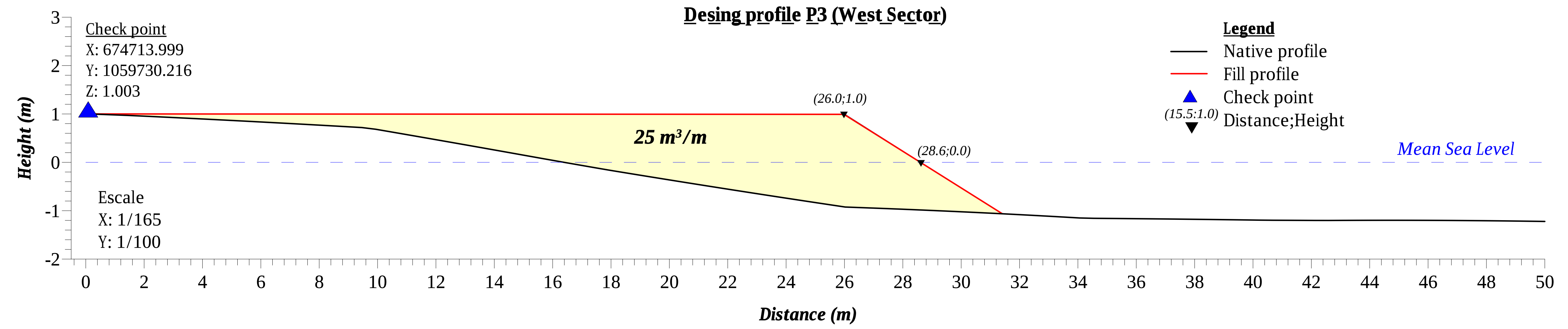
Simbology:

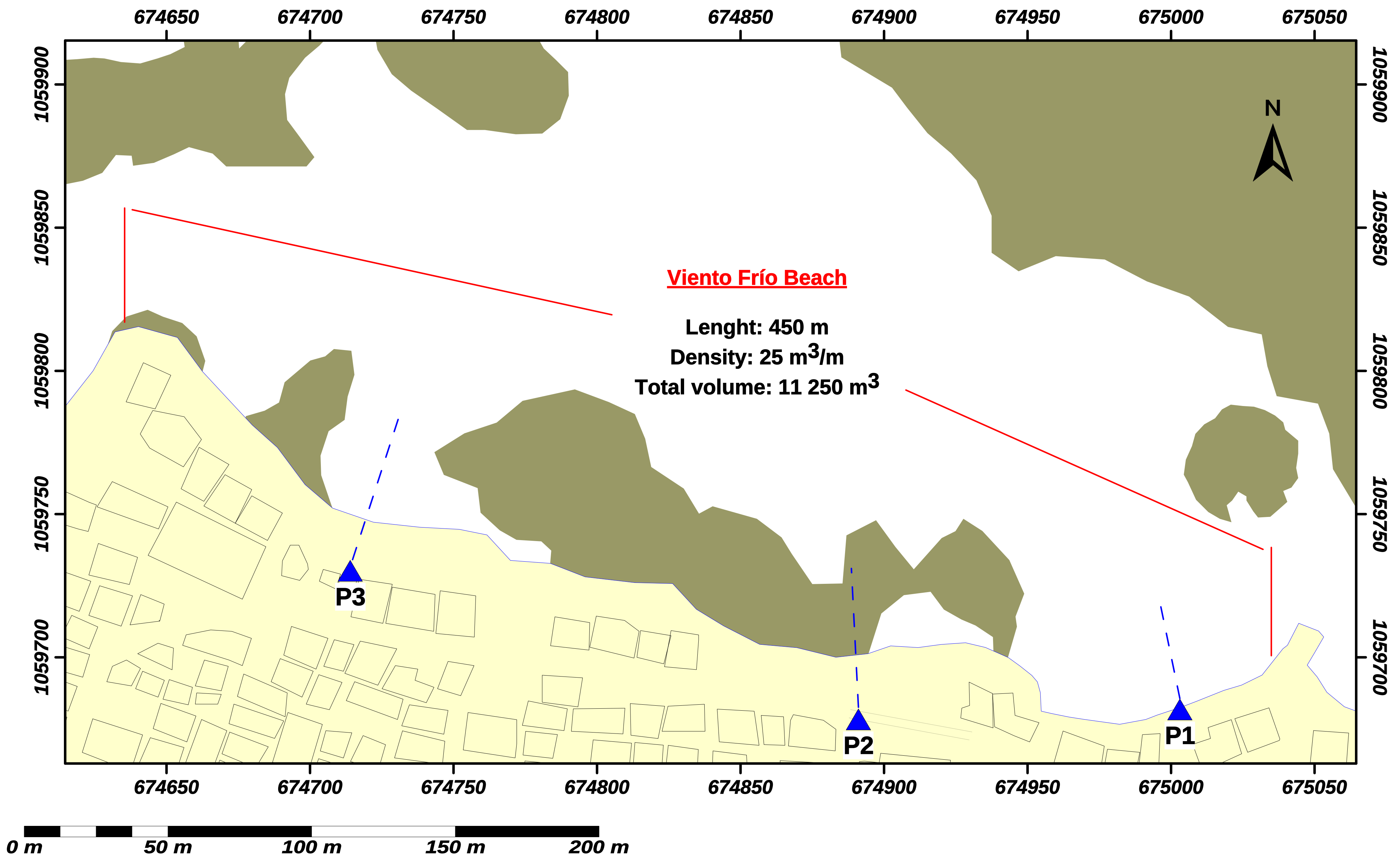
- Isobath
- Shore Line
- 10.65 Depth in meters
- Dog tooth terrace (Lapies)
- Mangrove area
- Cross section

GAMMA TECNOLOGIA Y MEDIO AMBIENTE	MINISTRY OF SCIENCE TECHNOLOGY AND ENVIROMENT. CUBA
PROJECT HEAD: Ing. Vladimir Caballero Camejo	**PROJECT:** EXECUTIVE PROJECT FOR THE REHABILITATION OF THE VIENTO FRÍO BEACH, COLÓN REPUBLIC OF PANAMÁ
MADE BY: Ing. Vladimir Caballero Camejo	
REVIEWED BY: Lic. Leonel Iván Peña Fuentes	**TITLE:** BATHYMETRY OF THE STUDY AREA
DATE: August 2022	**SCALE:** In the windows — **PLANE:** 1







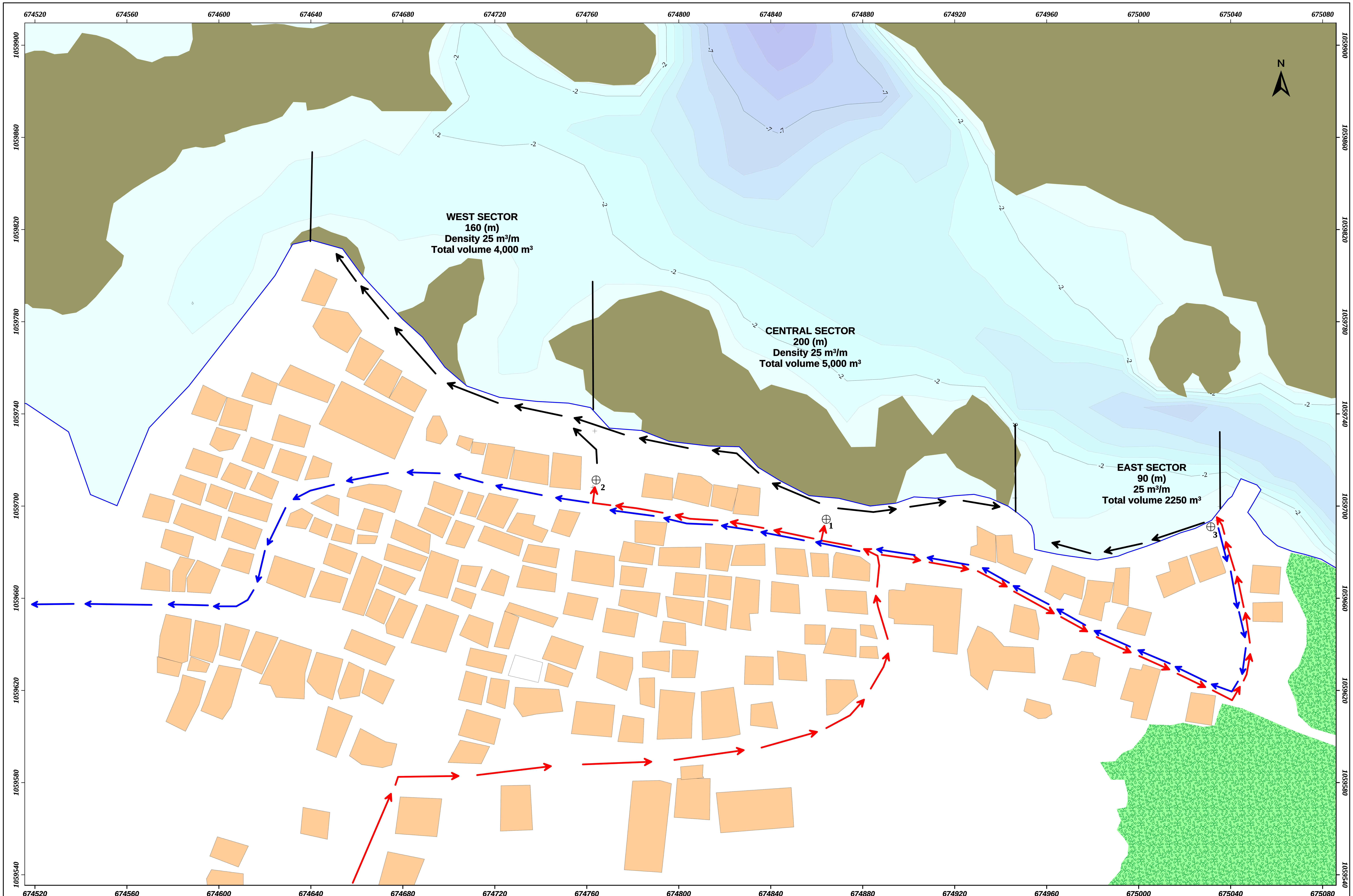


Escale 1: 1 750

Universal Transverse Mecator Projection
Datum: WGS-84
Coordinate System WGS - 84 UTM Zone 17

Desing profile

GAMMA	MINISTRY OF SCIENCE TECHNOLOGY AND ENVIRONMENT. CUBA
PROJECT MANAGER: Eng. Vladimir Caballero Camejo	PROJECT: EXECUTIVE PROJECT FOR REHABILITATION FROM THE VIENTO FRÍO BEACH, COLON REPUBLIC OF PANAMA
MADE BY: Eng. Vladimir Caballero Camejo	
REVIEWED BY: Lic. Leonel Iván Peña Fuentes	TITLE: DESIGN PROFILES FOR THE SAND FILLING
DATE: August 2022	SCALE: In the charts / PLANE: 2



Limit coordinates of the sectors and accesses to the beach. (UTM Zone 17 – WGS 84)

Sector	Límite Este		Límite Oeste	
	X	Y	X	Y
Este	675035.37	1059699.82	674946.16	1059703.51
Central	674946.16	1059703.51	674763.45	1059732.56
Oeste	674763.45	1059732.56	674639.54	1059819.49
Acceso 1			674862.89	1059689.51
Acceso 2			674762.68	1059708.16
Acceso 3			675034.06	1059693.83

0m 25m 50m 75m 100m

Scale 1: 750

Universal Transverse Mercator Projection
Datum: WGS-84
WGS Coordinate System - 84 UTM Zone 17

Legend:

- Isobaths
- Coastline
- Route from borrow area
- Route to the borrow area
- Dog Tooth Terrace (Lapies)
- Mangrove area
- Access point
- Feed direction

GAMMA TECNOLOGIA Y MEDIO AMBIENTE

MINISTRY OF SCIENCE TECHNOLOGY AND ENVIRONMENT. CUBA

PROJECT MANAGER: Eng. Vladimir Caballero Camejo

MADE BY: Eng. Vladimir Caballero Camejo

REVIEWED BY: Lic. Leonel Iván Peña Fuentes

DATE: August 2022

PROJECT: EXECUTIVE PROJECT FOR REHABILITATION FROM THE VIENTO FRÍO BEACH, COLON REPUBLIC OF PANAMA

TITLE: WORK EXECUTION

SCALE: 1:750

PLANE: 3

Houses and other facilities in the position of the beach profile and abrasive terrace in the area

Strip of sand and existence of logs and garbage on the beach

Central Sector

- Lenght 200 m
- Incomplete profile, narrow sand strip of 15 m on average
- Submarine slope dominated by intertidal abrasive terrace, with a variable width between 33 m and 66 m
- Existence of facilities in the dynamic profile of the beach
- Poor storm drainage
- Need to clean the beach of trunks and garbage in general

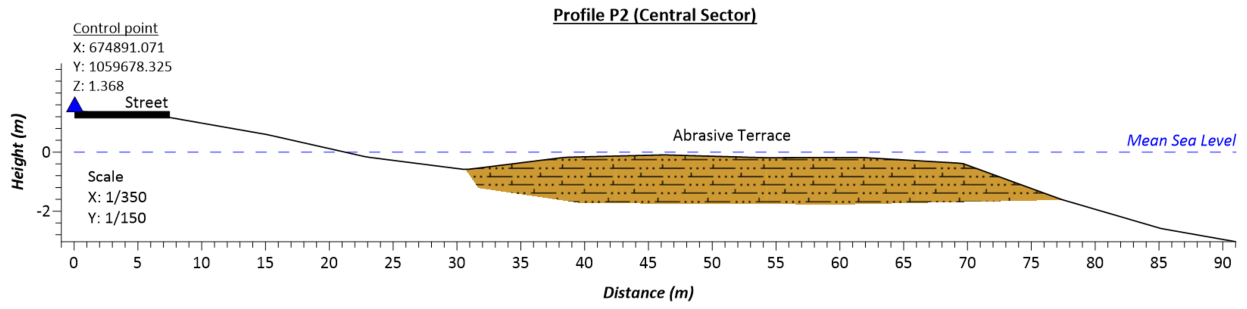
Long-term measures

- Solve stormwater runoff
- Relocation of the facilities on the first line of the coast
- Creation of an environmental education program for the community
- Offer alternatives to the inhabitants for the acquisition of sand for construction and prohibit their extraction.

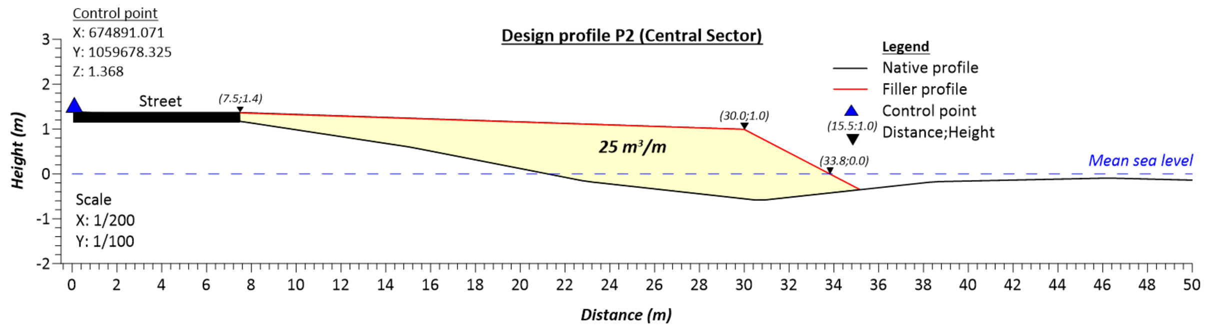
Short term measures

- Restoration of the beach profile through artificial feeding of sand with the use of trucks from the mouth of the Cuango River
- Total volume to pour 5000 m^3, density of 25 m^3/m

Profile P2 (Central Sector)



Design profile P2 (Central Sector)



Damage by the action of the sea to the walls of protection to facilities

Total loss of profile emerged from the beach

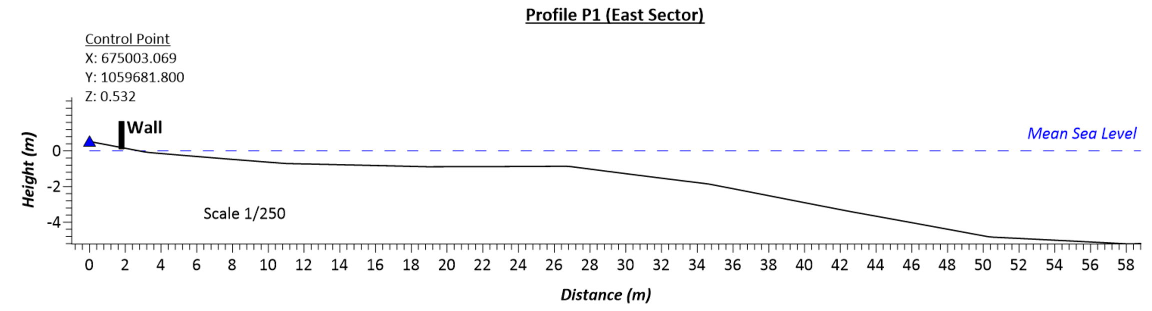
East Sector

- Lenght 90 m
- There is no profile emerged on the beach
- Gentle slope in the submerged profile up to a distance of 25 m from the coastline
- Existence of walls to protect properties in the coastal zone.

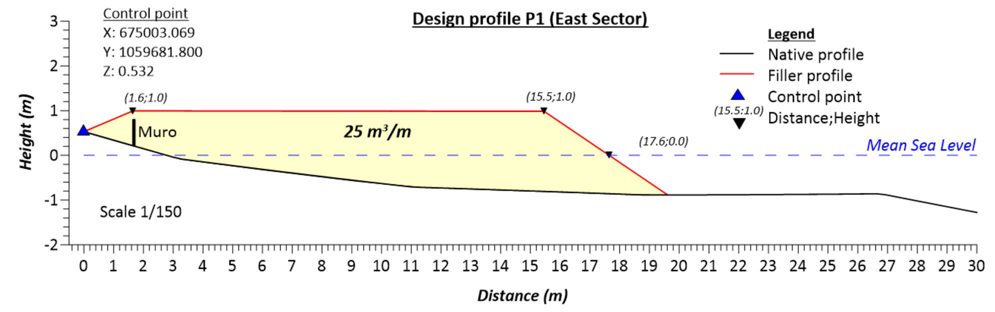
Measures for the sector

- Restoration of the beach profile through artificial feeding of sand with the use of trucks
- Total volume to be poured 2250 m^3, density of 25 m^3/m.

Profile P1 (East Sector)



Design profile P1 (East Sector)



West Sector

- Length 160 m
- Incomplete profile, narrow strip of sand 20 m wide
- Small coves with a sand profile on the underwater slope
- Existence of facilities in the dynamic profile of the beach
- Poor storm drainage
- Need to clean trunks and garbage in general

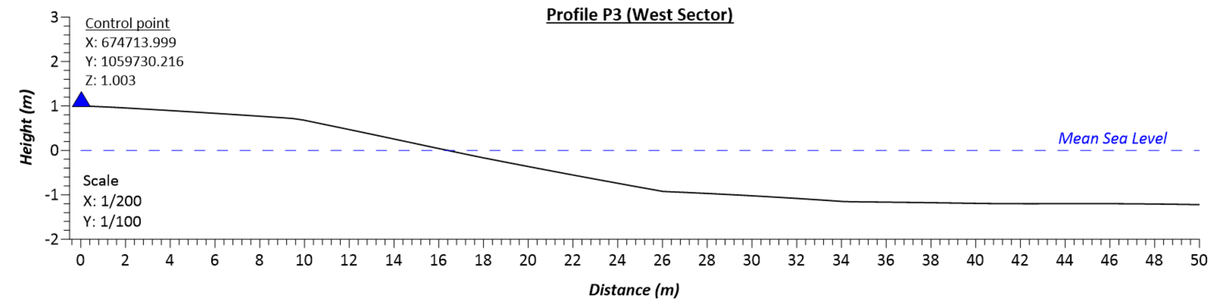
Long-term measures

- Solve stormwater runoff
- Relocation of the facilities on the first line of the coast
- Creation of an environmental education program for the community
- Offer alternatives to the inhabitants for the acquisition of sand for construction and prohibit their extraction.

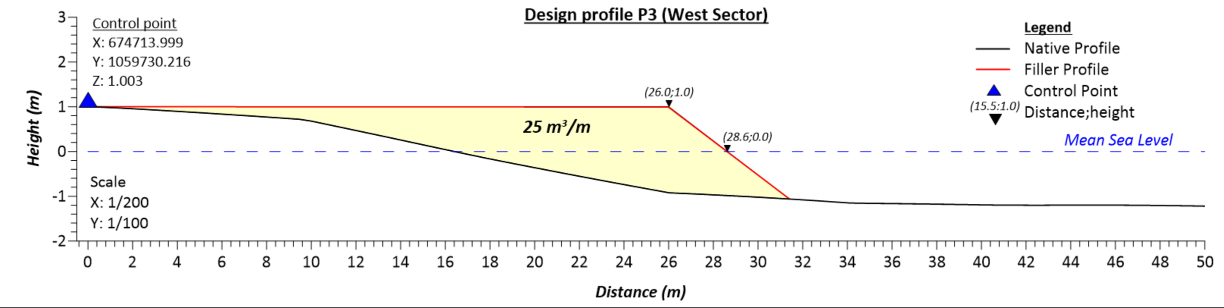
Short term measures

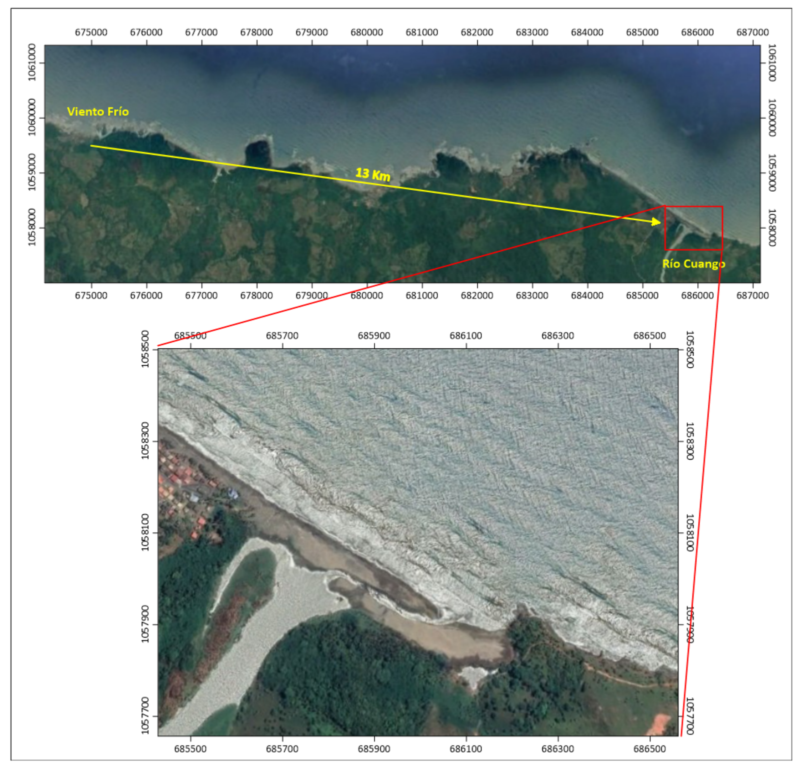
- Restoration of the beach profile through artificial feeding of sand with the use of trucks from the mouth of the Cuango River
- Total volume to pour 4000 m^3, density of 25 m^3/m

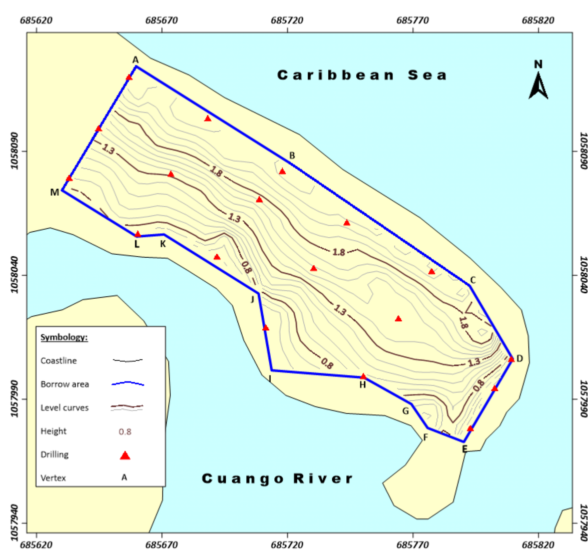
Profile P3 (West Sector)



Design profile P3 (West Sector)

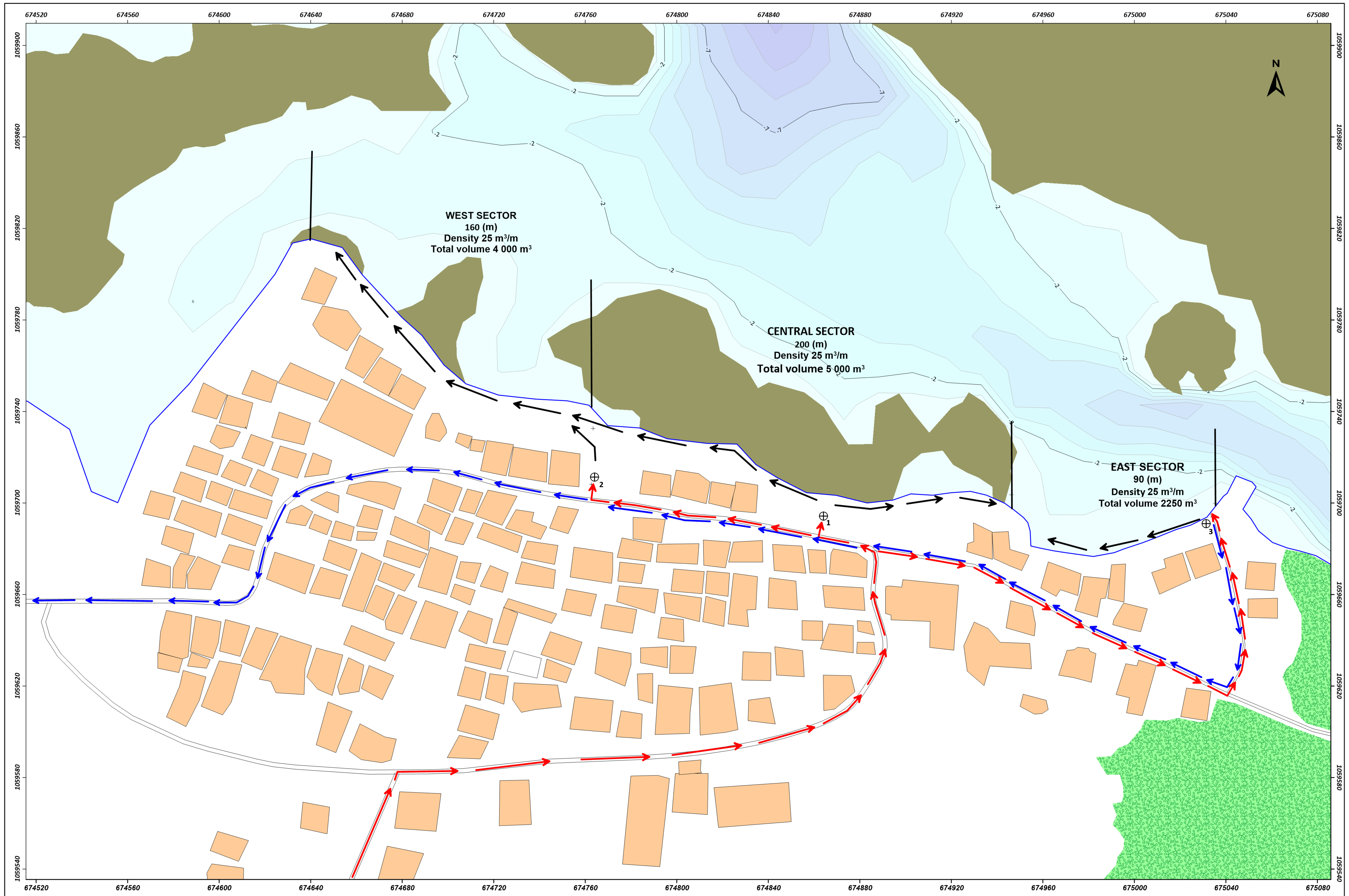






Borrow area at the mouth of the Cuango River

- Average distance from Viento Frío: 13 km
- Area: 10 730 m^2
- Average thickness: 1.60 m
- Volume of sand available: 17,168 m3
- Necessary volume to be extracted for the project: 11,250 m3



Boundary coordinates of the sectors and accesses to the beach. (UTM Zona 17 – WGS 84)

Sector	East boundary		West boundary	
	X	Y	X	Y
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Central	674946.16	1059703.51	674763.45	1059732.56
West	674763.45	1059732.56	674639.54	1059819.49
Access 1			674862.89	1059689.51
Access 2			674762.68	1059708.16
Access 3			675034.06	1059693.83

0m 25m 50m 75m 100m

Scale 1: 750

Mecator Universal Transverse
Datum: WGS - 84
Coordinate System UTM Zone 17

Leyenda:

Isobaths		Dog's Tooth Terrace (Lapies)	
Coastline		Mangrove area	
Route from the borrow area		Access point	
Route to the borrow area		Forward direction	

GAMMA TECNOLOGIA Y MEDIO AMBIENTE	MINISTERIO DE CIENCIA TECNOLOGIA Y MEDIO AMBIENTE. CUBA
PROJECT MANAGER: Ing. Vladimir Caballero Camejo	PROJECT: EXECUTIVE PROJECT FOR THE REHABILITATION FROM VIENTO FRÍO BEACH, COLÓN REPUBLIC OF PANAMA
MADE BY: Ing. Vladimir Caballero Camejo	TITLE: RESUMEN DE PROYECTO
REVIEWED BY: Lic. Leonel Iván Peña Fuentes	
DATE: August 2022	SCALE: 1 : 750 — PLANE: 4