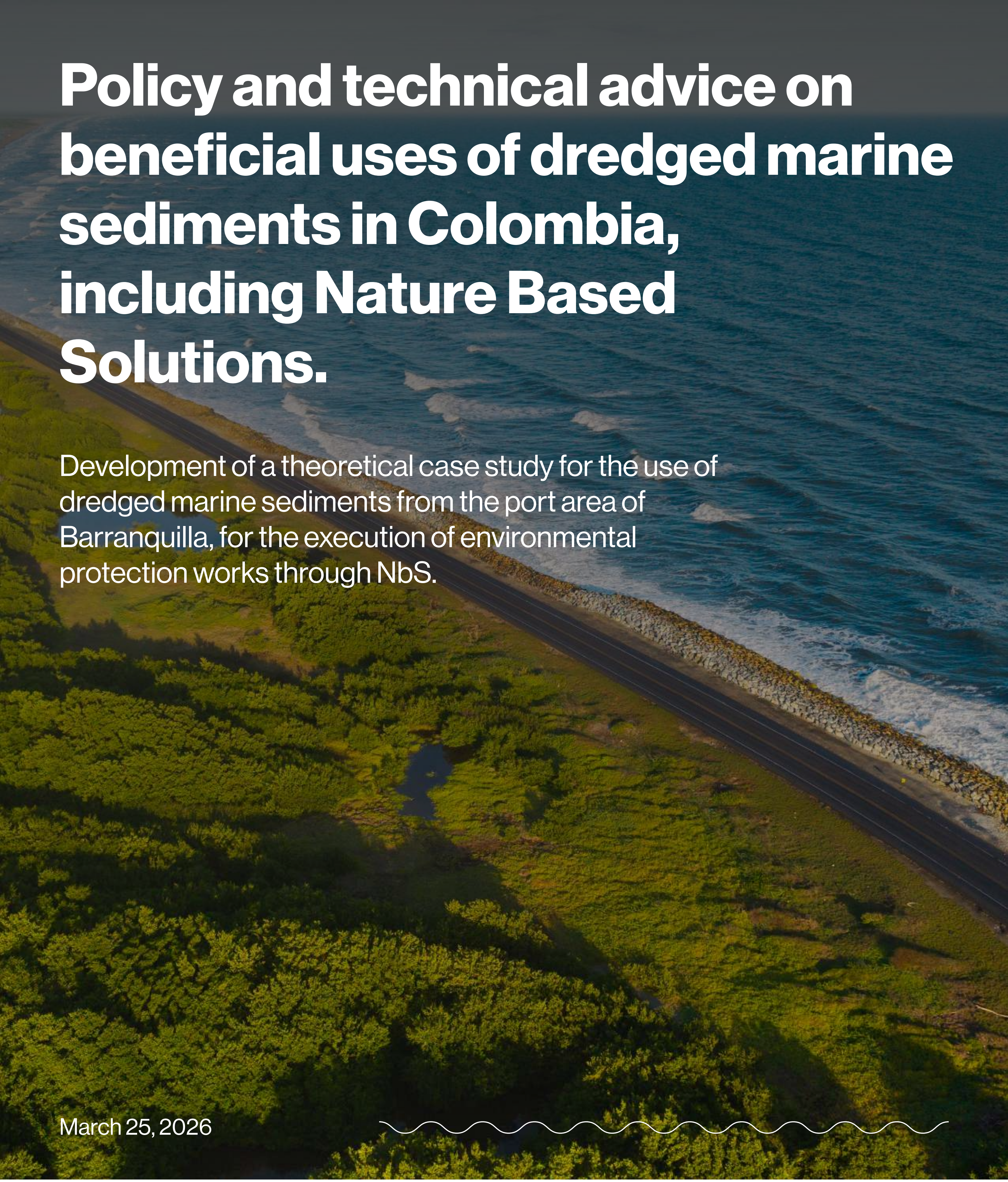
Policy and technical advice on beneficial uses of dredged marine sediments in Colombia, including Nature Based Solutions.



Development of a theoretical case study for the use of dredged marine sediments from the port area of Barranquilla, for the execution of environmental protection works through NbS.

March 25, 2026

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CO-CREATING IMPACT

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The project "Policy and technical advice on beneficial uses of dredged marine sediments in Colombia, including nature-based solutions" is part of a collaboration between the Government of the Netherlands, through the Partners for Water program, and the Colombian Ministry of Environment, the National Planning Department (DNP) and the Ministry of Transport. The project was executed by a consortium formed by Arcadis, Fundación Herencia Ambiental Caribe, JESyCA and Netics, in conjunction with government entities from both Colombia and the Netherlands.

Contents

1. Introduction

1. Introduction

1.1 Background

Within the broad collaboration between the Government of the Netherlands and the Government of Colombia on water and climate change adaptation, the beneficial use of dredged materials has been established as one of the priorities, at the specific request of the Colombian Ministries of Transport (MinTransport), Environment and Sustainable Development (MinAmbiente) and the National Planning Department (DNP). In Colombia, dredged marine sediments are still not used for beneficial uses and the dredged materials are dumped in offshore deposition areas previously approved by the environmental authority. In order to promote the beneficial use of dredged materials and strengthen the applicable regulatory framework in Colombia, this project aims to provide policy and technical advice for the use of dredged marine sediments, including Nature-based Solutions (NBS).

The policy partnership with the Government of Colombia on the issue of dredging and beneficial use of dredged materials has a long history, supported by several projects in which Arcadis and its partners have played a role:

- The National Maritime Dredging Plan, which includes a section on the beneficial use of dredged material.
- A series of webinars on dredging and reuse of dredged materials in Colombia, aimed at supporting stakeholders on the topic of dredging, including key principles such as Building with Nature and reuse of dredged materials for other purposes.
- In the Reuse of dredged materials in the Colombian context dredged materials in the Colombian context, opportunities for expanding the range of beneficial uses of dredged materials have been analyzed, including examples of legal frameworks and regulatory requirements in other countries, a case study of opportunities for beneficial uses of dredged materials resulting from capital and maintenance dredging activities in the Buenaventura port area, and an analysis of barriers and facilitators for the implementation of dredged materials reuse in Colombia.

In this sense, the current project is the next logical step in this line of work. It proposes a set of rules and parameters that could be incorporated into the main dredging guidance document and presents a set of case studies for a major port such as Barranquilla, illustrating possible applications of dredged material.

1.2 Project objectives and deliverables

The project focuses on enriching the regulatory guidelines for marine dredged materials in Colombia by compiling and making available the practical experience and regulatory framework in the Kingdom of the Netherlands, the limits and thresholds established for this purpose in various countries as well as proposing a set of rules and parameters for the main guidance document regarding dredging and including a case study for the port area of Barranquilla showing what can be done with dredged material[1].

The basis for improving the Colombian guidelines lies in providing technical advice in the form of rules and practical parameters for the beneficial use of dredged material, drawn from the experience of the Netherlands and other countries. Accompanying this technical advice is capacity building of key stakeholders in Colombia with respect to the main technical components of the study.

[1] Currently, in Colombia, the main guidance document on dredging is: Guía de manejo ambiental de proyectos de infraestructura, modos marítimos y fluviales, INVIAS 2022.

Our reference: 1 – Date: March 25, 2026

The project consists of 5 main deliverables:

Deliverable 1 — Information, experiences and lessons learned in the licensing, operation, monitoring and control of maritime dredging activities in the Netherlands, as well as in determining the requirements for approving in this country the uses of dredged marine sediments.

Deliverable 2 — Analysis of the parameters and steps of the procedure in the Netherlands and other countries to determine the quality requirements of dredged marine sediments for beneficial uses. Facilitating the use of lessons learned to support the determination of threshold values in Colombia for beneficial uses of dredged marine sediments.

Deliverable 3 — Evaluation of the physical and chemical quality of dredged sediments in the access channel to the port area of Barranquilla.

Deliverable 4 — Formulation of procedural guidelines to determine feasible and suitable uses of dredged marine sediments in Colombia, including nature-based solutions.

Deliverable 5 — Development of a theoretical case study for the use of dredged marine sediments from the port area of Barranquilla, for the execution of environmental protection works through NbS.

1.3 Objectives of this deliverable

1.3.1 General objective of deliverable 5

This deliverable presents the development of a theoretical case study on the use of dredged sediments from the port area of Barranquilla for the implementation of BNS for environmental protection purposes. Based on the knowledge acquired throughout this project (deliverables 1 - 4), the exercise will apply the procedural guidelines (proposals) and the information generated in the previous stages to formulate BNS projects that are theoretically feasible.

1.3.2 Specific objectives

The study identifies and evaluates sites in the Barranquilla area with potential for these applications, considering at least three viable BNS options. The resulting documentation includes descriptions of site selection, sediment quality assessments, and analysis of implementation techniques, potential impacts and risks, based on available information. A market study is also conducted to explore the business case for the use of dredged sediments for BNS in Barranquilla. As a theoretical exercise, this approach seeks to broaden the impact of the project results and facilitate their replicability in other contexts. The objective of this deliverable is, therefore:

- the application of a theoretical case of the beneficial use of dredged material in Barranquilla
- the identification of potentially interesting sites for the beneficial use of dredged material
- to provide the Colombian authorities with the steps to follow to promote these conceptual designs.
- describe the replicability of conceptual designs
- outline, with publicly available information, the business case of the most applicable conceptual design.

1.3.3 Methodological limits of the deliverable

It is important to note that this document is prepared only at a conceptual level, which implies that it presents general ideas and preliminary guidelines for the management and use of dredged material, without going into the details of design or execution engineering, financing and/or environmental and social impacts. In particular, the level of detail is conceptual, which means that no construction plans have been developed and no specific technical parameters for field implementation have been defined. Likewise, detailed hydrodynamic modeling and numerical simulations of flow, wave or sediment transport behavior, which would be necessary to accurately assess the technical feasibility of the proposed solutions, have not been performed at this stage. The information used is mainly based on secondary sources, such as technical literature, previous reports and reference data, and not on field campaigns or direct measurements specific to the study site. Therefore, in order to move towards a prefeasibility or pilot design phase, additional studies, including hydrodynamic modeling, risk analysis, environmental and social studies, and detailed topographic and bathymetric surveys, will be indispensable. The recommended next steps for moving towards implementation are described in Chapter 5 of this report. In summary, the case presented seeks to be a demonstrative and replicable tool, whose main objective is to serve as a reference model that can be adapted and applied in Barranquilla and other sites in Colombia, always subject to the completion of the necessary technical, financial and social studies to ensure its viability and sustainability.

1.4 Reading Guide

This report (Deliverable 5) presents a theoretical case study on the use of dredged marine sediments for the implementation of NbS, with the objective of functioning as environmental protection in Barranquilla. The structure of this report is as follows:

CHAPTER 2:
General context: Port of Barranquilla.

CHAPTER 3:
Identification and prioritization of BNS opportunities for sediment beneficiation, applicable in Barranquilla.

CHAPTER 4:
Market study: Demand for dredged material.

CHAPTER 5:
Recommendations and next steps

CHAPTER 6:
References

CHAPTER 7:
Appendices

APPENDIX A:
Barranquilla port concessions.

APPENDIX B:
Characterization of the Coastal Environmental Unit (UAC) of the Magdalena River in the Barranquilla port area.

APPENDIX C:
Diagnosis Coastal Zone between Castillo de Salgar, Punta Roca and Ciénaga de los Manatíes.

APPENDIX D:
Minimum physical and chemical requirements necessary for the proposed BNS.

2. General context:
Port of Barranquilla

Executive summary

The key points of this chapter are:

1. Barranquilla has a population of approximately 1.28 million inhabitants and a high coverage of public services in the urban area (99% in water and energy).

2. The economy is based mainly on commerce (45.2%), services (41.3%) and others (13.5%).

3. The port area is located on the western bank of the Magdalena River, 22 km from its mouth. Access is via a double-lane channel divided into four sectors, from Boya de Mar (K-2) to beyond K-22.

4. There are 28 port terminals under concession from Cormagdalena.

   - **Current:** 20 concession contracts in force, 12 are operating (1 under construction and 11 built) and 8 are not operating (3 built, 2 under construction, and 3 not built).
   - **Non-current:** 8 non-current concession contracts, 1 constructed and 7 unconstructed.

5. In 2025, 12.7 million tons were mobilized, down from 13.4 million tons in 2024. The port is the fourth most important in the country. Traffic is distributed in 70% import (highlighting solid bulk and general cargo) and 30% export (coal, bulk and containers).

6. The estimated capacity is 28.4 million tons. Current occupancy is between 44% and 47%. Projections indicate that by 2038, close to 17 million tons will be mobilized (60% occupancy).

7. The port generates approximately 25,000 direct and indirect jobs.

8. The average volume of the years 2023 to 2025 that was dredged in the four sectors of the access channel was 3.6 million m3 of material. The access channel is divided into four sectors where dredging activities are concentrated. Sector I (Bocas de Ceniza, K-2 to K2) is the most critical due to waves and sedimentation, concentrating 61% of the total volume dredged (average of 2.1 million m3). The rest of the dredging effort is divided into Sector II (7%), Sector III (16%) and Sector IV (16%).

9. The dredged material varies from sands to clayey silts. In general terms, the material has a mostly acceptable chemical quality.

2. General Context: Port of Barranquilla

2.1 Port of Barranquilla: location and description

It is located on the western bank of the Magdalena River, 22 km from its mouth in the Caribbean Sea. It is the fourth most important port in the country in terms of volume of cargo transported, after Cartagena, Buenaventura and Santa Marta.

Strategic importance:
It boosts foreign trade in the Colombian Caribbean. It connects the interior of the country through the Magdalena River with the Atlantic Ocean and international markets.
It is key to the logistical competitiveness of Barranquilla and the region.

Operational characteristics:
Type: Multipurpose (maritime-river).
Connectivity: Integrates river transport on the Magdalena River and maritime access to the Caribbean.
Access Channel: Requires periodic dredging to ensure operational drafts.

Port infrastructure:
1,058 meters of docks.
4 cranes (100-124 tons).
12 hectares of container storage, with capacity for 8,241 TEUs[2], and 181 electrical outlets for refrigerated and frozen cargo.

Key data 2024:
Throughput: More than 13.4 million tons of cargo. Growth: 9% increase over 2023, an all-time record. Draft: Historic draft of 10.4 meters, improving operability.

Employment impact:
Approximately 700 direct jobs in logistics, operations, maintenance and administration.
More than 600 vacancies offered in specialized recruitment campaigns.
Approximately 25,000 direct and indirect jobs, including transportation, logistics, customs, foreign trade, and related services.
The port not only generates employment, but also stimulates strategic sectors, promotes training and professional specialization, and strengthens the production chains of Barranquilla and the Caribbean region.

Navigation in the port sector of Barranquilla is carried out through a double-lane channel designed by Cormagdalena, allowing vessel traffic in opposite directions. The canal is divided into several sections, the most important being the Boya de Mar (K-2) and Bocas de Ceniza (K 0) section, which is in the open sea and subject to extreme wave and sedimentation conditions, which can restrict navigation during certain months of the year. Other sections are grouped from Bocas de Ceniza to K 22, with changes in width and the constant need for dredging due to variations in the river's hydrological regime and coastal weather conditions.

Barranquilla's port area, defined by the Magdalena River and its banks, has 28 port terminals under concession from CORMAGDALENA. Of these, according to the Port, Physical and Environmental Management Plan (POFPA) for the year 2023[3], 20 concessions are under concession. in force, 12 operating and 8 not operating. 8 concessions are not in force. Most terminals are private and dedicated to specific

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[2] TEU (Twenty-foot Equivalent Unit) is the standard unit used in shipping to measure the equivalent cargo capacity of a 20-foot container. FEU (Forty-foot Equivalent Unit) is the unit equivalent to a 40-foot container.
[3] Study conducted by Unión Temporal JESyCa - Steer - INP for the UNIDAD DE PLANEACIÓN DE INFRAESTRUCTURA DE TRANSPORTE - UPIT (Transportation Infrastructure Planning Unit).

cargoes, although multi-user terminals handle most cargo, including general cargo, bulk, liquids and containers.

The berthing infrastructure includes piers of different types and buoy terminals. In addition, the area has storage infrastructure consisting of yards, warehouses, and tanks. Available equipment includes gantry cranes, pipelines, forklifts, terminal tractors, and pumping systems, among others.

With respect to the 28 port concessions, Appendix A of this document presents a table with the concession contract number, the term of the contract (start date - end date) and the name of each of the port companies in the area.
Figure 2-1 of the Barranquilla port area (purple color), the location of the municipality of Puerto Colombia and the town of Salgar, the access channel, the location of the 20 active port concessions and the anchorage areas for vessels awaiting authorization to enter the access channel are shown below. For the Barranquilla region, there are no port developments or concession requests other than those described in the previous section and presented in detail in Appendix 7.1 (A).

2.2 Port of Barranquilla: Context

This section provides further information on the port of Barranquilla, with the objective of creating a knowledge and information base for developing conceptual designs for the beneficial use of dredged material, as described in Chapter 3. The following information reflects publicly available information and therefore does not constitute an independent analysis. For next steps, more detailed research is required to obtain sufficient information to move forward

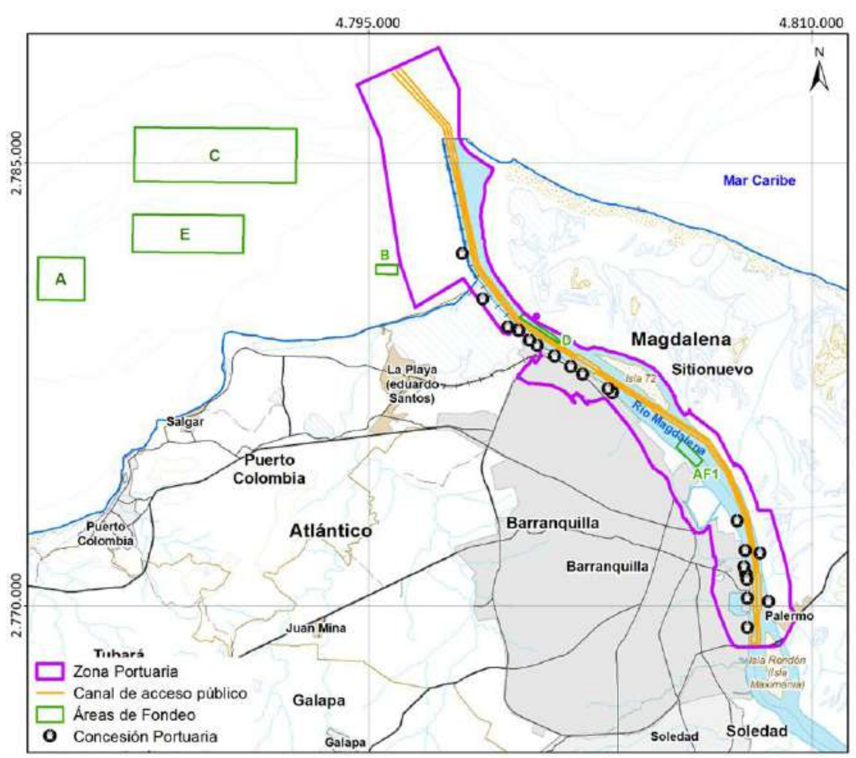

Figure 2-1 Barranquilla Port Zone, access channel and port companies. Source: Unión Temporal Serman Saenz- Steer - INP, 2024, based on Remac 2 - Dimar, 2024.

with the ideas presented in Chapter 3. These next steps are described in Chapter 5.

2.2.1 Charge

In the period from April to December 2025, 70% of port traffic in Barranquilla was imports, in which solid bulks other than coal and general cargo are the most important. On the other hand, exports accounted for 30%, with coal, bulk and containerized cargo standing out in its distribution. Additionally, during this period, 959 ship arrivals were recorded in Barranquilla, which represents 11% of all port areas in the country.

According to the most recent Statistical Bulletin of the Superintendence of Transportation, with data from January to September 2025, the country's **export cargo** by port area Barranquilla represents 4% (approximately 2.7 million tons), 29% and 20% corresponds to coal exported in the port area of Santa Marta - Cienaga, 26% of hydrocarbons in the port area of Golfo de Morrosquillo and Guajira respectively, another 4% is exported through the port area of Buenaventura. The remaining 17% corresponds to the other port zones[4].

For the percentages of **import cargo**, in the period from January to September 2025, Barranquilla represented 17% (approximately 5.9 million tons), Buenaventura 36%, Cartagena 25%, Santa Marta 18%, Golfo de Morrosquillo 3% and Guajira 1%.

According to the DNP study, 2019, Estimation of Port Demand, Capacity and Efficiency in Colombia, the capacity of the Port Zone of Barranquilla is of 28.4 million tons, according to the study, future expansions would be generated in the segments of solid bulk cargo, bulk coal and containerized cargo, but it was not possible to identify such investments in the period of 2025.

In the most recent reports of the BARRANQUILLA PORT ASSOCIATION (Asoportuaria), in the year 2025 a mobilization of 12.7 million tons was reached, a lower figure than in the year 2024, which was 13.4 million tons. Comparing the above data with the study of port capacity in the Barranquilla area of 28.4 million tons, in the years 2024 and 2025 show an occupation of 47% and 44% respectively.

The same DNP study, 2019, describes an estimate of demand by cargo segment; these projections were developed for cuts every five years considering a base scenario of trend growth. Figure 2-2 shows the results up to 2038, reaching a mobilization in the port area of Barranquilla of approximately 17 million tons. The projected volume for the year 2038 would represent a future occupation of 60% of the port capacity in the 2019 report.

According to the information gathered, it is estimated that the access channel will not have any future draft extensions (deepening) and it is expected that the navigability conditions will continue with maintenance dredging, which has ensured constant drafts in the port area in the last 3 years.

For the year 2026, it is projected that the dredging contractor that has been performing maintenance dredging since 2024 will continue to carry out activities until July 31, 2026, and that in this year it will be able to obtain a dredging volume of 1.5 million m3 and guarantee a constant depth of 12 meters (40 feet).

2.2.2 Environmental context

The country has an instrument that regulates the geographical areas that group coastal ecosystems with similar characteristics and functions, serving for their planning and management, including terrestrial areas, wetlands, mangroves and marine waters, where natural processes and human activities interact for planning and environmental sustainability. The above corresponds to Decree 1120 of May 31, 2013 "Whereby the Coastal Environmental Units - UAC - and joint commissions are

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[4] https://www.supertransporte.gov.co/index.php/superintendencia-delegada-de-puertos/estadisticas-trafico-portuario-en-colombia/

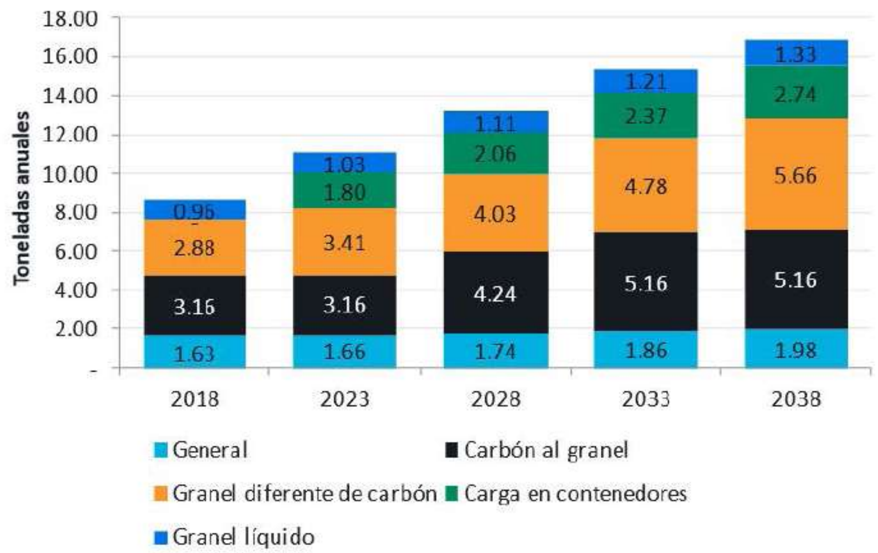


Figure 2-2 Demand projections for the Barranquilla Port Zone. Source; DNP, 2019. Estimation of Demand, Capacity and Port Efficiency in Colombia.

regulated, procedural rules and criteria are established to regulate the restriction of certain activities in seagrasses, and other provisions are issued". In total there are 10 UACs.

In each CAU there is a characterization of the **biotic and abiotic** components. The characterization includes a detailed analysis of several fundamental aspects of the environment.

- **Abiotic domain:** factors such as: hydrology, geology, geomorphology and hydrogeology will be considered, providing an in-depth understanding of the physical and chemical dynamics affecting these units.
- **Biotic scope:** vegetation cover, ecological units, landscape units, marine ecosystems and protected areas will be evaluated.

The port area of Barranquilla is located in the Coastal Environmental Unit (UAC) called "Magdalena River, Canal del Dique complex - Lagoon System of the Ciénaga Grande de Santa Marta". From the mouth of the Córdoba River to Punta Comisario. Includes Tierra Bomba Island, Baru Island, and the Archipelago of Nuestra Señora del Rosario.

The Magdalena River UAC experiences a warm and dry climate, with maximum temperatures between January-April and July- August and minimum temperatures between May-June and September-December. Rainfall varies, concentrating in the wet season from April to December, with October being the wettest month. Relative humidity averages 70%, with higher values during the wet periods. Annual evapotranspiration is around 1,700 mm, being higher during periods of drought. Solar radiation follows an inverse pattern to precipitation, with fewer hours of sunshine during the rainy season. Winds present their maximum magnitude in February and March and their direction is predominantly south-southwest. Appendix B presents the characterization of the environment abiotic and biotic environment the Barranquilla port area, including maps. The information was extracted from the characterization of the Coastal Environmental Unit (UAC) of the Magdalena River. Table 2-1 shows the description of each climatological variable:

Table 2-1 Climatology of the Magdalena River UAC (2025).[5]

VARIABLE	DESCRIPTION
Temperature	Average maximum temperatures occur in the north of the UAC between January-April and July-August and low temperatures between May-June and September-December with values of up to 33°C, while in the southern zone a monomodal behavior is identified, with high temperatures occurring between April and September. As for average temperatures these fluctuate between 25° and 30° C, average minimum temperatures are found at 25°C between the months of October and November (DAMCRA, 2018).
Precipitation	Dry season precipitation ranges between 0.3 and 9.5 mm between the months of January and March, while the wet season is found with precipitation between 3.7 and 256 mm between the months of April and December. Precipitation tends to decrease between the months of June to September and in October it is characterized by The rainfall tends to decrease between June and September and October is characterized by the highest precipitation. Annual precipitation is between 453 and 1500 mm (DAMCRA, 2018).
Relative humidity	It is maintained in a homogeneous zone with averages of 70%, where in dry periods it oscillates in 72% and in wet periods with 84% (CORPOGUAJIRA, 2013).
Evapotranspiration	Evapotranspiration values are close to 1700 mm/year, the values with the maximum periods coincide with drought periods.
Solar brightness	Solar radiation is coincident with rainfall, so the lowest radiation value coincides with the rainiest period in September and October with 130.9 and 127 hours/month. While, the months with the highest value occur between January to March with 228.4 and 238.5 hours/month being the least rainy period (DAMCRA, 2018).
Winds	The maximum values in wind magnitude are found in the months of February and March with values between 2.95-10.53 m/s with a south-southwest direction. The lowest values in the months of May to November with values between 0.37-6.51 m/s.
Climatic classification	According to Holdridge it is characterized by having warm dry.

Source: Guidelines of the ordinance and management plan of the Coastal Environmental Unit (Pomiuac) Magdalena River, Canal del Dique complex- lagoon system Ciénaga Grande de Santa Marta, coastal zone sector of the department of Bolívar. CARDIQUE - INVEMAR 2014.

[5] https://experience.arcgis.com/experience/d6ce04a6bee7477a9954291940567a0b/page/P%C3%A1gina

2.2.3 Socioeconomic context

The main variables and indicators that characterize the social and economic conditions of the district of Barranquilla are presented below in Table 2-2, with the purpose of offering an integral analysis of the demographic, socioeconomic and productive context of the city, as follows from information from official statistical sources. This context allows understanding the social and economic realities of the territory, in which is located the port access channel from which the sediments proposed for use under the NbS approach, within the framework of this deliverable 5 report, originate.

Table 2-2 Analysis of the demographic, socioeconomic and productive context of the city, based on information from official statistical sources in Barranquilla.

DIMENSION	VARIABLE/INDICATOR	DESCRIPTION	SOURCE
Demographic	Population 2024	1.279.120	DANE - Projections National Population and Housing Census 2018
	Men	616.476 - 48,19 %	
	Women	662.644 – 51,79 %	
	Urban area (Headwaters)	1.278.419 – 99,94 %	
	Rural area (Rural and dispersed)	701 – 0,06 %	
	Population density	7.706 (Area: 166 km2)	
	Ethnic population 2023	NARP (Black, Afro-Colombian, Raizal and Palenquero): 69.760 Indigenous: 1.521 Roma: 23	
	Number of persons per household 2018	4,3	DANE - National Population and Housing Census 2018
	Literacy rate population aged 5 years and over 2018.	94,1 %	
Poverty	Multidimensional Poverty Index (MPI) urban	55,7 % households	DANE - Projections National Population and Housing Census 2018
	Rural Multidimensional Poverty Index (MPI)	17,4 % households	
	Unsatisfied Basic Needs (UBN) rural head of household	9,08 % population	
	Rural Basic Unsatisfied Needs (UBN)	45,79 % population	
	Urban poverty	1,39 % population	
	Rural poverty	15,22 % population	
Public services	Urban water supply coverage 2024	99 %	Departmental Plan for Business Management of Water and Sanitation Services (PDA). Secretariat of Potable Water and Basic Sanitation
	Rural water supply coverage 2024	95 %	
	Urban sewerage coverage 2024	99 %	
	Rural sewerage coverage 2024	80 %	
	Urban sanitation coverage 2024	100 %	
	Rural sanitation coverage 2024	95 %	

Our reference: 1 – Date: March 25, 2026

DIMENSION	VARIABLE/INDICATOR	DESCRIPTION	SOURCE
Public utilities	Urban and rural electricity coverage 2023	100 %	Mining and Energy Planning Unit (UPME)
	Natural gas coverage 2024	90,80 %	Gases del Caribe S.A. E.S.P.
	Percentage of households with Internet access 2023	22,94 %	Open data Colombia
Economic	Economic establishments 2018	Trade: 45,2 % Services: 41,3% Industry: 12,0 % Other activities: 1,4 %	DANE - National Population and Housing Census 2018
	Rural dwellings with agricultural and livestock activity 2018	84,8 %	
	Exports Atlántico January-September 2025	USD 1.749 million FOB	LegisComex 2025
	Main exported products (Millions of USD FOB)	Doors, windows and frames: 462,082,836 Crude palm oil: 149,433,020 Copper waste and scrap: 105,754,702 Aluminum waste and scrap 94,554,265 Fungicides: 72,349,059	
	Atlantic imports January-September 2025	USD 2.333 million FOB	
	Main exported products	Aluminum alloys: 51,899,351 Priridine compounds: 39,397,505 Cold rolled alloy steels: 34,568,970 Frozen pork: 34,549,635 Plates and sheets of poly(vinylbutyric acid): 31,295,758	

DIMENSION	VARIABLE/INDICATOR	DESCRIPTION	SOURCE
Económica	PFE exports (Barranquilla, Internacional del Atlántico and La Cayena) January-September 2024	133.621 tons	DANE 2025
	Imports PFE (Barranquilla, Internacional del Atlántico, La Cayena and Palermo) January-September 2024	127.406 tons	
	Tourism Atlántico January-September 2025	53.390 foreign visitors	Migration, ProData 2025

2.3 Port of Barranquilla: Dredged material

The Magdalena River in its access channel to the port of Barranquilla has been intervened through hydraulic works that have modified the sedimentary dynamics in a way that is convenient for navigation. However, the factors that cause sedimentation cannot be completely eliminated since they are inherent to the hydrological nature of the river and cannot be controlled; it is necessary to maintain a continuous maintenance dredging effort to guarantee the operational draft required for port activity.

The hydrosedimentological dynamics of the Magdalena River in this final stretch is characterized by intense sedimentation processes, resulting from the material that the river carries from its source and deposits at the mouth, a phenomenon exacerbated by the hydrodynamic interaction of mixing when it meets the sea. Cormagdalena's technical studies (Report on Estimation of Dredging Volumes in the Magdalena River Forecast 2024 to 2026) determine a direct and robust correlation (R2=0.84) between liquid flow and sediment volume; that is, increases in water flow necessarily imply a greater sediment load that must be removed. To model this behavior accurately, in Cormagdalena's technical study.

The study used USGS (United States Geological Survey) methodologies and historical records from the Calamar hydraulic station dating back to 1940, ensuring a solid statistical basis that links the historical behavior of the river with the current dredging needs.

Finally, the integration of these hydrological variables with probabilistic Monte Carlo simulations allows estimating the dredging volumes needed to maintain navigability. A total cumulative volume of about 9,004,022 m3 is projected for the three-year period 2024-2026, which represents an average annual removal of approximately 3 million m3. The probability curves generated offer a high degree of certainty for financial and operational decision making, establishing with 90% confidence that the volume of sediment to be removed will not exceed 9.87 million m3, and with 95% probability that it will not exceed 10.46 million m3 in the period analyzed. More information on the access channel and the quality and quantity of dredged material can be found in the report of deliverable 3 (chapter 3 and 4).

2.3.1 Dredged material: quantity

Currently, the access channel has a depth of 40 feet (12 m), Base less than 150 m (500 ft). The zone of greatest sedimentation is located in the first two kilometers of the access channel entrance in the Bocas de Ash (K0 to K2). Figure 2-3 shows the abscissa of the access channel and

the table describes the 4 sectors of the Barranquilla access channel. To maintain the depth of the access channel at 12 meters (40 feet) and ensure that vessels entering the Barranquilla port area do not have navigation restrictions, Cormagdalena

Figure 2-3 Access channel map and description of sectors. Source: Own elaboration with information from Cormagdalena.

SECTOR	KM INTERVAL	MAXIMUM DEPTH CHANNEL (M)	WIDTH OF CHANNEL (M)	DESCRIPTION
I	-K2-800 a K02+000	13.7	Begins with 315 m at K2-800 and ends with 200 m at K0+000.	Sector with strong winds and waves that influence hydrodynamics. Some bars are located as a result of the growth of the subtidal low in the east.
II	K02+000 a K08+000	12.0	200	Sector with hydrodynamics determined by the K02+000 interaction between the Caribbean Sea and the Magdalena River. Normally in the area there are some bars that reduce the depth of the access channel. access channel. These bars are recurrent and require immediate intervention as soon as they occur.
III	K08+000 a K16+000		150	Imminently fluvial zone with incidence of some affections generated by waves. Due to the saline wedge that enters during low flows and other special conditions, there is a dynamic that requires dredging. Fluvial zone requiring constant monitoring.
IV	K16+000 a K21+750			

contracts annual maintenance dredging activities. Figure 2-4 shows a profile. The longitudinal section of the access channel with the amount of material dredged in the last 3 years in the 4 sectors described above also shows the location of the port companies (see 7.1 Appendix A) that make up the port area.

The information collected between 2023 and 2025 and grouped into the sectors of the access channel, managed to establish a remarkable characteristic, identifying that the greatest effort to maintain the navigability of the access channel is made in Sector I, in which 61% of the dredged volume is carried out. Sector II accounts for 7%, the Sectors

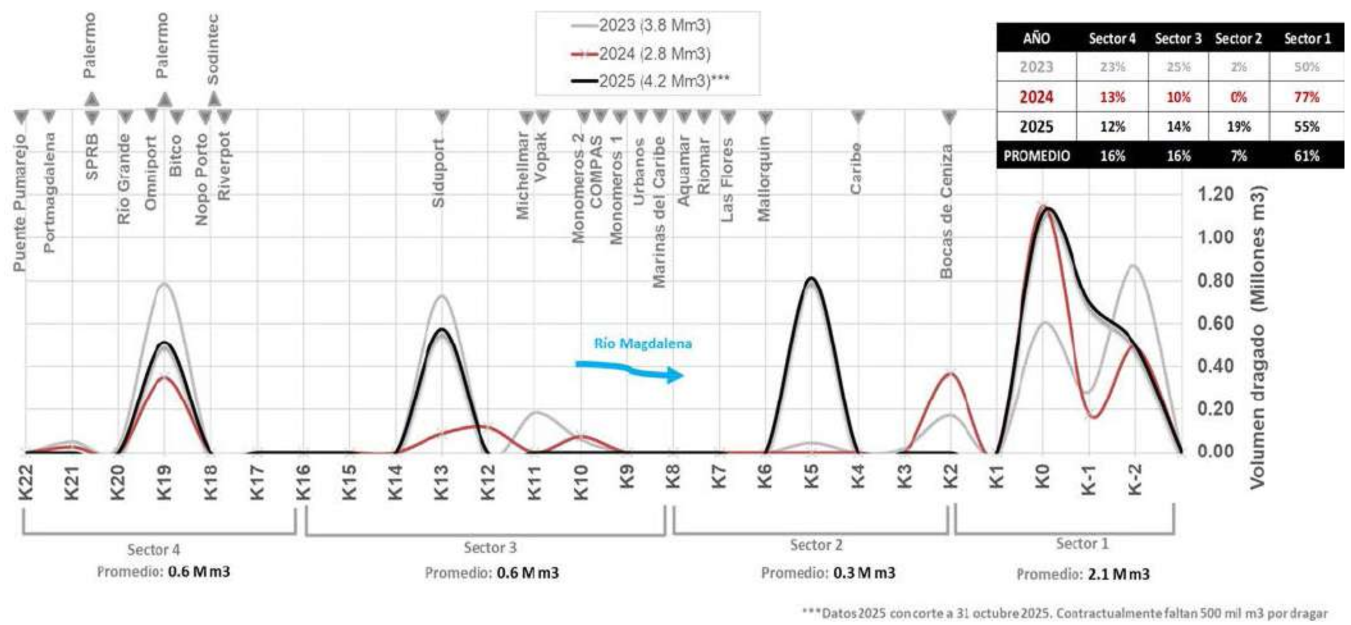


Figure 2-4: Longitudinal profile of the access channel and maintenance dredged volume (2023 to 2025). Source: Own elaboration with Cormagdalena data.

III and IV each represent 16% of the volume dredged annually. The average volume in the four sectors resulted in a total of 3.6 million m3 of material. This represents a value close to the value estimated in the Cormagdalena study described at the beginning of section 2.3.

Table 2-3: Average volume and percentages of dredging in the access channel sectors (2023 to 2025). Source: Own elaboration with Cormagdalena data.

SECTOR	INTERVAL	AVERAGE VOLUME 2023 TO 2025 (MILLIONS M3)	PERCENTAGE
Sector I	K -2 a K 2	2.1	61%
Sector II	K 2 a K8	0.3	7%
Sector III	K8 a K16	0.6	16%
Sector IV	K16 a K 22	0.6	16%

Table 2-3 shows the average volume for each of the sectors, projecting that these quantities should be produced annually in the access channel to maintain stable navigability in the coming years.

The hydrosedimentological information studied by Cormagdalena with the results of the previous table showed that the dredging volumes of the Magdalena River do not correspond to isolated events, but rather to a process of

Our reference: 1 – Date: March 25, 2026

dredging recurrent and highly predictable over time. The technical studies demonstrated a direct and robust correlation between liquid flow and sediment load. This relationship made it possible to anticipate with a high level of certainty that the volumes of sediment to be removed with an annual average of about 3 million m3.

Such predictability is reinforced by analyzing the volumes dredged between 2023 and 2025, where a consistent pattern of sediment accumulation is identified. The total annual average volume of approximately 3.6 million m3 confirms the recurrence of sediment supply and its preferred location (see Table 2-3). This combination of temporal recurrence and spatial concentration constitutes a strategic opportunity to systematically plan the beneficial use of dredged material by NbS in the coming years.

2.3.2 Dredged material: quality

2.3.2.1 Physical quality

Organic Carbon Content

As highlighted in the report of deliverable 3 (chapter 3), the total organic carbon content (%) in the sediments of the access channel shows an irregular spatial variation and a slight temporal decrease between the evaluated periods. Since organic carbon content is not a variable taken into account in the Sediment Quality Guidelines (SQG) of other countries, organic carbon contents were evaluated in terms of the potential use of dredged sediment as a soil amendment in agriculture. In this context, the observed organic carbon contents are classified as low, which limits its contribution from a soil improvement point of view.

Granulometry

The analysis of grain size in the Barranquilla port area, deliverable 3 (Chapter 3), reveals a remarkable diversity in sediment textures. Plotting the results (see Figure 2-5) shows that the dredged sediments vary from sands to clayey silts, reflecting a wide range of textural classes.

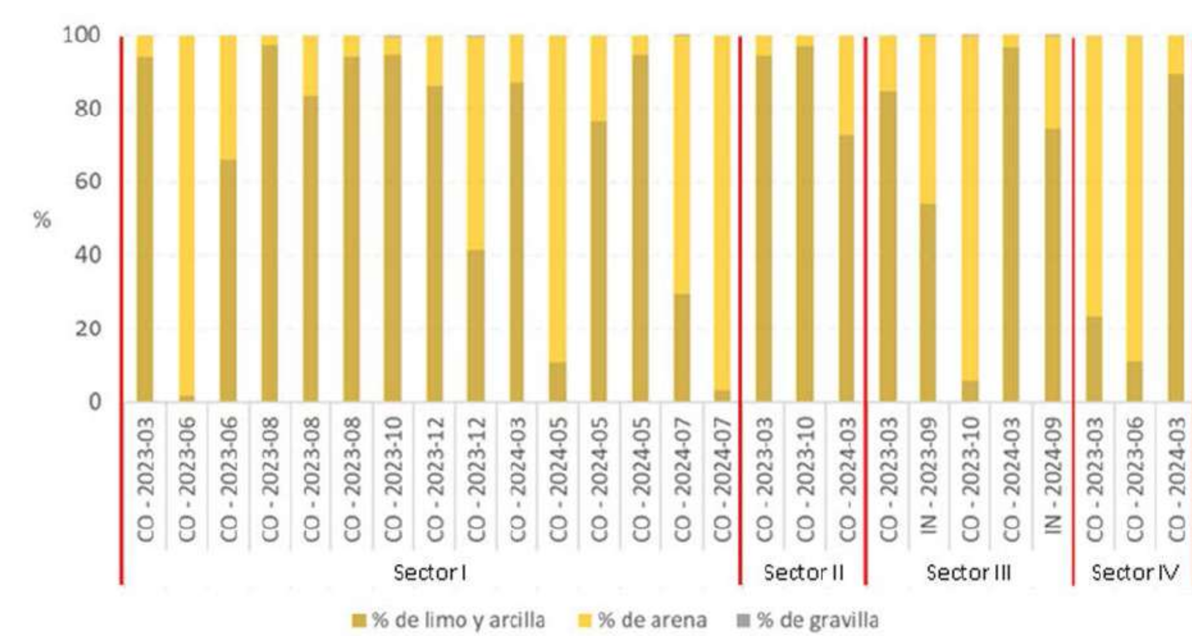


Figure 2-5 Sediment granulometry in each sector of the access channel intervention, between Mar/2023-Sep/2024 (Source: Deliverable 3 Report)

This variability not only characterizes the area analyzed, but, when extrapolated to other regions of Colombia, allows us to anticipate a great diversity in the quality and granulometry of the materials dredged at the national level.

Granulometry is key to understanding how sediments behave. From the grain size it is possible to identify if a material offers stability, if it retains water or if it favors certain ecological processes. Therefore, knowing the grain size allows us to assign each type of sediment to the most appropriate use: sands are usually used in coastal protection because of their greater resistance to waves, while fine sediments (such as silts and clays) are preferred in ecological restoration.

2.3.2.2 Chemical quality

The evaluation of the chemical quality of the sediments dredged in the access channel to the port area of Barranquilla (deliverable 3, chapter 3) indicates that, in general terms, the material presents a mostly acceptable chemical quality. However, the analysis also reveals several limitations of the available information that should be taken into account when interpreting the results. Different entities (INVEMAR, Cormagdalena and Cartagena University) have reported information on the physical and chemical quality of the sediments. The chemical quality of dredged sediments can be divided into mineral substances (heavy metals and arsenic) and organic substances.

- **Mineral substances (heavy metals and arsenic):** the concentrations reported in the deliverable 3 report (chapter 3) were below the respective Dutch threshold levels 1 for both freshwater and coastal ecosystems. For some substances it is not possible to identify whether they exceed the limits established in Florida and Brazil, because the thresholds are lower than the detection limits of the laboratory techniques used. used. Florida and Brazil are used as reference in the report of deliverable 4 (chapter 3), since these places are the most related to the environmental conditions of Colombia.
- **Organic substances:** Of this type of substances, only the concentrations of some pesticides and some polycyclic aromatic hydrocarbons (PAH) have been determined.

With the information currently available for which Colombian entities have reported (INVEMAR, Cormagdalena and Universidad Cartagena) sediment concentrations in the access channel and marine deposition zone, it can be assumed that copper (Cu) and cadmium (Cd) are the mineral substances of greatest concern, especially in the deposition zone (see Figure 2-6) and, potentially, in scenarios of dispersion of dredged materials to other coastal or marine areas. For the other heavy metals, it is not possible to conclusively establish their level of concern, due to the lack of representative, updated or quantified information with the necessary precision.

For organic substances, the available information is limited to some pesticides and polycyclic aromatic hydrocarbons (PAHs). For PAHs, the low sampling frequency and density do not allow conclusions to be drawn. For pesticides, 2014 sampling shows that only atrazine exceeds the Tier 1 threshold for freshwater ecosystems under the Florida criteria.

Appendix E provides an overview of nature-based solutions and their chemical and physical requirements for dredged material to facilitate a preliminary analysis of which solutions might be applicable to a given dredged material.

	Florida (EEUU)		Zona de depósito	Ceará (Brasil)		Zona de depósito	São Paulo (Brasil)		Zona de depósito
	Nivel 1	Nivel 2	Feb/25	Nivel 1	Nivel 2	Feb/25	Nivel 1	Nivel 2	Feb/25
Zn	124,00	271,00	53,00	543,00	603,00	53,00	52,60	190,20	53,00
Cu	18,70	108,00	44,00	15,60	19,40	44,00	9,40	17,60	44,00
Cr	52,30	160,00	20,00	44,50	59,00	20,00	24,90	31,50	20,00
Cd	0,68	4,21	1,40	N/A	1,10	1,40	0,40	0,80	1,40
Ni	15,90	42,80	15,29	20,20	24,10	15,29	10,80	14,60	15,29
Pb	30,20	112,00	25,70	24,00	47,30	25,70	6,70	16,60	25,70

< Nivel 1 | Entre niveles 1 y 2 | > Nivel 2

Figure 2-6 Heavy metal concentrations in marine depositional zone sediments compared to DCS thresholds for coastal ecosystems in Florida and Brazil (Source: E3 - Assessment of physical and chemical quality of dredged sediments in.

2.3.3 Applicable regulatory framework

MinAmbiente is developing regulations on "Environmental management for the use and disposal of dredged material", which is planned to be incorporated as an additional chapter to Decree 1076/2015. This normativity consists of a procedure to establish the thresholds of mineral and organic substances that are acceptable to be able to make two types of uses of dredged materials (ecosystemic uses and non-ecosystemic uses). This decree is made in accordance with the action plans of the National Port Policy (CONPES 4118/2023), and regulates Article 240 of the National Development Plan 2022-26, referring to the use of dredged materials.

The additional chapter deals with the environmental management for the use and disposal of dredged materials in projects, works or activities of the transportation infrastructure sector that involve deepening and maintenance dredging, maritime and fluvial, and fluvial improvement dredging. It also establishes the technical and environmental criteria for its management, use, exploitation, deposit and final disposal. More details can be found in deliverable 4 (chapter 2.3).

3. Identification and prioritization of BNS opportunities for the use of dredged sediments in the Barranquilla access channel

Executive summary

The key points of this chapter are:

1. This chapter provides an overview of NbSs, categorized into eight different applications, including descriptions and examples:

- Habitat recovery for mangrove restoration.
- Gray infrastructure: construction of roads and building materials
- Coastal regeneration against erosion: material management and beach regeneration
- Filling
- Submerged wave-breaking constructions
- Fertilizers
- River flood dikes and retention areas
- Land cover

2. These BNS categories were presented and discussed with key stakeholders in Barranquilla, which led to the prioritization of BNS and their locations in the vicinity of the Barranquilla port area.

Based on the prioritization results obtained during the Exchange Session and 5 training, which was held in Barranquilla on December 4, 2025, 3 NbS and 4 locations were identified for further development of conceptual designs:

- Coastal Protection:
  - Castillo de Salgar
  - Mallorquín marsh
- Submerged wave-breaking constructions
  - Ciénaga Los Manatíes and Punta Roca marshes
  - Salgar Castle
- Mangrove restoration
- Fertilizer, soil improvement, storage

This chapter incorporates and merges the information gathered in the previous deliverables (1-4) and applies it to the port of Barranquilla. Together with key stakeholders in the region, preliminary conceptual designs for the beneficial use of dredged material were developed and are described below.

3. Identification and prioritization of BNS opportunities for the use of dredged sediments in the Barranquilla access channel

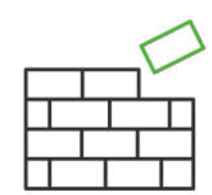
3.1 Long list of BNS applications

BNS are sustainable strategies that take advantage of natural processes to improve ecosystem resilience, mitigate risks and promote biodiversity. Their fundamental value lies in generating environmental, social and economic benefits while adapting to changing climate and land use conditions. In this chapter, we will analyze a theoretical case in Barranquilla, starting with an extensive list of BNS, categorized by type and illustrated with examples. Subsequently, we will move from this list to a specific selection of NbS, focusing specifically on the beneficial use of dredged material applications most applicable to Barranquilla, based on relevant climatic factors.

Beneficial use of dredged materials encompasses a wide range of applications; below, eight SbN alternatives have been categorized to provide interested parties with a tangible overview of the options:

USES | **DESCRIPTIONS AND EXAMPLES**

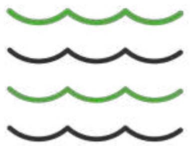
Habitat Recovery for Mangrove Restoration
OBJECTIVE: Restore and enhance degraded mangrove ecosystems to increase biodiversity and coastal protection.
BENEFIT:
- Restoration of coastal habitat
- Protection against erosion
- Improved environmental quality



Gray infrastructure[6]:
- Road construction
- Construction Material

OBJECTIVE: To reuse dredged sediments as raw material in civil engineering works, reducing the need for natural resource extraction.
BENEFIT:
- Waste reduction.
- Resource optimization.
- Economic savings

—
[6] Strictly speaking, some of the uses described may not be officially classified as BNS, such as the beneficial use of dredged material for construction, including building blocks and roads. However, these uses have been included because they can significantly reduce raw material extraction, boost circularity and therefore generate cost reductions.



Coastal regeneration against erosion:

- Material handling
- Beach regeneration

OBJECTIVE: To combat coastal erosion and restore beaches using dredged sediments to stabilize and rebuild coastal areas.

BENEFIT:

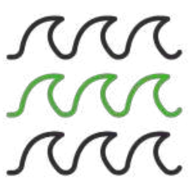
- Restoration of coastal habitat.
- Protection against erosion
- Improved environmental quality

Backfill

OBJECTIVE: Use sediments as fill material for land reclamation and elevation of low-lying areas, supporting urban or industrial expansion.

BENEFIT:

- Resource optimization and waste reduction
- Economic savings
- Improved coastal protection



Submerged wave-breaking constructions

OBJECTIVE: Implement submerged structures using dredged material to reduce wave energy and protect shorelines from erosion.

BENEFIT:

- Effective coastal protection
- Reduction of debris
- Creation of new habitats

River flood levees and retention areas

OBJECTIVE: Construct or reinforce levees and retention areas using dredged sediments to prevent fluvial flooding and manage water flows.

BENEFIT:

- Economic savings
- Effective flood protection
- Environmental restoration
- Soil stabilization and improvement

Land cover

OBJECTIVE: Use sediment as a cover layer for landfills, degraded sites or to encapsulate contaminated soils.

BENEFIT:

- Immediate improvement of degraded soils and habitats
- Recovery of ecosystem services

Fertilizers

OBJECTIVE: Transform nutrient-rich sediments into soil improvers or fertilizers for agricultural use

BENEFIT:

- Use of nutrients
- Waste reduction
- Economic savings
- Improvement of soil structure

These options illustrate the versatility of dredged material, allowing its use in construction, environmental enhancement, land creation, habitat maintenance and climate adaptation. The optimal choice of beneficial application depends on several interrelated factors:

- **Climate:** Local temperature, precipitation patterns, and extreme weather events affect sediment stability and ecological outcomes.
- **Quality and quantity of dredged material:** Physical and chemical composition, contamination levels and type, and available volume determine potential applications.
- **Environmental aspects:** Ecosystem requirements, water quality and biodiversity objectives must be addressed to ensure positive outcomes.
- **Social and economic aspects:** Community needs, land use priorities, development plans and cost effectiveness guide the selection process.

Since technology can overcome complications, such as contaminated material, inappropriate type of dredged material, quantity, etc., a stakeholder workshop was held to identify and prioritize beneficial use of options and locations.

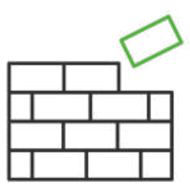
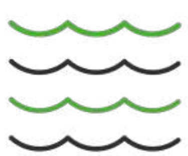
3.2 Prioritization with local stakeholders

During the workshop entitled "Case study for the beneficial use of dredged sediments in Barranquilla", which took place on December 4, 2025, with the participation of 18 people and 10 government institutions, a participatory methodology was used that brought together representatives of national, regional and local entities to strengthen decision-making on the use of these materials. The participants were organized into three working groups (A-1, B-2 and C-3) which, with a comprehensive vision, identified and classified possible uses of sediments, such as mangrove restoration, gray infrastructure, coastal regeneration, submerged constructions, fertilizers, dikes and land cover. Each proposal was graphically represented on a regional map to analyze its territorial distribution. Finally, the alternatives were prioritized by means of a valuation matrix, ranking them according to their impact and feasibility in a consensual manner. This process made it possible to collectively visualize and rank the most promising options for sustainable sediment use in the region. An overview of the locations and beneficial applications mentioned by each group is included in Section 0 Appendix C[7].

[7] Details on the methodology used and the stakeholders involved are included in the proceedings of training session 5.

Our reference: 1 – Date: March 25, 2026

Table 3-1 Overview of uses and locations prioritized during workshop 5 in Barranquilla.

USES	A-1	B-2	C-3
Habitat recovery for mangrove restoration 	1. Mangrove habitat restoration processes in the VIPIS (Salamanca Island Parkway) with application of dredged sediments. 2. Soil remediation through forest plantations with usable crops, in accordance with the Life Areas defined by Resolution 1491 of 2025 of the Ministry of Environment and Sustainable Development. This use should be in remediation	1. Los Manatíes marsh 2. Mallorquín marsh 3. Ciénaga de Balboa (Pto Colombia) 4. Directional dike or 1972 Due to coastal erosion and anthropogenic intervention.	1. Recovery of mangrove areas in areas, islets or zones that have been lost or disappeared. 2. Recovery of mangrove areas in Baru and Isla Grande. 3. Recovery of areas due to erosion processes in Isla Verde. 4. Recovery of mangrove areas in the areas of Vía Parque Isla de Salamanca and Ciénaga Grande de Santa Marta. 5. Establishment of mangrove islands in front of the Barranquilla seawall, to protect the structure and reduce the impact of water on the margin of the road, and to recover the connectivity of the internal marshes. 6. Recovery of the Manzanillo islet and nearby areas that disappeared and lost mangrove cover, as well as the recovery of fishing areas. Recovery of mangrove areas in the Ciénaga de la Virgen, la Boquilla and Sereno del Mar; water connectivity must be rehabilitated to guarantee the results of the action.
Gray infrastructure: • **Road construction** • **Construction material** 	1. Support material for the construction of the future viaduct of the Ciénaga Grande de Santa Marta. 2. Increase of the leveling level of the ports in Gamarra (Cesar) to gain land through the disposal of dredged sediments. 3. Sale of dredged material to block companies as an input for construction. 4. Construction of low-income and non-high-income housing by using dredged sediments as fill and support material.	Kilometer 14 to kilometer 19: storage site for dredging material.	Disposal of dredged material to be processed and converted into construction material.
	1. Disposal of dredged sediments in the aquatic area in front of the Mallorquín swamp, so that the currents can transport them to the Atlantic coast. This use is not understood 2. Mitigation of coastal erosion at Km 19 (Santa Marta - Barranquilla road). 3. Regeneration of beaches along the entire coast of the departments of Atlántico and Magdalena through the disposal of dredged sediments.	1. Salgar Castle 2. Los Manatíes and Punta Roca marshes 3. Mallorquín marsh 4. Aquamarina Beach (Condominium) 5. Santa Veronica 6. Puerto Mocho II Beach	1. Mitigation of coastal erosion from Ciénaga Los Manatíes to Tajamar Bocas de Ceniza. 2. Coastal regeneration against coastal erosion in the Salguero beach area. 3. Beach nourishment against marine energy.
Submerged wavebreaking constructions 	Artificial coral restoration pilot project.	1. Salgar Castle 2. Los Manatíes Swamp 3. Aquamarina Becah (Condominium)	1. Solution with mangrove and submerged infrastructure to reduce wave energy on the Ciénaga-Barranquilla route.

Our reference: 1 – Date: March 25, 2026

Table 3-1 Overview of uses and locations prioritized during workshop 5 in Barranquilla.

USES	A-1	B-2	C-3
Fertilizers	1. Fertilizers in banana plantations through application of dredged sediments for soil fertilization. 2. Pasture and soil improvement for cattle ranching.	Kilometer 14 to kilometer 19: stockpile site for dredged material.	Development of fertilizers to be used in intensive agriculture and soil recovery, especially in the banana zone.
Filling	1. Backfill for the construction of the future deep water port in Barranquilla. 2. Construction and/or fill material for the creation of an island for tourism purposes. 3. Dredged material collection centers for future construction of megaprojects. 4. Fill material and mangrove restoration for the construction of a biopark. 5. Recovery of quarries and mining areas through the disposal of dredged sediments for environmental and productive rehabilitation.	1. Directional dike or 1972 2. Puerto Mocho II beach	1. Increase soil elevation in an area of 300 hectares for use in river logistics. 2. Increasing the height of the protection dike in the marshes of Sabanagrande, Santo Tomás and Palmar de Varela (ANLA license 293/17). 3. Filling in SPRBAQ dock. 4. Landfill in port area of Palermo group. Right bank of the Magdalena River.
River flood dikes and retention areas	1. Improvement of the western beach. 2. Potentiation of Galerazamba's economy through sediment retention areas that support salt production and strengthen tourism, taking advantage of the fact that at one time of the year the water turns pink. 3. Construction of a dike in front of Salamina and other municipalities near the river to mitigate flooding.		Protection works for the banks of the Dique canal in the municipality of Santa Lucia (Atlántico) and other municipalities of the Dique canal.
Land cover	1. Remediation of land for vegetable cultivation, taking advantage of dredged sediments in soils with salinization problems.		

3.3 Selection of BNS applicable in Barranquilla

Based on the information gathered throughout this project, the knowledge of the conditions of the port area of Barranquilla and the workshop held with the stakeholders, the prioritization matrices were analyzed, the results of which are illustrated in Figure 3-1, Figure 3-2 and Figure 3-3 and (considering the categories of "positive" and "necessary").

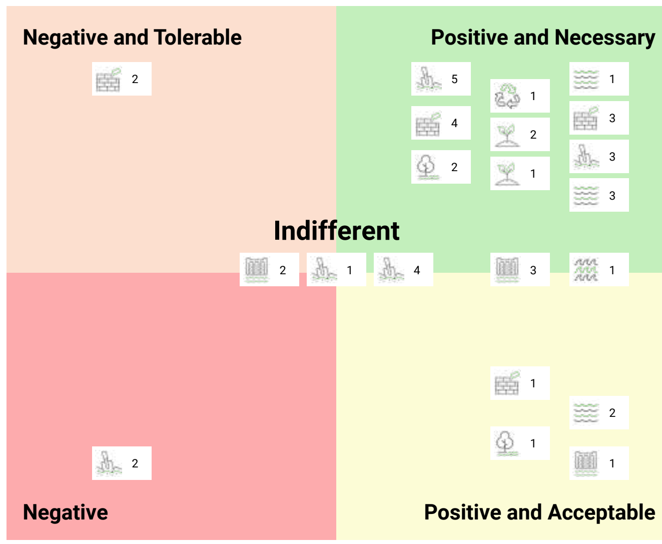


Figure 3-1 Prioritization of beneficial uses of dredged material in Barranquilla - Group A-1

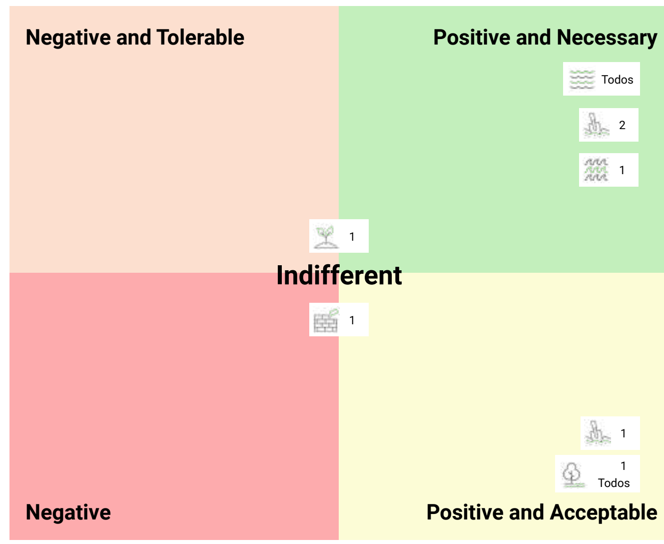


Figure 3-2 Prioritization of beneficial uses of dredged material in Barranquilla - Group B-2

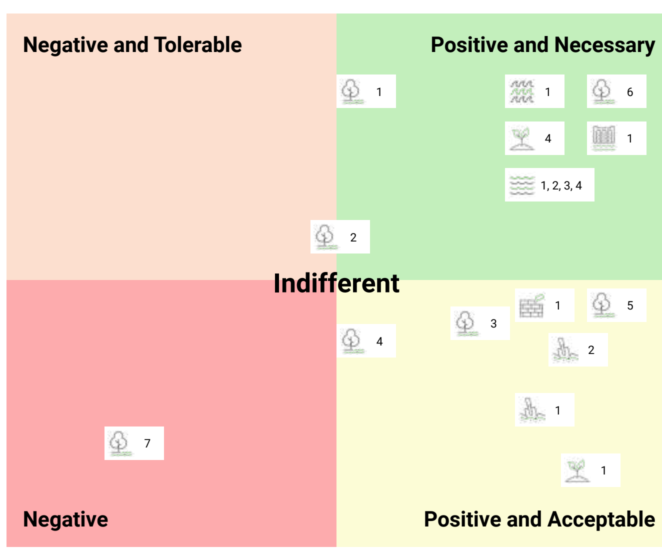


Figure 3-3 Prioritization of beneficial uses of dredged material in Barranquilla - Group C-3

Subsequently, the team identified for conceptual development, the four uses most frequently categorized as "Positive and Necessary":

Coastal protection:
- Salgar Castle
- Mallorquín marsh

Submerged constructions to break the waves
- Salgar Castle
- Los Manatíes and Punta Roca marshes

Mangrove restoration:
- Several

Fertilizers, soil improvement, storage:
- Various

Among the social criteria considered in the **NbS oriented to coastal protection**, priority was given to protecting the homes of the local population and the tourism activities carried out by the communities in these areas. Although the homes in **Los Manatíes** marsh and **Punta Roca** correspond to high socioeconomic strata, the social approach emphasized that the local population carries out economic subsistence activities associated with tourism. Likewise, the restoration of the mangrove ecosystem in the Los Manatíes swamp contributes to improving fishing productivity, benefiting artisanal fishermen who depend on this activity for their livelihood.

After prioritizing the 4 uses and locations, the team held validation discussions with two organizations to ensure that the cases resonated with local organizations, such as the CRA and national parks. These meetings provided a more detailed understanding of the context of each location.

Below is a brief summary of the information gathered during these meetings:

- **Erosion:** the rest of the coastline affected by erosion should not be forgotten (requiring an analysis of the coastal system).
- **Quantity:** the greatest demand for sediment is found in coastal protection projects, while mangrove restoration will require smaller volumes and very specific actions. Important to prioritize projects capable of absorbing most of the dredged material (3-4 million m3), thus avoiding its disposal in waste sites and promoting its sustainable and beneficial use for the environment.
- **Important aspects:**
  - Sediment dynamics: such as the need for coastal dynamics studies to optimize sediment disposal and take advantage of coastal drift,
  - Market study: such as the importance of considering transport costs, and the need to consider the cost of transport.
  - Governance: the coordination between stakeholders (dredgers, authorities, beneficiaries), and
  - Climate variability: The implementation of BNS and the beneficial use of dredged material acquire special relevance in the face of climate change and variability associated with El Niño and La Niña events.[8]

For coastal protection and submerged wave-breaking constructions, the locations are more detailed, while the information gathered on specific locations for storage of dredged material is more general. Therefore, the conceptual designs for coastal protection and submerged wave-breaking structures will be developed at a more detailed level, while the other two (land improvement and mangrove restoration) will be developed at a more abstract level. Both approaches will allow for scalability and replicability.

[8] During La Niña, increased wave energy and bed-tide events increase coastal erosion, testing the effectiveness of NbS as a sand engine or mangrove restoration. On the other hand, El Niño often increases sediment input from the Magdalena River, which can influence the availability of material for beach nourishment and the frequency of maintenance or replenishment of the sand engine. In addition, the resilience of restored mangroves becomes a key factor in buffering the impacts of extreme events and providing protection to coastal communities. Therefore, the success of each proposed NbS should be evaluated considering these climate scenarios, which will allow the design of more robust and sustainable adaptation and management strategies.

3.4 Conceptual designs

For each case, the following aspects are described: the problem, the objective of the solution in terms of beneficial use of the dredged material, the conceptual design, the materials needed (quality and quantity), the rough cost estimate, the preliminary environmental and social risks, and international examples for reference. At the end of this section, designs are compared to show the most viable options

The level of detail in the design varies according to the information available for each alternative. In the case of the sand engine, a higher level of development has been achieved thanks to the existence of replicable international experiences, such as the sand engine in the Netherlands, the urgency represented by coastal erosion in the area and its capacity to absorb large volumes of sediment -about 5.4 million m3, even higher than the annual volume of dredging-. However, this greater level of detail does not mean that the least promising alternatives are the solutions developed are less viable; they simply require additional primary information to be obtained in order to be able to advance their development in the future.

It is important to note that any solution must be based on a system analysis. Therefore, this report presents a conceptual design based on the current understanding of the system and three conceptual designs for specific locations, reflecting stakeholder input during the Deliverable 5 workshop.

For this report, an initial systems analysis was conducted based on secondary information. A more comprehensive systems analysis will be required to finalize the design. This analysis would examine erosion and accretion rates, detailed bathymetry, and wave conditions. Solutions implemented at one specific location could influence and have ramifications in other coastal areas. To avoid negative impacts at other locations, a systems analysis is necessary. An initial systems analysis, both overall and for individual locations, is presented in the appendices.

3.4.1 Conceptual design at the system level

The main problem affecting the entire coastline between Castillo de Salgar, Punta Roca, Ciénaga de los Manatíes and Puerto Mocho is chronic and progressive coastal erosion caused by a combination of natural and anthropogenic factors. Natural processes include high wave energy from the northeast, strong winds, cold fronts, and the progressive rise in sea level, which together favor the migration and loss of sediments, the scouring of cliffs, and the reduction of beach width. These effects are aggravated by the soft rock geology in sectors such as Punta Roca, which increases vulnerability to marine erosion and facilitates the accelerated retreat of the coastline.

At the regional level, the dominant coastal transport and channelization of the Magdalena River have altered the sedimentary balance, reducing the natural contribution of sediments and favoring their deposition in deep areas or their escape from the beach system. Added to this are severe human impacts, such as unregulated urbanization and rigid construction on coastal terraces, indiscriminate shell extraction, and riparian occupation of wetlands, which overloads the slopes, reduces protective vegetation, and limits the natural buffering capacity against erosion and salinization. As a result, there is a continuous retreat of the shoreline (approximately 5 m, see Section 7.3 (Appendix C) for more information), loss of beaches and mangroves, increased exposure and risk to infrastructure and housing, and functional deterioration of key coastal ecosystems such as the Ciénaga de los Manatíes. All of this shows that coastal erosion in this stretch of the Colombian Caribbean is a complex and structural problem that requires solutions. The area is also vulnerable to the effects of the sea, since

isolated interventions offer only temporary relief and can aggravate the vulnerability of neighboring sectors. Based on the analysis of a diagnostic prepared by DIMAR[9] using satellite images for the period 2013-2023, a coastal erosion rate of close to 5 meters per year is estimated. This value is used only as a technical approximation and should be understood as data derived from the available satellite analysis.

Figure 3-4 Coastal line near Barranquilla, between Castillo Salgar and the access channel to the port of Barranquilla on the Atlantic, with indication of the access channel to the Magdalena River, and indications of places of interest.

Solution: Protect the headland by adding sand using a "sand engine[10]" to supply the area, see Figure 3-5. This strategy allows the sand to be progressively distributed to the southwest by the effect of the swell coming from the northeast, improving coastal safety throughout the bay. Sediment transport is dominated by waves. This means that sediments are transported in the same direction as wave energy. After analyzing the wave climate diagrams, it is observed that the average wave direction is from the northeast, which results, over time, in sediment transport along the coast from east to west. The use of soft sand-based solutions, such as artificial beach replenishment, represents a viable alternative to restore the natural wave dissipation capacity. In addition, under a climate change scenario, with sea level rise, this measure facilitates the natural accumulation of sand along the coast, strengthening climate adaptation to long-term and protecting the coastal infrastructure. The sand engine will primarily have the function of coastal nourishment to restore the sediment balance, with a slope of 1:30, a width of 800 m, a cross-sectional area of 2700 m²/m and an estimated volume o f 5.4 million m³, see Figure 3-6. This volume is a first estimate, providing an approximate order of magnitude. The ideal volume should be determined as a function of the sediment deficit in the area (annual erosion rate) and the effectiveness of the dredger. Environmental modeling of sediment dynamics caused by wind and waves is required to quantify effectiveness (and estimate dimensions, including dredging strategy). Depending on the results of further studies, the size of the dredger could be adjusted, which would change the volume required.

Especially during the first year after construction, the emerged surface area will decrease and the sand mass will deform, while littoral transport will redistribute the material. In this sense, a sand engine could be created in a

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[9] Dimar presents diagnostic of coastal erosion in the Atlantic Ocean | Colombian Maritime Portal - Dimar
[10] Sand motor: sand motor

few years. In addition, it should be remembered that, in a more detailed feasibility analysis, it is also necessary to take into account the real operational capacity, the logistics of material placement and the environmental constraints that condition the execution of the work.

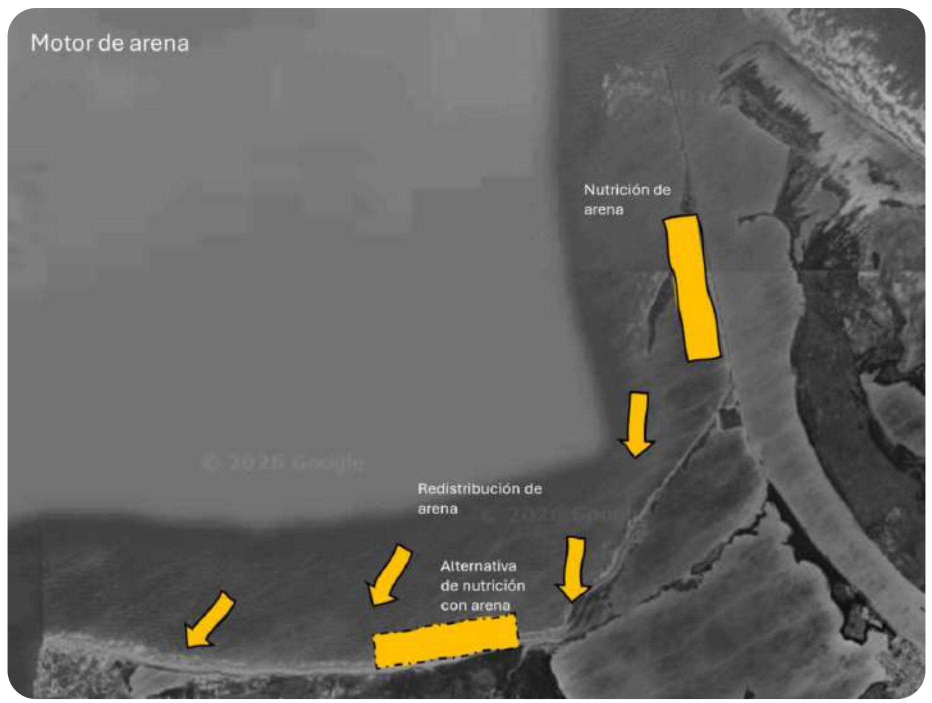

Figure 3-5 Conceptual idea of the sand motor on the tajamar side of the sand engine

To compensate for the redistribution of material due to coastal transport, some of the dredging from subsequent years can be used. It is not advisable to place fill material on top of existing fill material, as this is not beneficial to the development of nature, however, the sand engine could be expanded a little each year in one direction by placing the sediment next to the previous year's fill. This can be planned for in advance, but it can also be evaluated each year and the sediment placed strategically. With a strategic plan and proper design, the l i f e s p a n of the sand engine could be around 20 years. However, depending on design and replenishment, this could vary; therefore, it is important to develop a maintenance plan for the coming decades in the next stages.

The sand motor is a preferable solution to rigid structures, such as breakwaters or jetties, for the following reasons:

1. It is a systemic solution that addresses the problem at its source and offers a comprehensive solution. A fixed or rigid solution seeks to stabilize the shoreline, which is beneficial locally and in the short term, but will generate problems elsewhere and in the future.
2. It is adaptable and easy to modify (e.g., by increasing its volume) in the face of climate change.
3. It is multifunctional, allowing for the creation of various functions, such as nature development, a recreational area, coastal protection, etc.

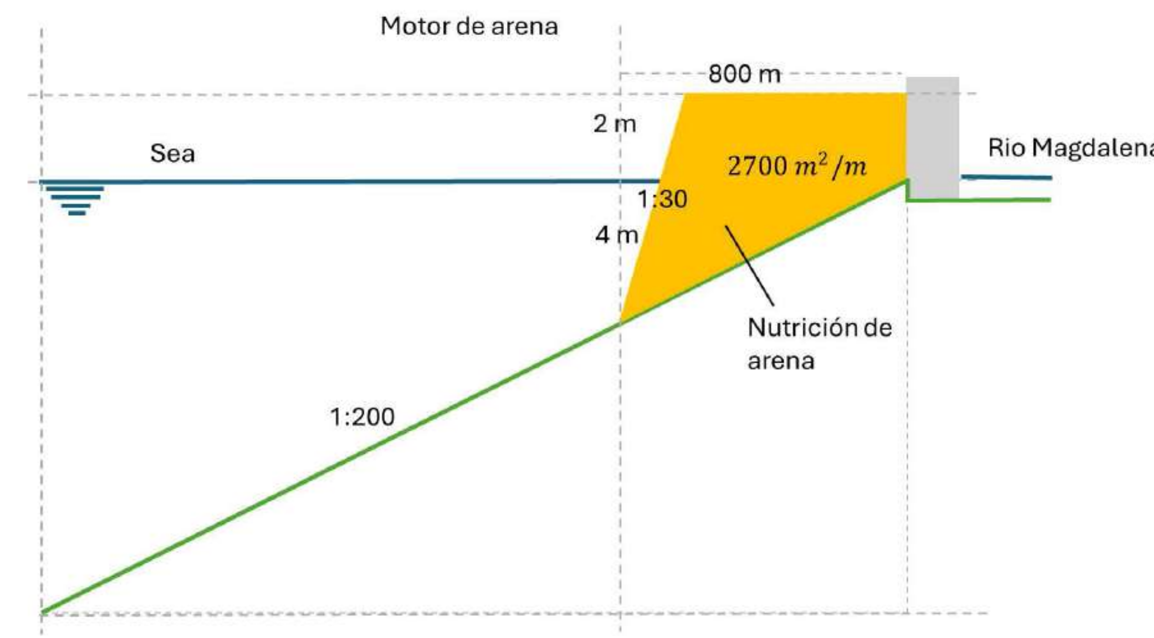

Figure 3-6 More detailed conceptual design with indication of volume: Indication of total volume = average cross-sectional area x length = 2700 x 2000 = 5,400,000 m3

Type of dredged material: The sedimentary material used in this solution consists mainly of dredged sandy sediments, where ideally fine sand (200-350 μm) is used; sand that is too fine or silts do not settle fast enough, while coarse sand settles too quickly. From previous samples, it is clear that the grain size of the material at the river mouth varies with the seasons. During the rainy season, all the material is discharged towards the shore, whereas, during the dry season, the discharge from the river is less. Therefore, during the construction phase of the project, the contractor could take advantage of the seasons to obtain the appropriate granulometry for the project stage. According to information reviewed, the document "Rio Magdalena: maritime and river navigation (1986-2008) Alvarado Manuel", describes that the river bed in the access channel is mainly composed of very fine sands - coarse silty sands (d50 = 70.6 μm). With respect to suspended particles, the document "Dinámica Sedimentaria en Micromareal Deltas - Stratified High Discharge: Magdalena River Delta (Restrepo L. 2014), identified that in some samples taken in November 2012 (high flow seasons) and other samples taken in April 2013 (low flow seasons), the grain sizes of suspended particles measured in the surface layer of the water column are coarse silts (d50 = 14.1 μ m) in high flows and in low flows the silts are medium (d50 = 7.8 μm).

This solution is always allowed if the sediment has a chemical quality below action level 1 (Figure 2-6). A chemical quality between action levels 1 and 2 requires more detailed testing (e.g., environmental assessment). This is true since similar legislation has been adopted in Colombia. Based on available data, most sandy sediments, due to their lack of fine particle binding chemicals, will be chemically suitable for direct application. If this is not the case, or if the sediment is not sufficiently sandy to be applicable, sand separation techniques may be considered. This includes techniques such as placing sand traps in the river, creating artificial sand sedimentation ponds or mechanical separation (e.g. hydrocycling).

Logistics:
Normally, the principle of the sand motor requires spreading the sand as liquid as possible at a fixed point from where it can be transported with the currents. For this purpose, ideally a hopper barge with sand spreading capacity or a similar hydraulic dredge with liquid outlet is used. The transport capacity is limited by the pumping capacity of the dredge.

Rough cost estimate:
For large-scale sand feeding, this solution could be relatively inexpensive, as the sand will be fed right next to the river mouth, west of Bocas de Ceniza. Therefore, this alternative does not require significant changes in the distance dredging vessels would have to travel to deposit the material. It is estimated that the level of costs will be equal to or less than deep sea disposal of sediment (as is the baseline scenario).

Preliminary environmental and social risks:
From an environmental and social standpoint, the disposal of large volumes of sand may impact local flora and fauna, as well as increase water turbidity, so these aspects will need to be evaluated in detail in later phases of the design. In addition, the continued dispersion of sand could close connections between the Ciénaga de Mallorquín and the ocean, negatively affecting the brackish wetland environment; additional analysis will be required to assess impacts to the wetland. It should be noted that there are two port concessions in the area that should be considered in planning.

In terms of effectiveness, the solution may help to restore the sediment balance in the area, although the influence of existing local structures, such as jetties, on its performance is uncertain. The breakwaters hinder effective sediment transport, which could limit sand regeneration along the coast as it moves westward, so they may need to be restructured.

Risks identified include the formation of shoreline arrows if the angle of incidence of the waves is too oblique (which is likely at the main location); this phenomenon may reduce the effectiveness of the sand engine, although an angle of 35 to 40 degrees would be adequate. There is also a risk of closure of the Mallorquin marsh, so an alternative location is included in the plans that could improve the wave angle and avoid wetland closure[11]. Table 3-2 provides a preliminary risk and impact analysis.

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[11] In addition to environmental risk, the project should be integrated into existing regulations and concessions. Any further work will need to consider the existing concessions and their impact on the economic viability of the project, as well as the stakeholders to be involved, such as the Ministry of Mines and Energy. The initial proposed site is located in an area under concession to the private entity Sociedad Portuaria Bocas De Ceniza S.A. The concession expires in 2028 and no information is available online.

Our reference: 1 – Date: March 25, 2026

Table 3-2 Preliminary identification of social and environmental risks related to the sand engine.

DESCRIPTION OF RISK	PROBABILITY	POTENTIAL IMPACT	COMBINED SEVERITY	SUGGESTED MITIGATION MEASURES	SPECIFIC STUDIES REQUIRED
Negative impact on local flora and fauna due to disposal of large volumes of sand.	Medium	High	High	Define deposition periods outside of sensitive seasons, ecological monitoring and design adjustment	Environmental impact study and biological monitoring
Increased water turbidity during sand placement and dispersal.	High	Medium	High	Limit activities in critical periods, use of turbidity barriers, real-time monitoring	Turbidity and water quality modeling
Closure of connections between the Ciénaga de Mallorquín and the ocean, affecting the wetland environment.	Medium	High	High	Selection of strategic sand engine location, include maintenance channels and continuous monitoring	Hydrodynamic modeling and connectivity analysis
Interference with existing port concessions in the area.	Low	High	Medium	Early coordination with port operators, design adjustments if necessary	Use compatibility analysis
Reduced efficiency due to the presence of breakwaters that hinder sediment transport.	High	Medium	High	Evaluate restructuring or modification of jetties prior to implementation	Coastal and sediment transport modeling
Need for frequent feedback due to fasterthan-expected dispersion	Medium	Medium	Medium	Continuous monitoring and adaptive maintenance plan	Sediment balance analysis and postharvest monitoring
Social acceptance and perception of negative impacts (e.g. on tourism or local fisheries)	Low	Medium	Low	Communication strategy and active stakeholder involvement, social monitoring	Social perception study and community consultation
Formation of shoreline arrows if the angle of incidence of waves is too oblique	Medium	Medium	Medium	Adjust design and orientation of sand motor, consider alternative locations	Morphodynamic modeling and wave simulation

Replicability:
The “sand engine” solution has great potential for replication in other coastal regions of Colombia facing similar problems of chronic erosion and sediment deficit. Its success in the area between Castillo de Salgar and Punta Roca demonstrates that by adapting the design and feeding strategy to local conditions, it is possible to restore sediment balance and improve coastal resilience in the face of climate change and human intervention. Furthermore, the experience gained in the Barranquilla region can serve as a model for implementing sand nourishment solutions in other critical areas of the Colombian coast, always taking into account site-specific technical, environmental and social studies.

Figure 3-7 Delfland Sand Engine (source: Rijkswaterstaat)

International examples:
The Sand Engine (Zandmotor), located off the coast of Delfland (The Netherlands), is an innovative nature-based solution for coastal protection and beach regeneration. Built in 2011 as a pilot project, the Sand Engine consisted of the placement of 21.5 million m3 of sand on a hook-shaped peninsula off the Dutch coast near Ter Heijde. Instead of resorting to traditional and frequent beach regeneration, the Sand Engine harnesses natural forces (wind, waves and currents) to gradually distribute the sand along the coastline over a period of 20 years. This approach not only strengthens coastal defenses against sea level rise and storm surges, but also creates new opportunities for recreation and nature development. The project, developed by Rijkswaterstaat (Figure 3-7), the Province of South Holland and various research and engineering partners, is recognized worldwide as a pioneering example of “Building with Nature,” demonstrating how collaboration with natural processes can improve resilience and sustainability in coastal management.

3.4.2 Conceptual designs at the local level

During the Deliverable 5 workshop, general opportunities for beneficial use of dredged material were discussed, and several specific locations were identified by stakeholders, as described in section 3.3. Three identified and prioritized locations are discussed in more detail below, along with a possible conceptual design to mitigate the challenges associated with each location.

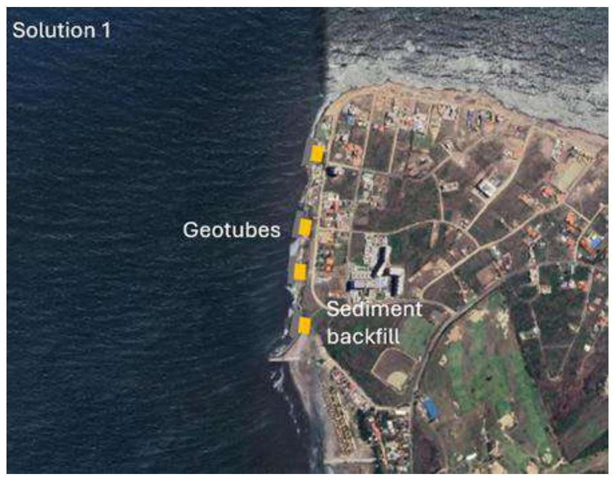
3.4.2.1 Coastal Erosion: Castillo de Salgar and Punta Roca

Castillo de Salgar: Coastal erosion in the area is due to the combined action of high-intensity winds (particularly the northern trade winds), intense swells, storm surges, and progressive sea level rise. In addition, wave refraction around the cape favors the formation of erosive cavities and basal undercutting of the cliff. This vulnerability is aggravated by the presence of soft rock in combination with large waves, which increases the risk of erosion. Furthermore, many of the existing local solutions have altered the sediment balance, further contributing to the coastal erosion problem.

Objective of the solution in relation to the beneficial use of dredged material: Strengthen vulnerable areas and increase future coastal resilience by implementing submerged wavedissipating structures.

Punta Roca: Coastal erosion at Punta Roca is the result of high wave energy, strong winds and cold fronts, which generate intense waves and persistent coastal currents. Wave refraction around the headland concentrates the energy in specific sectors, accelerating the scour of the cliffs and the loss of sediment on the beach. The combination of soft rock and large waves increases the vulnerability of the shoreline, and many existing local solutions, such as jetties and revetments, have altered the sediment balance, reducing natural transport and input. In addition, human impacts have amplified erosion: haphazard development along the coastal strip increases surface runoff and the overburden of the indiscriminate extraction of mollusk shells eliminates deliverables that stabilize the sediment and serve as a refuge for fauna, further aggravating the problem. As a result, the area has a receding coastline, loss of beaches, and puts infrastructure and housing at risk.

Objective of the solution in relation to the beneficial use of the dredged material: To fill existing weak links and increase coastal resilience in the future.

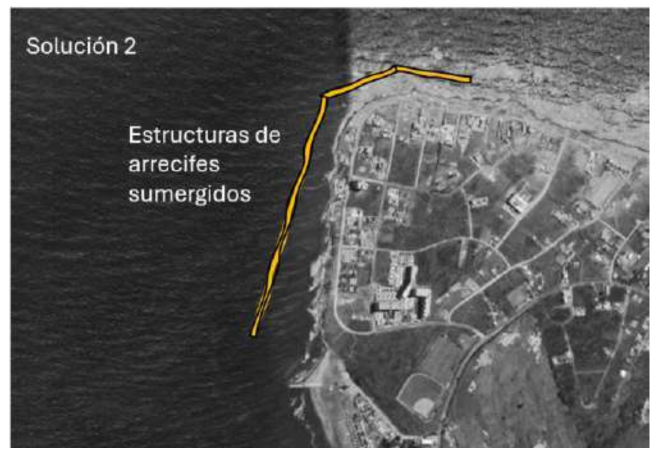


Material needed (quantity and quality):

Solution 1:
Cover erosion holes with geotubes containing dredged sediments. The area behind the geotubes can be filled with sediment and potentially planted with vegetation to stabilize it against wind erosion. Geotubes also prevent undercutting of the cliff.

Type of material dredged:
Geotextile tubes can be filled with any sedimentary material. The use of sandy sediments is easier, while the use of finer sediments may be more beneficial, as they are more frequently disposed of. Geotextile tubes can be beneficial for sealing moderately contaminated sediments in some situations.

In general, sediments below action level 2 are always suitable for use in geotextile tubes (see section 3.4.1). However, in



Material needed (quantity and quality):

Solution 2:
The main function of this intervention is to reduce wave energy to prevent wave scour at the base of the cliffs. To this end, the construction of a submerged breakwater is proposed, consisting of a sandy part that serves as a foundation and a rockfill part that acts as a wave energy dissipator. The design envisages a gentle slope of 1:30, a width of 150 meters, a cross-sectional area of 200 m²/m and an estimated volume of 200,000 m³. Reports indicate that the maximum waves (around Hs=3 m) break at a depth of approximately 1.8 meters, i.e., over the breakwater itself, assuming a breakup ratio of 0.6. To simplify the design, no tidal fluctuations, swell or sea level rise are considered. A risk associated with this solution is the possible deformation or instability of the sandy base.

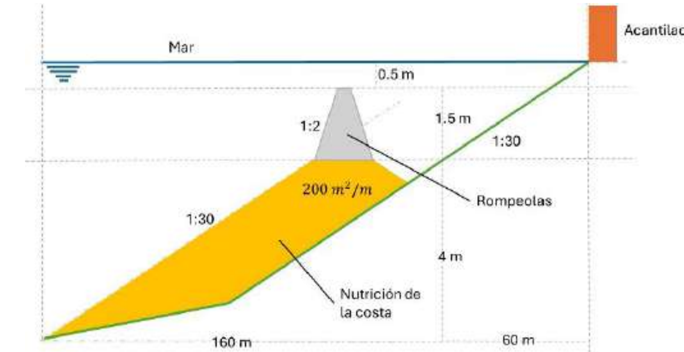
order to be able to use (moderately) contaminated sediments (e.g., above action level 2 in Figure 2-6), it is necessary to be able to demonstrate that the geotextile has an adequate service life and that the discharge water exiting through the pores of the geotextile is clean. Discharge water quality is no longer assessed using sediment quality guidelines, but should be compared to water quality or discharge guidelines, where applicable.

Geotextile pipe logistics:
Geotextiles are usually pre-installed in a small trench and fixed with wooden poles. After fixation, the tubes can be filled directly by the dredging vessel's pumping system in case of hydraulic dredging or, in case of mechanical dredging, the material is pumped from a barge using a concrete/earth pump into the tubes.

Rough (qualitative) cost estimate:
Similarly, geotextile tubes are at least as cost-effective as conventional breakwaters because rock fill can be omitted.

Preliminary environmental and social risks:
Because this solution is local in nature, there is a risk that it will cause erosion and increase vulnerability in other parts of the headland. In addition, limited amounts of sediment will be used, raising doubts about its effectiveness as a stand-alone solution and suggesting that it should be implemented in combination with other alternatives.

Finally, this measure will not necessarily contribute to improving the coastal system as a whole, which may limit its positive impact both environmentally and socially. Table 3-3 provides a preliminary analysis of risks and impacts.



Type of dredged material: The breakwater core can be constructed using dredged sediments; for this purpose, the use of coarse sand (which remains stable if covered with a layer of filtering geotextile and grouting) or clayey dredged material is recommended, provided that it is previously dewatered. In addition, the solution can be complemented by incorporating artificial reef systems into the breakwater, which would enhance biodiversity in the coastal ecosystem.

Approximate (qualitative) cost estimate:
Et is slightly more expensive, as this solution requires more steps. However, other benefits can be obtained if, for example, the breakwater is designed or constructed in a way that is attractive to biodiversity, such as reef systems.

Preliminary environmental and social risks:
In order for the submerged breakwater to be stable under wave action, a stone cover layer is needed. Placement of "hard" protective structures could further alter the natural sediment balance in the area. Table 3-3 provides a preliminary risk and impact analysis.

Table 3-3 Preliminary identification of social and environmental risks related to geotextiles and breakwaters.

RISK DESCRIPTION	PROBABILITY	POTENTIAL IMPACT	SEVERITY COMBINED	MITIGATION MEASURES SUGGESTED	SPECIFIC STUDIES REQUIRED
Erosion and increased vulnerability in other parts of the headland due to the local nature of the solution	Medium	High	High	Evaluate form the regional morphodynamic coastal and combine with other interventions	Modeling regional morphodynamics
Limited amounts of sediment reduce the effectiveness of the solution as a standalone measure	High	Medium	High	Implement the solution in conjunction with other alternatives and ensure continuous supply	Sediment balance analysis and availability
The measure does not contribute to improving the coastal system as a whole, limiting the positive impact	Medium	Medium	Medium	Integrate the intervention into a coastal management master plan	System-scale impact assessment
Instability of the submerged breakwater due to insufficient stone cover	Medium	High	High	Ensure proper design of the reinforcement layer and quality control during construction	Structural design study and stability testing
Risk of limited social acceptance or conflicts with local users (e.g., fishermen, tourism)	Low	Medium	Low	Consultation and communication process with stakeholders	Social analysis and community consultation

Replicability:
This solution has great potential for scalability and replicability in other stretches of the Colombian coast where chronic and progressive coastal erosion is a serious problem. Wherever similar conditions of sediment deficit, wave energy, and vulnerable shorelines exist, the use of beneficially placed dredged material-whether in “sand engines,” geotextile tubes, or submerged breakwaters-can be evaluated as a sustainable and adaptive intervention. An important factor is that placement of these submerged structures works best if bottom slopes are not too steep. The approach can be tailored to the local conditions at each site, allowing it to contribute to coastal resilience and sedimentary balance in multiple vulnerable locations beyond the initial pilot area.

International examples:

Maasvlakte 2, Róterdam. Here, geotextile pipes have been laid on the beach to raise it and build a wind farm. Source: NETICS

Maldivas. Here artificial islands have been created using sandy dredged material pumped into geotextile tubes. Source: NETICS

Playa de Sigandu, Java; a breakwater has been built here to protect the sandy beach from erosion. Source: SolMax

3.4.2.2 Mangrove Restoration - Ciénaga de los Manatíes

The Ciénaga de los Manatíes is facing a general degradation of its mangrove ecosystem and a significant alteration of the sedimentary balance. The water body is exposed to strong winds along long stretches, causing bank erosion. In addition, sediments from the Magdalena River do not contribute to the coastal areas, as they flow directly through a deep ditch, submarine canyon, escaping from the system and ceasing to function as sediment providers.

The loss of mangrove cover is mainly related to logging along the banks and the reduction of freshwater input, which has increased salinity and limited natural regeneration; hydrological disconnection, caused by the cutting of water flows, aggravates hypersalinity and ecosystem deterioration. Mangrove restoration must consider these factors and can benefit from dredging to restore water flow and generate useful sediments, especially by creating small mounds that serve as a stable substrate for new seedlings in degraded areas. However, since the Ciénaga is a protected and ecologically valuable coastal wetland, interventions should be limited to micro-interventions that support mangrove regeneration without modifying the natural configuration of the wetland, avoiding negative social or environmental impacts.

Goal of the solution regarding beneficial use of dredged material: Restore the mangrove ecosystem and restore the sediment balance.

Solution: Planting and restoring mangrove vegetation along the northern part of the wetland will help restore the mangroves, increase coastal protection and benefit the biodiversity of the area.

Volume and type of material dredged: To restore directly mangrove vegetation, the use of finer sediments is limited. Ideally, these range from clay to silty sand. Organic materials are not a problem, whereas mangrove vegetation may be sensitive to high levels of contamination and salinity. Specifically, due to this sensitivity and the fact that fine sediments contain more contaminants, a large portion of the current sediments will not be directly suitable for this solution under the new guidelines. If this is the case, different mitigation strategies can be considered. In this regard, cleaning the finer sediments requires advanced techniques that, in most cases, are too costly to apply. It is more interesting to study the application of sediments in a naturally or artificially contained area (e.g. CAD cells or reclamation areas) in combination with mangrove development. In terms of volumes, for mangrove restoration using mounds, approximately 2 m^3 of sediment per mangrove is required, where up to 10 seedlings can be planted to ensure that the most resilient individual is the one that ultimately survives.

Rough cost estimates:
Mangrove restoration costs are relatively low. However, it is important to include monitoring and maintenance costs in the estimates to ensure the long-term success of the project.

Preliminary environmental and social risks:
It is unclear whether the dredged sediment is suitable for mangrove growth. Table 3-4 provides a preliminary analysis of risks and impacts.

Replicability:
This solution has great potential for scalability and replicability in other coastal wetland areas of Colombia facing similar problems of mangrove degradation and sediment imbalance. Wherever hydrological disconnection, shoreline erosion and mangrove habitat loss occur, the beneficial use of appropriately selected dredged material combined with selective planting of mangroves could be evaluated as a restoration strategy. International project experiences demonstrate that these types of nature-based interventions can be adapted to local contexts to improve coastal resilience and biodiversity, while mitigating environmental and social risks.

International examples:
Ecoshape BwN mangrove restoration project, Demak District, Indonesia.

Table 3-4 Preliminary identification of social and environmental risks related to mangrove restoration.

RISK DESCRIPTION	PROBABILITY	POTENTIAL IMPACT	COMBINED SEVERITY	SUGGESTED MITIGATION MEASURES	SPECIFIC STUDIES REQUIRED
The dredged sediment is not suitable for mangrove growth (due to texture, salinity, or contaminants).	Medium	High	High	Conduct preliminary quality studies and adapt sediment treatment or mixing techniques, select optimal sites	Physical-chemical and biological analysis of the sediments
Failure in mangrove regeneration due to adverse environmental conditions (salinity, flooding, waves)	Medium	Medium	Medium	Selection of adapted species, pilot micro-interventions, monitoring and adaptive adjustment	Pilot planting trials and growth monitoring
Social rejection or conflicts due to negative perception of the use of dredged sediments	Low	Medium	Low	Communication and environmental education strategies, participatory workshops with local communities	Social perception studies and community consultation
Unforeseen changes in the hydrological dynamics of the wetland that affect the restoration	Medium	Medium	Medium	Hydrodynamic monitoring, flexible and adaptive design, continuous evaluation	Hydrological modeling and wetland dynamics studies
Decreased biodiversity due to the introduction of invasive species along with sediment	Low	High	Medium	Prior control of seeds/ spores in the sediment, post-intervention biological monitoring	Biological risk analysis and species identification

3.4.3 Sediment bank - around the access channel

Problem: Primary materials such as sand, clay and soil amendments are expensive for use in low value applications, while dredged material as primary material is widely available for multiple purposes.

Goal of the solution regarding the utilization of dredged material: Reuse of dredged materials for use as beneficial soil, the soil bank concept.

Material required (quantity and quality):
20 ha soil deposit, 100,000 m³ surface area. 33,000 m³ of sand. The sand should contain a low proportion of fine particles and a low proportion of organic matter.

Sand can be sold directly on the market as concrete filler, for ground elevation, for covering tailings deposits, and for backfilling mining caverns. Due to its coarse grain size, the sand will most likely not reach action level 1 (Figure 2-6). However, since the material will be land applied, it is recommended that the sediment quality also be assessed in accordance with current soil quality regulations.

Rough cost estimate:
Sediment storage, drying and processing costs approximately €10 to €15/m3.

Preliminary environmental and social risks:
Leaching, odor, perception of waste streams, stability of the deposit.

Material required (quantity and quality):
20 ha land deposit, 100,000 m³ of surface area.
33,000 m³ of fines. High levels of organic matter can pose difficulties for the constructability of the fines.

The fines can be used as raw material for the brick industry, land elevation and dam construction. Depending on the final application chosen, different chemical requirements may apply in addition to the performance levels for sediments. If the material is applied as soil on the ground, soil quality regulations apply. If the material is used for brick making, building materials regulations apply, where there may be a possibility of using contaminated sediments (e.g. when burning or stabilizing the material).

Rough cost estimate:
Sediment storage, drying and processing costs approximately €10 to €15/m3.

Preliminary environmental and social risks:
Leaching, odor, perceived waste streams, deposit stability.

Our reference: 1 – Date: March 25, 2026

Material required (quantity and quality):
20 ha soil tank, 100,000 m³ surface area.
33,000 m³ of organic matter. Organic matter is very suitable for soil amendment in agriculture and nature restoration. Since organic sediments are often rich in contaminants, much of it will be chemically unsuitable for this solution under the new guidelines. However, since the material will be applied in the field, it is recommended that the quality of the sediments also be assessed according to current soil quality regulations. In addition, it is important to also consider the salinity of the sediments.

Logistical sediment storage:
The sediment reservoir is usually constructed on land, taking advantage of a natural concave topography or by raising dikes that form the reservoir walls, usually with a hydraulic excavator. Depending on the type of dredging method used and the transport distance, the sediment basin may be filled by pipeline or by discharge from a barge using a crane or excavator.

Rough cost estimate:
Sediment storage, drying and processing costs approximately €10 to €15/m3.

Preliminary environmental and social risks:
Leaching, odor, perceived waste streams, repository stability.

Table 3-5 provides a preliminary risk and impact analysis.

Table 3-5 Preliminary identification of social and environmental risks related to sediment banks.

RISK DESCRIPTION	PROBABILITY	POTENTIAL IMPACT	COMBINED SEVERITY	SUGGESTED MITIGATION MEASURES	SPECIFIC STUDIES REQUIRED
Leaching of contaminants from the deposit into soils and groundwater	Medium	High	High	Waterproofing of the reservoir, groundwater monitoring, pre-selection of sediments	Chemical analysis of sediment, hydrogeological studies
Emission of unpleasant odors during storage and drying	Medium	Medium	Medium	Covering the deposit, proper sludge management, and selecting sites away from urban centers	Air quality monitoring, organic composition analysis
Negative perception of the local population due to association with waste or pollution	Medium	Medium	Medium	Information and environmental education campaigns, community participation	Social perception studies, community consultation

Table 3-5 Preliminary identification of social and environmental risks related to sediment banks.

RISK DESCRIPTION	PROBABILITY	POTENTIAL IMPACT	COMBINED SEVERITY	SUGGESTED MITIGATION MEASURES	SPECIFIC STUDIES REQUIRED
Difficulties for constructability due to high levels of organic matter in the fine sediments	High	Medium	High	Pretreatment, mixing with other materials, selection of appropriate applications	Physical composition analysis and laboratory tests
High salinity of the sediments limits their use for agriculture or ecological restoration	Medium	Medium	Medium	Sediment washing, mixing with low salinity soils, selection of tolerant species	Salinity analysis and agricultural/ecological compatibility tests
Structural instability of the reservoir (dam collapse, settlements)	Low	High	Medium	Appropriate technical design, stability monitoring, drainage and compaction	Geotechnical study and stability modeling
Use of sediments containing contaminants for applications not permitted by regulations	Low	High	Medium	Rigorous evaluation of sediment quality according to end use, application of treatment technologies if necessary	Detailed chemical analysis and regulatory compliance

Replicability:
This solution-the beneficial reuse of dredged material as fill soil, sand or organic amendment-presents great potential for scalability and replicability anywhere along the coast where access to traditional fill materials is costly and dredged material is abundantly available. In locations where there is demand for low-cost fill, land elevation, brick production, or soil improvement, evaluating the use of dredged sediments as part of a managed soil bank could offer both economic and environmental benefits. With proper assessment of sediment quality and site-specific environmental protection measures, this approach can be adapted to multiple contexts, turning a waste stream into a valuable resource for land development and restoration.

International examples: sand traps (city of Houston), large commercial sand mining practices around the world (such as the Mekong Delta in Vietnam).

Rotterdam port depot where sandy dredged materials are dewatered and used for the production of paving stones. Source: NETIC

International examples: Kleirijperij ED2050, a large reservoir built for the maturation of clay dredged from the nearby harbor. The same concept has been applied throughout the Netherlands by local water authorities to dry dredged materials. Source: Van Oord

Canada Surrey Sea Dykes: here dredged clay has been used to construct the foreshore of the dyke to enhance erosion resistance. Source: City of Surrey.

International examples: Malmfjarden soil amendment: in the picture, dredged materials from a nearby lake, dewatered through geotextile tubes, are used as a soil amendment.

U.S. Corps of Engineers.

3.5 Governance context

3.5.1 Stakeholder participation in project formulation and implementation

In the framework of this project, stakeholder participation is conceived as an active, voluntary and continuous process through which community and institutional stakeholders are involved in the identification, design, implementation and monitoring of maintenance dredging projects that promote the use of dredged sediments. This participation involves contributing ideas, assuming responsibilities, evaluating results, and contributing to the strengthening of governance, ensuring that benefits are shared, rights are respected, and transparency and the common good prevail.

It is recommended that the formulation and implementation of the prioritized BNS projects be developed in coordination with institutional and community stakeholders, following the stages listed in Table 3-6.

Table 3-6 Stages for carrying out the social participation process

STAGE	OBJECTIVE	KEY ACTIONS	EXPECTED OUTPUTS	PROPOSED INDICATORS
1. Stakeholder identification	Recognize communities, organizations and institutions with influence or interest in the project.	Identification of local communities and users of the dredging area. Identification of social organizations and leaders. Identification of relevant public and private entities.	Database of social and institutional actors with contact information.	Number of communities identified. Number of social organizations identified. Number of public and private entities identified. Percentage of actors with complete information in the database.
2. Socialization and interest mapping.	To inform about the project and to learn about the interests, expectations and capabilities of the actors.	Creating spaces for socialization. Gathering interests, needs, and expectations. Identifying potential roles.	Records of socialization meetings. Inputs for the interests and capabilities matrix.	Number of socialization sessions held. Number of participating stakeholders. Percentage of stakeholders who expressed interest in participating. Document that incorporates the community's interests and roles into the project.
3. Participatory design and consultation	Formulate the project jointly and agree on the uses of the dredged material.	Participatory workshops. Participatory social mapping. Definition of roles and responsibilities.	Minutes of participatory workshops approved by the community. Map of stakeholders and roles.	Number of participatory workshops held. Percentage of agreements validated by the community.
3. Participatory design and consultation		Establishment of coordination and communication mechanisms. Collective validation of actions and results.	Matrix of interests, needs, and capacities. Design document of the collaborative project. Photographic record and attendance lists.	Existence of the agreed-upon design document (yes/no). Level of participation of key stakeholders (% attendance).
4. Participatory implementation	Ensure the active participation of communities and entities in the execution of the project.	Formation of monitoring committees. Regular evaluation meetings. Recruitment of local labor. Training processes. Documentation of best practices.	Minutes and reports from participatory follow-up. Photographic and audiovisual records. Training session minutes and attendance lists. Progress reports. Systematization of experiences.	Number of committees formed. Number of follow-up meetings held. Percentage of local labor involved. Number of people trained. Systematization document prepared (yes/no). Community follow-up reports, including aspects to be incorporated or improved vs. aspects incorporated or improved by the implementing entities.

3.5.2 Cross-cutting principles to be considered in participation processes.

In the social participation processes developed during the implementation of the proposed projects, it is essential to incorporate a series of cross-cutting principles that guarantee inclusion, equity and sustainability of the actions. These principles strengthen the legitimacy of the process and ensure that the results represent the interests and needs of the different stakeholders involved. Table 3-7 presents the cross-cutting principles that should be considered in participatory processes.

Table 3-7 Cross-cutting principles to consider in participatory processes

PRINCIPLE	PURPOSE	GUIDELINES AND KEY ACTIONS	MEANS OF VERIFICATION
Integration of community needs and knowledge	Incorporate local knowledge and real needs to ensure social and environmental relevance and ownership of the project.	Conduct participatory assessments of productive, environmental, and cultural practices. Create spaces for dialogue and knowledge sharing among communities, authorities, and technical teams. Systematize community contributions through written records, social maps, and participatory cartography. Ensure continuous feedback to adjust and strengthen project actions.	Number of knowledge-sharing workshops held. Number of participants in participatory spaces. Number of maps or social mapping exercises created. Document compiling community contributions.
Gender, differential and inclusion approach	To guarantee equitable participation and equal opportunities for all social groups.	Promote the active participation of women, men, youth, and traditionally excluded groups. Recognize and value the diverse roles and contributions of each group within the community. Eliminate cultural, social, and economic barriers that limit participation. Strengthen equity, social cohesion, and the project's sustainability.	Number of participatory events held with a differential approach. Total number of participants, broken down by sex and population group. Percentage of female participation. Percentage of participation of young people or other priority groups. Number of social monitoring reports produced.
Intercultural communication and respect for diversity	Ensure respectful, inclusive, and culturally relevant participatory processes.	Recognize and value the cultural, ethnic, and social diversity of the region. Promote intercultural dialogue and mutual understanding. Adapt messages, methodologies, and materials to the cultural, linguistic, and organizational characteristics of the communities.	Number of culturally adapted outreach materials. Number of workshops using intercultural methodologies. Number of audiovisual recordings produced. Number of perception surveys administered. Percentage of participants who rated the dialogue sessions positively.

Table 3-7 Cross-cutting principles to be considered in participation processes

PRINCIPLE	PURPOSE	GUIDELINES AND KEY ACTIONS	MEANS OF VERIFICATION
Transparency and access to information	Strengthening trust, legitimacy, and co-responsibility among actors	Ensure timely, clear, and understandable access to project information. Share objectives, activities, timelines, progress, and decisions. Establish mechanisms for community communication, monitoring, and accountability.	Number of outreach sessions held. Number of informational materials distributed. Number of accountability meetings held. Number of participants in informational sessions. Percentage of participants who report being aware of the project's progress (according to surveys).
Sustainability and organizational strengthening	Consolidate local capacities and ensure the continuity of project actions	Strengthen community organizations and local leadership. Promote training in leadership, environmental management, resource management, and conflict resolution. Foster collaboration between communities and public and private institutions. Promote shared responsibility in land management and the sustainable use of dredged material.	Number of training processes conducted. Number of people trained. Number of community organizations strengthened. Number of inter-institutional agreements signed. Document of systematization of experiences prepared.

3.5.3 Governance schemes

The legal analysis related to emerging lands is not part of the scope of this project. The regulation of this aspect corresponds to the competent Ministry, within the framework of the decree that is currently in the process of formulation. In this sense, it is considered that this issue should be addressed and regulated in this normative instrument.

However, as an indicative purpose, some governance schemes (Table 3-8, Table 3-9, Table 3-10 and Table 3-11) are proposed for the four prioritized projects, in order to establish an organizational and relational framework that defines the decision-making bodies, roles and responsibilities of the actors involved, as well as the mechanisms for coordination, participation, monitoring and accountability, in order to ensure effective, transparent and sustainable management of the projects.

Table 3-8 Proposed governance scheme for the NbS Project: Sand Engine

NbS: SAND ENGINE PROJECT			
Site: Coastline between Castillo de Salgar and Puerto Mocho			
INSTANCE	ACTORS	FUNCTIONS	MECHANISMS
Interinstitutional Governance Committee	Regional Autonomous Corporation of the Atlantic (CRA). Regional Autonomous Corporation of the Magdalena River (CORMAGDALENA). National Environmental Licensing Authority (ANLA). General Maritime Directorate (DIMAR). Barranquilla Verde Environmental Public Establishment. Government of the Department of Atlántico. Mayor's Office of Barranquilla. Barranquilla Risk Management Office. Mayor's Office of Puerto Colombia. Puerto Colombia Risk Management Office.	To coordinate institutional responsibilities within the project framework. To ensure consistency with current environmental, maritime, and territorial regulations. To review and approve the required technical and environmental studies and designs. To conduct environmental and social monitoring of the project.	Periodic inter-institutional coordination meetings. Minutes of decisions, agreements, and follow-up. Technical review of studies and designs. Periodic progress and compliance reports. Mechanisms for resolving inter-institutional conflicts.
Executing company or entity	To be defined	Prepare the required technical, environmental, and social studies. Coordinate project implementation with the Inter-institutional Governance Committee. Implement the project, ensuring the participation of institutional and community stakeholders. Ensure compliance with established environmental, social, and technical guidelines.	Approved work plan and timeline. Periodic technical, administrative, and financial reports. Interinstitutional coordination protocols. Technical, environmental, and social oversight. Formal communication channels with communities and institutions.

Table 3-8 Proposed governance scheme for the NbS Project: Sand Engine

NbS PROJECT: SAND MOTOR			
Site: Coastal line between Castillo de Salgar and Puerto Mocho			
INSTANCE	ACTORS	FUNCTIONS	MECHANISMS
Community participation	Homeowners and business owners. Organizations of fishermen, artisans, farmers, community action boards, community tourism initiatives, ethnic minorities, among others, from the following locations: Municipality of Barranquilla: La Playa district and neighborhoods of Las Flores, Villa Carolina, Villa del Este, Villa Santos, Villamar, Villas del Puerto, among others. Municipality of Puerto Colombia: Sabanilla and Salgar districts and Punta Roca neighborhood.	Actively participate in the different phases of the project. Contribute relevant local and traditional knowledge. Contribute local labor, when applicable. Conduct community social and environmental monitoring. Strengthen community ownership and the legitimacy of the project.	Spaces for socialization, information sharing, and consensus building. Participatory workshops and community meetings. Mechanisms for citizen oversight and social monitoring. Permanent community communication channels. Strategies for environmental education and outreach.

Table 3-9 Proposed Governance Scheme for Project NbS: Shoreline Protection with Submerged Structures

NbS PROJECT: COASTAL PROTECTION WITH SUBMERGED STRUCTURES			
Site: Salgar Castle and Punta Roca			
INSTANCE	ACTORS	FUNCTIONS	MECHANISMS
Interinstitutional Governance Committee	Regional Autonomous Corporation of the Atlantic (CRA). Regional Autonomous Corporation of the Magdalena River (CORMAGDALENA). General Maritime Directorate (DIMAR). Government of the Atlantic. Mayor's Office of Puerto Colombia. Puerto Colombia Risk Management Office.	Coordinate institutional responsibilities. Ensure regulatory consistency. Review and approve the required design and studies. Conduct environmental and social monitoring.	Periodic inter-institutional coordination meetings. Decision minutes, agreements, and follow-up. Technical review of studies and designs. Periodic progress and compliance reports. Mechanisms for resolving inter-institutional conflicts.
Executing company or entity	To be defined	Conduct the required studies. Coordinate all project activities with the Inter-institutional Governance Committee. Implement the project with the participation of institutional and community stakeholders.	Approved work plan and timeline. Periodic technical, administrative, and financial reports. Interinstitutional coordination protocols. Technical, environmental, and social oversight. Formal communication channels with communities and institutions.
Community participation	Homeowners and business owners. Organizations of fishermen, artisans, farmers, community action boards, community tourism, ethnic minorities, among others, from the following locations: Municipality of Puerto Colombia: Sabanilla and Salgar districts and Punta Roca neighborhood	Participate in the project. Contribute local knowledge. Contribute labor. Conduct environmental and social monitoring. Strengthen the project's social ownership and legitimacy.	Spaces for socialization, information sharing, and consensus building. Participatory workshops and community meetings. Mechanisms for citizen oversight and social monitoring. Permanent community communication channels. Strategies for environmental education and outreach.

Table 3-10 Proposed governance scheme for Project NbS: Mangrove Restoration Project NbS: Mangrove Restoration

NbS PROJECT: MANGLAR RESTORATION			
Site: Los Manatíes Swamp			
INSTANCE	ACTORS	FUNCTIONS	MECHANISMS
Interinstitutional Governance Committee	Regional Autonomous Corporation of the Atlantic (CRA). Regional Autonomous Corporation of the Magdalena River (CORMAGDALENA). General Maritime Directorate (DIMAR). Government of the Atlantic. Mayor's Office of Puerto Colombia. Puerto Colombia Risk Management Office.	Coordinate institutional responsibilities. Ensure regulatory consistency. Review and approve the required design and studies. Conduct environmental and social monitoring.	Periodic inter-institutional coordination meetings. Decision minutes, agreements, and follow-up. Technical review of studies and designs. Periodic progress and compliance reports. Mechanisms for resolving inter-institutional conflicts.
Executing company or entity	To be defined	Conduct the required studies. Coordinate all project activities with the Inter-institutional Governance Committee. Implement the project with the participation of institutional and community stakeholders.	Approved work plan and timeline. Periodic technical, administrative, and financial reports. Interinstitutional coordination protocols. Technical, environmental, and social oversight. Formal communication channels with communities and institutions.
Community participation	Homeowners and business owners Organizations of fishermen, artisans, farmers, community action boards, community tourism, ethnic minorities, among others, from the following locations: Municipality of Puerto Colombia: Sabanilla and Salgar districts and Maizal neighborhood	Participate in the project. Contribute local knowledge. Contribute labor. Conduct environmental and social monitoring. Strengthen the project's social ownership and legitimacy.	Spaces for socialization, information sharing, and consensus building. Participatory workshops and community meetings. Mechanisms for citizen oversight and social monitoring. Permanent community communication channels. Strategies for environmental education and outreach.

Table 3-11 Proposed governance scheme for the NbS: Sediment Bank Project

NbS PROJECT: BANK OF SEDIMENTS			
Site: Access channel to the Port of Barranquilla.			
INSTANCE	ACTORS	FUNCTIONS	MECHANISMS
Interinstitutional Governance Committee	Regional Autonomous Corporation of the Atlantic (CRA). Regional Autonomous Corporation of the Magdalena River (CORMAGDALENA). General Maritime Directorate (DIMAR). Barranquilla Green Environmental Public Establishment. Government of the Atlantic. Mayor's Office of Barranquilla. Barranquilla Risk Management Office.	Coordinate institutional responsibilities. Ensure regulatory consistency. Review and approve the required design and studies. Conduct environmental and social monitoring.	Periodic inter-institutional coordination meetings. Decision minutes, agreements, and follow-up. Technical review of studies and designs. Periodic progress and compliance reports. Mechanisms for resolving inter-institutional conflicts.
Executing company or entity	To be defined	Conduct the required studies. Coordinate all project activities with the Inter-institutional Governance Committee. Implement the project with the participation of institutional and community stakeholders.	Approved work plan and timeline. Periodic technical, administrative, and financial reports. Interinstitutional coordination protocols. Technical, environmental, and social oversight. Formal communication channels with communities and institutions.
Community participation	Homeowners and business owners. Organizations of fishermen, artisans, farmers, community action boards, community tourism initiatives, ethnic minorities, among others, from the following locations: Municipality of Barranquilla: La Playa district and Las Flores neighborhood	Participate in the project. Contribute local knowledge. Contribute labor. Conduct environmental and social monitoring. Strengthen the project's social ownership and legitimacy.	Spaces for socialization, information sharing, and consensus building. Participatory workshops and community meetings. Mechanisms for citizen oversight and social monitoring. Permanent community communication channels. Strategies for environmental education and outreach.

4. Market study: Demand for dredged material.

Executive summary

The key points of this chapter are:

1. Market potential: Barranquilla dredges 3.7 million m³/year; dredged material is a valuable resource for various uses including coastal protection.

2. Policy support: National policies and regulations facilitate the sustainable use of dredged material, in line with the SDGs.

3. Stakeholder engagement: Success depends on collaboration between public, private, academic and international actors.

4. Economic and environmental benefits: Use of dredged material reduces flood r i s k , improves soil and water quality, and supports tourism and fisheries.

5. Cost considerations: Major costs include studies, dredging, transport and monitoring.

6. High level quantification of costs and benefits.

7. Next steps: It is recommended to develop technical guidelines, financial mechanisms and strong public-private-academic partnerships.

The chapter gathers the key tools to propose a market study based on the use of dredged material focusing on the use for coastal protection applicable to a future pilot in the city of Barranquilla; part of the market context where it is evident that currently in the city, an average of 3.7 million m3 per year is contracted for dredging and the monetary value is between COP 21.000 m3 and COP 31,000 m3, which are reference values that can be adjusted since the following dredging contracts in the city of Barranquilla are taken as a basis for the information:

1. Years 2024-2025 SECOP contract: 0-525-2024.
2. Year 2024 SECOP contract: PAF-CORMAGDALENA-O-128-2023.
3. Year 2023 SECOP contract: 111251-003-2023 (PAF-CORMAGDALENA-O-007-2023).
4. Years 2021-2022 SECOP contract: 101496-001-2021 (PAF-CORMAGDALENA-O-061-2021).

There is international evidence on the use of dredged material for coastal protection that allows us to approximate the potential use for the city of Barranquilla, which requires an effort by the public and private sectors. Additionally, there are the following policy tools on which the use of the material can be framed and which aim at sustainability with the development of actions based on the Sustainable Development Goals (SDGs). In this context, a series of benefits and costs have

been elucidated that should be included in the development of a project for the sustainable use of dredging, which make up the edges of the sustainability pyramid, comprising the economic, social and environmental categories.

4. Market study: Demand for dredged material.

4.1 Objective of the market study

The study identifies market signals, national policies and key environmental, economic and social aspects as inputs for the structuring and development of policies around the sustainable use of dredged materials for coastal protection. The resulting data will be fundamental to evaluate their potential application in the Barranquilla area and can guide decision making from a sustainable perspective.

4.2 Market environment: local and national

Natural habitat degradation, channel degradation and shoreline degradation are the main stressors affecting the coastal ecosystem. Therefore, they constitute the starting point to analyze the market environment around the use of dredged material for beneficial use, focusing on coastal protection (Slob et al., 2008).

The market is the mechanism that can contribute to respond to these issues, through the internalization of the following variables, which become benefits associated with the sustainable use of dredged material in coastal protection (CEDA, 2019):

- Flood risk
- Soil productivity
- Soil biological quality
- Tourist activity
- Natural habitat quality
- Fishing
- River route
- Biodiversity
- Water quality

The market is conditioned by costs and benefits, for which it is necessary to take into account the following aspects:

Available supply of dredged material: Table 2-3 shows the average volume of each of the sectors, projecting that these quantities should be carried out annually in the access channel to maintain stable navigability in the coming years. The average volume of the canal is 3.6M m3 (average volume from 2023 to 2025).

The city of Barranquilla can take advantage of the material of dredging, since its use can contribute to the city's coastal protection. The use of the resource depends on the implementation of a mixed strategy that articulates resources from port considerations, concessions and public-private alliances, through which the active participation of local companies could be encouraged (see Figure 4-1):

- *Port consideration:* it is mainly framed by the Statute of Maritime Ports (Law 1 of 1991). It corresponds to the payment made by the port companies to the Nation and the municipalities where their activity is located, in order to be able to usufruct the public use goods for the construction and development of the port activity; the use is allowed by a long term contract.

- *Concession:* it is a form that seeks to generate private investment in the use of dredged material for coastal protection, it is governed by Law 1106 of 2006, and corresponds to a state contract that assigns to a private party the exploitation of a public service for a period of time in exchange for the private party making a remuneration to the State.

- *Public-private partnership:* it is a public-private financing scheme to finance infrastructure projects and public services with Law 1508 of 2012. The process has a term of 30 years, which makes an investment attractive since the private sector resources enter in the prefeasibility, preconstruction and construction stage; and the public resources are invested later.

Potential demand for dredged material: Barranquilla presents a potential use of dredged material for coastal protection, which is calculated under the assumption that the proposed solutions for coastal protection at the systemic level together with the local level. Section 3.4 showed diverse applications with a large variation in the required volume of dredged material. Table 4-1 presents some of the outstanding international and national experiences in the use of dredged material.

Figure 4-1 Key aspects for the business on the use of dredged material for coastal protection (Source: own elaboration)

- ***Current price for dredging material in the city of Barranquilla:*** the current price per m3 of dredging for the city of Barranquilla is established based on the dredging contracts that have been implemented since 2022, where material prices have been increasing from 23,000 - 31,000 COP/m3 , values expressed in current prices for the year, see Figure 4-2; it should be clarified that this price is indicative data that does not represent comparable data from year to year. As explained in section 3.4.1, the large-scale sand feeding in the Sand Engine solution could be relatively inexpensive, as the sand will be fed just off the river mouth, west of Bocas de Ceniza. Therefore, this alternative does not require significant changes in the distance dredging vessels would have to travel to deposit the material. It is estimated that the level of costs will be equal to or less than deep sea disposal of sediment (as is the baseline situation).

Tabla 4-1 Experiencias en el uso de material de dragado (Fuente: elaboración propia)

ACTIVITY	QUANTITY DEMANDED M3	LOCATION	YEAR	BIBLIOGRAPHIC SOURCE
Delfland Sand Engine	22.000.000	The Netherlands	2011	Ecoshape
Norfolk Sand Engine	1.500.000	United Kingdom	2019	Ecoshape
Reuse in habitat projects, Mississippi River	100.000	United States	2022	PIANC Envicom Report on Beneficial Use of Dredged Material.
Ecological restoration of wetlands, Cauca Valley Wetlands	15.000	Colombia	2019	https://minas.medellin.unal.edu.co/institutos/agua/servicios.html
Beach restoration / erosion control, Cartagena.	30.000	Colombia	2021	CORNARE - Terms of reference for dredging.
Landfill for port infrastructure, Buenaventura.	50.000	Colombia	2022	National Maritime Dredging Plan - MinAmbiente/DNP
Beach regeneration in Cadiz	254,000 for 8 km of beach	Spain	2020	https://www.miteco.gob.es/es/prensa/ultimas-noticias/2025/diciembre/el-miteco-financia-con-casi-43m--la-regeneracion-de-playas-danad.html
Agricultural use and land reclamation	50.000	Italy	2024	“Dredge Sediment as an Opportunity: A Comprehensive and Updated Review of Beneficial Uses in Marine, River, and Lagoon Eco-Systems” (2024, Environments, Vol. 12, Issue 6). It provides a systematic overview of how dredged sediments can be reused sustainably instead of being treated as waste.

Socioeconomic factors:

- The value of transport is benchmarked against the tariff policy for intermodal freight services, and is calculated from: - Fixed costs: amortization and investment, financing, preventive maintenance, policies, personnel.administrative and operating costs, and use of the dock. - Variable costs: fuel and lubricants, crew maintenance, hydrofoil usage fee and crew relief. - Other costs: taxes, stationery, miscellaneous and incidental expenses. For the present analysis, the tariff was calculated based on river services on the Barrancabermeja-Puerto Capulco and Puerto Capulco-Barranquilla routes, differentiating between export and import operations. They calculated the average value recorded in 2020 and obtained that the value is equivalent to 179.5 COP /Tonne/Kilometer (Mintransporte, 2020).

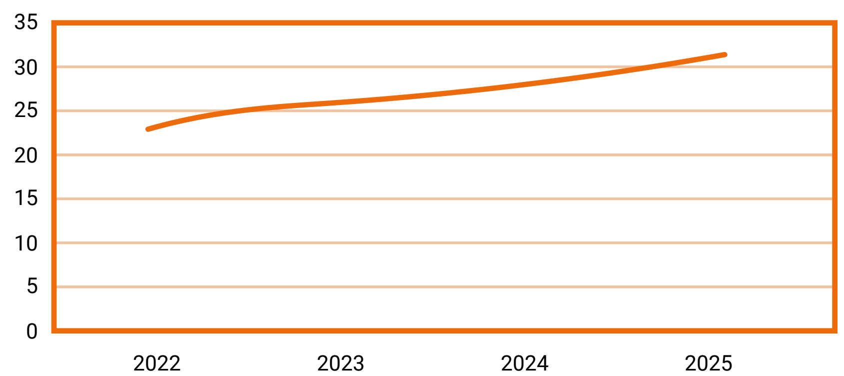


Figure 4-2 Dredging price COP/m3 - thousands (Source: own data based on dredging contracts in Barranquilla)

- The city of Barranquilla is considered the industrial and commercial capital of the Colombian Caribbean, and is a strategic port at the national and international level (Barranquilla Chamber of Commerce, 2024), which guarantees the flow of labor for the development of actions aimed at coastal protection, also, the city has approximately 18 universities that can contribute with research activities on the use of dredging, among which the Universidad del Atlántico, Universidad del Norte and Universidad de la Costa stand out (Barranquilla, 2018
- Additionally, the city has sufficient infrastructure and business fabric to be able to develop business initiatives that contribute to coastal protection. It has port infrastructure with multimodal logistics vocation with eight terminals. It has a warehouse and a refrigerated and frozen cargo center. It has road infrastructure, such as the Cartagena-Barranquilla road to the sea, which connects both in a two hour drive that facilitates trade and business mobility. In addition, there are 28 industrial parks, including PIMSA Malambo, which is in the process of being certified as an Eco- Park, and four free trade zones where more than 180 companies operate (Barranquilla Chamber of Commerce, 2024).

4.2.1 Public Policies/ Regulatory Advances

Public policies that contribute to the implementation of actions for coastal protection are as follows:

1. The National Development Plan 2022-2026 “Colombia world power of life”, raises within its goals the human right to food, for which, it establishes the strengthening of 96 port facilities for this purpose.
2. The 2017 National Maritime Dredging Plan seeks to prioritize the access channels to Colombian ports; its objective is to develop an efficient strategy for the maintenance of these channels and the aquatic fore-port areas, defining design and construction criteria that design and construction criteria that take into account the use of dredged material.
3. CONPES document 4174 of the year 2025, in establishing the strategic territories around water at the national level. The policy tool incorporates the concept of green infrastructure in the territories, encourages conservation and ecological and multifunctional restoration of ecosystems.
4. Law 1508 of 2012, which establishes the legal regime for Public-Private Partnerships.
5. The Intermodal Transportation Master Plan (2021-2035), seeks to modernize transportation infrastructure, focusing on intermodality (road, rail, river, maritime and air) to improve competitiveness, connectivity and regional equity.
6. The 2016 Coastal Erosion Master Plan develops the vision and long-term national strategy that seeks to prevent, mitigate and control coastal erosion and its consequences in the country.
7. The 2015 River Master Plan, which aims to generate the enabling factors for Colombia to have a more competitive, clean, safe and social river transport.
8. The Port Physical and Environmental Management Plan, which allows zoning for the sustainable use of coastal areas with a long-term vision and articulates investments and infrastructure improvements within the framework of territorial and environmental management.
9. The Specific Port Master Plan for the port of Barranquilla, with a vision of 10 to 20 years, and will be developed with a long-term vision. focuses on spatial efficiency and sustainability articulated with other planning tools.
10. CONPES 4118 of 2023, which establishes the National Port Policy: Modernization and Sustainability of the Port Activity and its Articulation with the Territory. Its objective is to promote the adaptation of the Colombian port system to the global and territorial environment, under the principles of environmental sustainability, to promote efficiency in its operation and development.
11. Decree 1333 of 1986, which develops the regulatory framework for urban planning.
12. Law 9 of 1989, which implements the urban reform.
13. Law 388 of 1997, which establishes the guidelines for territorial development.
14. Decree 1076 of 2015, which regulates the projects subject to environmental licensing and specific terms of reference for dredging.

Once the analysis of public policy tools has been carried out, it is essential to define their importance in action planning and the direct and indirect impact they can have on the implementation of a business around coastal protection with the use of dredged material. Therefore, the following policy and financing aspects identified within the planning tools should be taken into account (Figure 4-3):

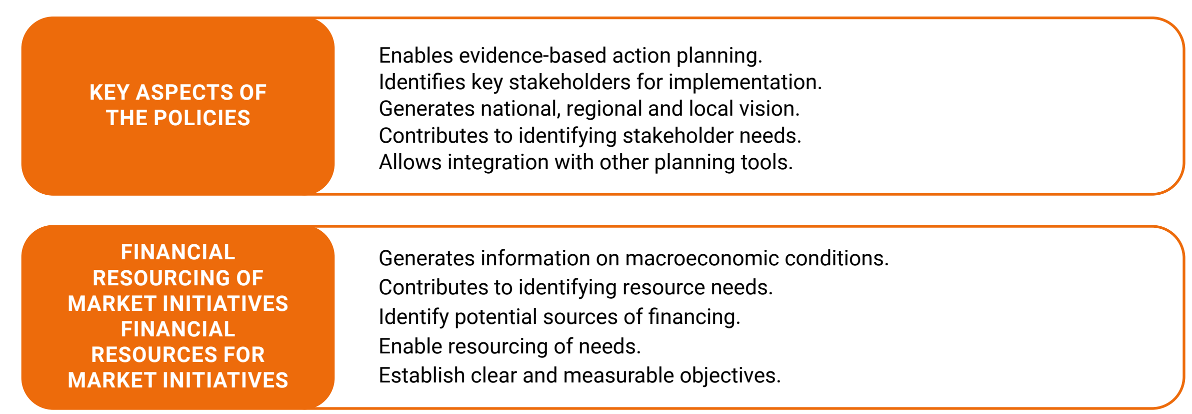


Figure 4-3 Relevance of current public policies in the implementation of coastal protection actions (Source: own elaboration).

4.2.2 Key Stakeholders

In order to identify the stakeholders in the development of initiatives for the use of dredged material for coastal protection, four types of actors are identified: public, private, academia and research, and international cooperation; who directly or indirectly may have an impact on the development of initiatives for the use of this material. The actors and their roles in relation to the coastal protection initiatives that can be developed are detailed below (Table 4-2).

Table 4-2 Typology, actors and roles in the use of dredged material for coastal protection (Source: Prepared by the authors)

TYPOLOGY	ACTOR	FUNCTION
Public	National Planning Department Ministry of Transport Ministry of Defense Ministry of Commerce, Industry and Tourism Ministry of Environment and Sustainable Development Ministry of Finance and Public Credit Ministry of Agriculture Ministry of Mines and Energy Government of Atlántico Mayor's Office of Barranquilla Cormagdalena Community Action Boards Invias Findeter DIMAR Port Authority	Develop the enabling public policy for the use of dredged material in coastal protection. Provide some of the financial resources to contribute to the development of a market for the use of dredged material in coastal protection. Develop the technical and procedural guidelines for the use of dredged material in coastal protection. Convene the productive sectors that may be interested in developing coastal protection actions using dredged material. Create tax incentives for investors in coastal protection actions using dredged material.
Private	Barranquilla Regional Port Authority State Infrastructure Contractors	Explore business opportunities related to the use of dredged material for coastal protection. Contribute to the development of initiatives that utilize dredged material for coastal protection.

Table 4-2 Typology, actors and roles in the use of dredged material for coastal protection (Source: Prepared by the authors)

TYPOLOGY	ACTOR	FUNCTION
Private	Camacol ANDI	Invest in actions that use dredged material in coastal protection based on public policy guidelines.
Academia and research	University of the North Simón Bolívar University INVEMAR IDEAM	Generate scientific information that enables the use of dredged material for coastal protection. Create spaces for dialogue that contribute to the informed use of dredged material with local stakeholders.
International cooperation	Cooperation from the Government of the Netherlands Cooperation from the Government of the United States of America Global Partnership for Waterborne Transport Infrastructure (PIANC) International Maritime Organization (IMO)	To contribute technical assistance for the implementation of dredged material use in coastal protection. To disseminate research advances on the use of dredged material for coastal protection.

4.2.3 Align the use of dredged material with the Sustainable Development Goals.

The use of dredged material as an input for coastal protection is framed within the policies described in the previous paragraph, which are aligned with the Sustainable Development Goals (SDGs) of the United Nations (CBD et al., 2016). Mainly with five (5) SDGs, which are associated with ecosystem services related to the provision and regulation of water resources; as well as their influence on quality of life, species habitat, industrial viability and adaptation to climate change (Figure 4-4).

SDG 6. Clean water and sanitation: Improves water quality and prevents flooding by removing sediment.

SDG 9 Industry, Innovation and Infrastructure: Maintains port and waterway infrastructure, essential for trade and the economy.

SDG 14 Underwater Life: Sustainable dredging can create artificial reefs and restore habitats, supporting marine biodiversity.

SDG 11 Sustainable Cities and Communities: Protects populations from flood risks and improves quality of life.

SDG 13 Climate Action: Contributes to the resilience of coastal and river ecosystems to climate change.

Figure 4-4 Articulation of the sustainable use of dredged material with the Sustainable Development Goals (Source: own elaboration).

The use of dredged material is also projected as a basis for public policy driven by the Ministries of Transportation and Environment, focused on habitat creation, land filling and ecosystem recovery (DNP, 2017). Likewise, the National Policy for the Management of Biodiversity and Ecosystem Services that seeks the conservation of ecosystems and sustainable use can be linked the use of dredged material with the sustainability approach mainly with a focus on the restoration of marinecoastal ecosystems (MinAmbiente et al., 2012).

Another key deliverable for the sustainable use of dredged material in coastal protection in Colombia is the existence of the environmental assessment of projects by the National Environmental Licensing Agency (ANLA), which analyzes the generation of negative impacts on ecosystems, specifically those that can positively or negatively affect aquatic ecosystems by the intervention through a project, work or activity.

4.3 Analysis of the priority alternative in relation to the market viability

Referring to Chapter 3, the priority use of dredged material in the Barranquilla area is coastal protection. The section below is analyzing in more detail the costs and benefits of the priority use.

4.3.1 Categorization of benefits

The use of dredged material in coastal protection is an essential strategy for ecosystems under degradation (considered in NbS), as it offers direct and indirect benefits. These benefits have the following characteristics (Slob et al., 2008) (Figure 4-5):

1. They possess a specific scope, objective or action.
2. They are measurable over time and should therefore be subject to economic valuation through market structures.
3. They influence public and private decision making and thus guide public policy.
4. They should be monitored through different planning tools and market-related indicators.

To generate the categories of benefits, the nature of each one is taken into account, based on an economic, social and environmental analysis (DNP, 2018) (Figure 4-6).

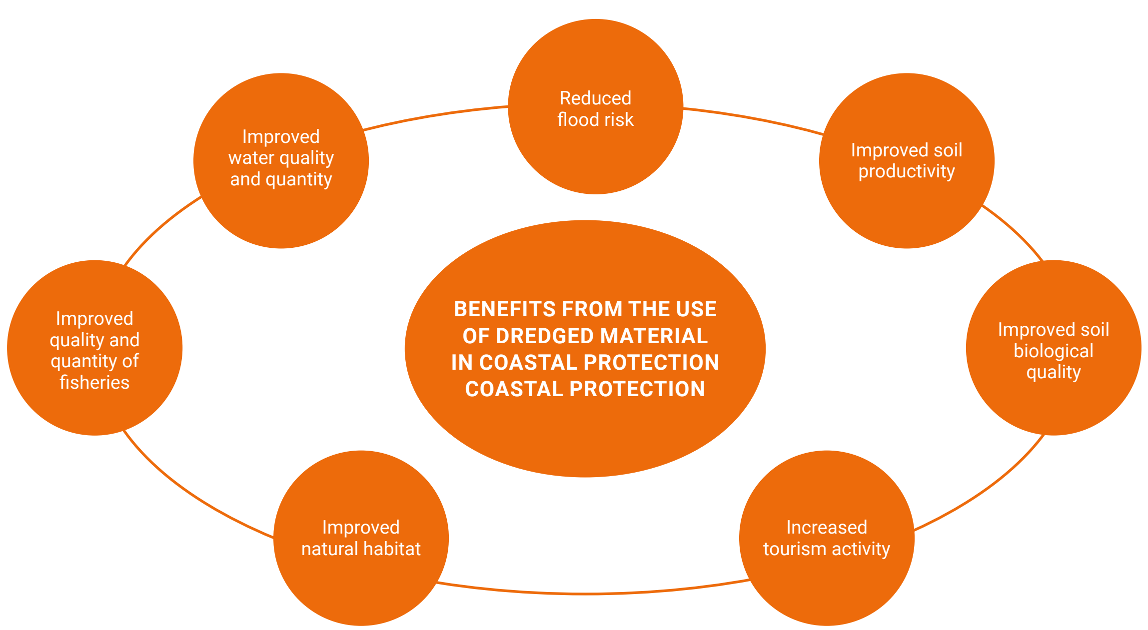


Figure 4-5 Benefits of using dredged material for coastal protection (Source: Prepared by the authors)

Our reference: 1 – Date: March 25, 2026

- *The benefits that have the category of economic:* corresponds to benefits that can be measured through money, for the purposes of a market with the use of dredging in coastal protection such as: reduction of flood risk, improvement in soil productivity, increase in tourism activity, improvement in quality and quantity of fishing, improvement in quality and quantity of water.
- *The benefits that have the social category:* corresponds to benefits that can have improvements in the quality of life of people, such as: reduction of risk, reduction of environmental impact, and reduction of environmental impact. Reduction of flood risk, increase in tourist activity, improvement in quality and quantity of fishing, improvement in quality and quantity of water.
- *The benefits in the environmental category:* correspond to benefits that seek to maintain the ecological balance and guarantee the provision of ecosystem services. The following are identified for the use of dredging for coastal protection: reduction of flood risk, improvement in the biological quality of the soil, improvement in the natural habitat.
- *The costs that have the category of economic:* these are the costs that allow quantifying the coherent and orderly budget, such as: cost of the intervention service, environmental guide adaptation program, monitoring costs, follow-up costs.

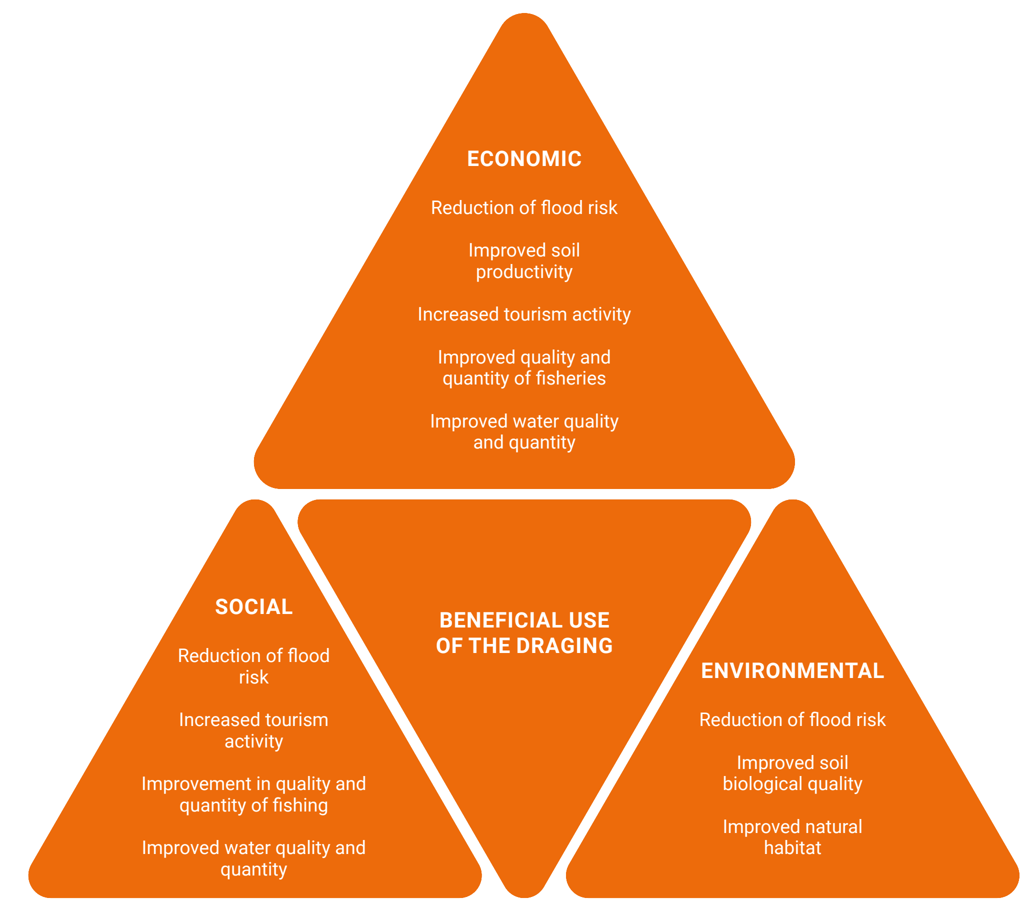


Figure 4-6 Economic, social and environmental categorization of the benefits of the use of dredged material in coastal protection (Source: own elaboration).

4.3.2 Categorization of costs

To determine the costs of using dredged material for coastal protection, three levels of costs are considered, see also (Figure 4-7):

1. Studies and planning: conducting a bathymetric survey and performing additional dredging work in the perimeter channels of the locations. In addition, studies are needed to identify the problem or improvement to be implemented, analyze options for action and conduct an Environmental Impact Assessment (EIA), etc.
2. Dredging and use of material for coastal protection: Carry out maintenance of the area to be intervened and develop actions for the use of dredged material for coastal protection.
3. Monitoring and follow-up: Conduct monitoring of the area where dredging activities are carried out and the subsequent use in coastal protection; generate the required reports to the environmental authority and document the process being carried out.

4.3.3 Valuation methodologies and information requirements

To determine the methodologies to be implemented for the benefits and costs of using dredged material for coastal protection, the following aspects are taken into account (Table 4-3):

- The extent of the benefit or cost and whether or not it has a market.
- The methodologies used by environmental economics to value the externalities produced by an action on an ecosystem (Ripka et al., 2018).
- The information requirements are conditioned by the methodologies that capture the value of change by the action on the ecosystem and the variables that are determined in the environmental economics literature.
- Allocation of benefits to ecosystem services: (a) Regulatory services, (b) Provisioning services, (c) Cultural services.

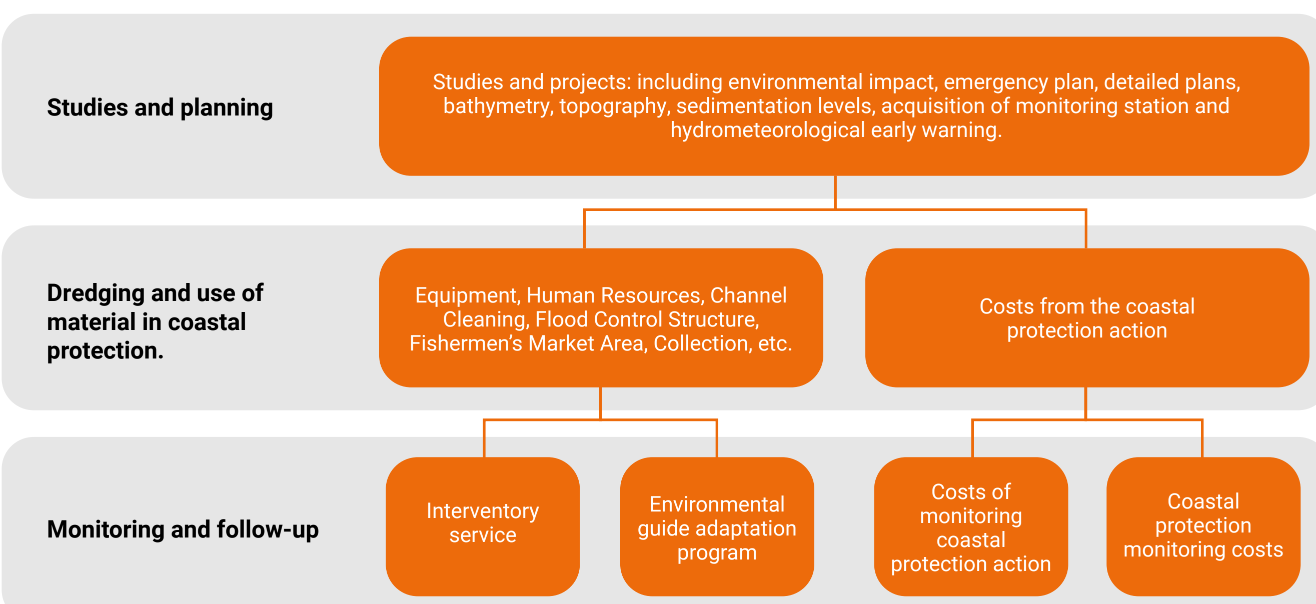


Figure 4-7 Costs of the use of dredged material in coastal protection (Source: own elaboration).

Our reference: 1 – Date: March 25, 2026

Table 4-3 Methodologies for quantifying the benefits and costs of using dredged material in coastal protection (Source: own elaboration).

BENEFITS OF DREDGED MATERIAL IN COASTAL PROTECTION	TYPE OF ECOSYSTEM SERVICE	COSTS OF DREDGING MATERIAL IN COASTAL PROTECTION	ASSESSMENT METHODOLOGIES	INFORMATION REQUIREMENTS
Flood risk reduction	Regulatory service		Market prices for infrastructure damage. Willingness to pay for risk reduction.	Analysis of cartographic information, water information, socioeconomic information, risk reduction measures, costs of risk reduction measures.
Improvement in soil productivity	Provisioning service		Market prices for productivity improvements (higher production at lower cost)	Biophysical characterization, hydrological and climatic information, socioeconomic aspects, measures to improve productivity.
Increase in tourist activity	Cultural service		Market prices - visitor revenue to tourist areas	Tourist attractions, tourist demands, resources required for tourist activity.
Improvement in the natural habitat	Regulatory service		Willingness to pay for variation in the quality of the natural habitat.	Ecological characteristics, socioeconomic aspects, measures to improve the habitat.
Improvement in the quality and quantity of fishing	Provisioning service		Market prices for the quantity and quality of fish produced in the project's area of influence.	Characteristics of fishery resources, fisheries development, socioeconomic aspects.
Improvement in water quality and quantity	Regulatory service		Market prices vary depending on the quantity and quality of water. Willingness to pay for the quantity and quality of water.	Water characterization, water quality, uses and demands, measures to improve quality and quantity.
		Studies and planning	Market prices for studies.	SECOP - where state contracting documents are published.
		Dredging and the use of the material in coastal protection	Market prices for dredging (operational and investment)	SECOP - where state contracting documents are published.
		Monitoring and tracking	Market prices for monitoring and tracking strategies.	SECOP - where state contracting documents are published.

Costs and benefits: case study example

The following block presents a high-level example of a cost-benefit analysis of using dredged material for coastal protection between Castillo de Salgar and Punta Roca, based on the conceptual designs in section 3.4.

The costs and benefits are based on assumptions summarized in Table 4-4. The annual erosion assumption/estimate used comes from the DIMAR assessment, prepared using satellite imagery from 2013 to 2023[12].

Due to the lack of consistent secondary data and the high variability of erosion depending on local conditions (waves and tides), the approximate loss of 55 meters over ten years reported by DIMAR, equivalent to 5 meters per year, was adopted as a reference. This value is used solely as a technical approximation and should be understood as data derived from the aforementioned satellite analysis. The other parameters (such as the number of dwellings and establishments per area, resettlement costs, and associated economic volumes) are incorporated as inputs to quantify the potential impacts on residential infrastructure, hotels, and restaurants within the analyzed coastal corridor. Additionally, it is estimated that the cost per cubic meter will be equal to or less than the baseline scenario where

Table 4-4: Assumptions used for cost-benefit analysis.

CATEGORIES	ESTIMATES	
Cost difference (CAPEX/OPEX)	It is estimated that the cost level will be equal to or less than deep sea sediment disposal (as is the baseline situation).	$ 0
Erosion	Meters of beach erosion / tide line (meters/years)	5
Housing	# people/household	4
	Cost of resettlement/housing	$ 225.000.000
Hotels and other tourist accommodations in the hazard zone	# guests/hotel/year	2.500
	Turnover/guest	$ 135.000
	Resettlement cost/hotel	$ 675.000.000
Restaurants	#Customers per restaurant/year	2.500
	Turnover/guest	$ 45.000
	Resettlement/Restaurant cost	$ 300.000.000
Cost of lost rearing space and fish habitat	Biological productivity loss every 5 years	20%
	Tons of fish produced in Barranquilla in 2025	7.000
	Tons of fish lost by 2050	3.416
	Price per ton of fish	$ 13.000.000

[12] Dimar presents diagnostic of coastal erosion in the Atlantic Ocean | Colombian Maritime Portal - Dimar

Our reference: 1 – Date: March 25, 2026

sediment is dredged and disposed of in the deep sea, as there are no additional costs.

With these estimates, and supported by a detailed review of satellite images using Google Earth, the number of hotels, homes and establishments that could be affected by the natural progression of coastal erosion was calculated. From this, the analysis compares the costs derived from the damages that would occur if the material is not used.

dredging, i.e., the expected losses from continued erosion, versus the benefits of avoiding them through their use in coastal protection. Appendix 7.4 includes the Google Earth satellite imagery used to estimate the amount of housing, restaurants, and other infrastructure at risk, as well as the projected shoreline loss for the years 2030, 2040, and 2050. Below is a table (see Table 4-5) summarizing the economic and social cost benefits avoided from coastal erosion:

Table 4-5: Projected socioeconomic impacts of coastal erosion (2025 - 2050) and avoided costs.

CATEGORIES	RESULTS	2025	2030	2040	2050
Erosion	Meters of beach erosion / tideline	0	25	75	125
	Erosion area (m2)	0	77	229	393
Housing	Number of homes in danger zone	0	12	95	191
	Number of people in danger zone	0	48	380	764
	Cost of resettlement outside the danger zone	$ 0	$ 2.700.000.000	$ 21.375.000.000	$ 42.975.000.000
Hotels and other tourist accommodations in the danger zone	Number of hotels in danger zone	0	0	12	16
	Number of guests lost/year	0	0	30.000	40.000
	Lost business volume	$ 0	$ 0	$ 4.050.000.000	$ 5.400.000.000
	Cost of resettlement outside the danger zone	$ 0	$ 0	$ 8.100.000.000	$ 10.800.000.000
Restaurants	Number of restaurants in danger zone	0	1	30	42
	Number of customers lost/year	0	2.500	75.000	105.000
	Lost business volume	$ 0	$ 112.500.000	$ 3.375.000.000	$ 4.725.000.000
	Cost of resettlement outside the danger zone	$ 0	$ 300.000.000	$ 9.000.000.000	$ 12.600.000.000

Table 4-5: Projected socioeconomic impacts of coastal erosion (2025 - 2050) and avoided costs.

CATEGORIES	RESULTS	2025	2030	2040	2050
Fish farming and habitat	Tons of fish in Barranquilla	7.000	5.600	4.480	3.584
	Loss from fish production	$ 0	$ 18.200.000.000	$ 32.760.000.000	$ 44.408.000.000
Total net benefit		$ 0	$ 21.312.500.000	$ 78.660.000.000	$ 120.908.000.000

The results of the cost-benefit analysis based on the assumptions in Table 4-4 show that, although no impacts are projected in 2025, erosion progresses rapidly after 2030, generating increasing impacts on housing, population, and tourism and commercial infrastructure.

By 2050, cumulative shoreline loss exposes more than 190 homes, 16 hotels, and 42 restaurants, with total avoidable costs estimated at more than $120 billion. Such (avoided) costs consist of annual impacts (e.g., lost business volumes) and one-time costs (e.g., resettlement costs). Possible customer redistribution processes have not been taken into account.

However, these projections confirm that the use of dredged material for coastal protection represents a highly cost-effective measure, since it prevents economic and social damages that will increase at an accelerated rate in the coming decades.

Preventing coastal erosion also avoids impacts on other land functions, such as roads, small businesses and local services that depend on the stability of the coastal edge. Protecting the coastline reduces the risk of damage to road infrastructure and maintains accessibility to the area. It also benefits street vendors, whose activity depends on the flow of visitors/tourists to the beach.

Our reference: 1 – Date: March 25, 2026

5. Recommendations and next steps

5. Recommendations and next steps

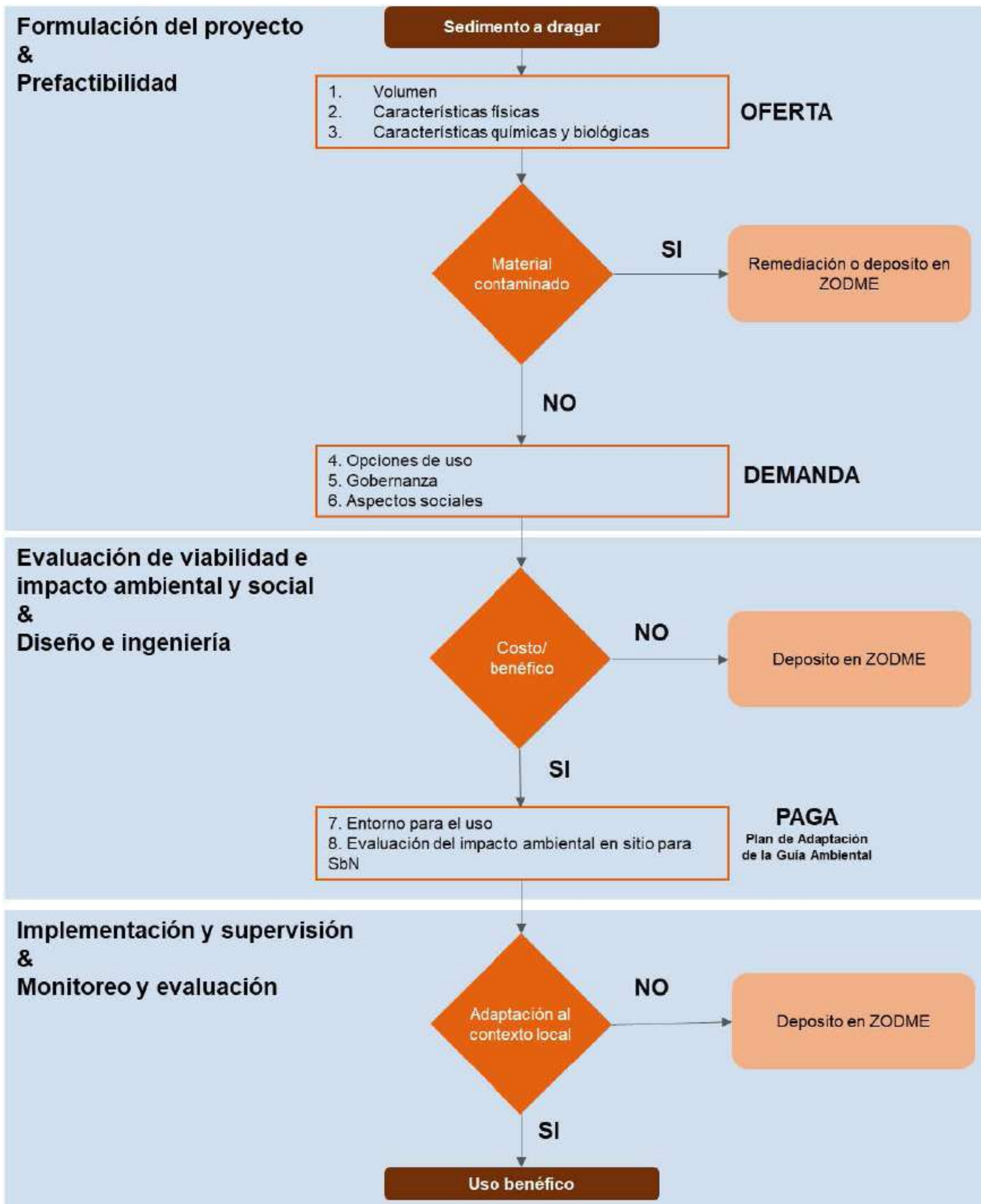


Figure 5-1 Decision Tree and Project Cycle

Our reference: 1 – Date: March 25, 2026

Deliverable 5 describes the potential for beneficial use of dredged material in the Barranquilla port area to address various environmental challenges, such as coastal erosion. It then provides a description of the alignment of the decision tree with the project cycle and what activities will need to be undertaken from technical, economic and social perspectives. However, as deliverable 4 (Chapter 5) highlights, key areas of MinAmbiente's efforts to complement Decree 1076/2015 by defining sediment quality, serving as a technical basis for the Colombian model to ensure clear standards and feasibility of final use or disposal. It is proposed to integrate these guidelines in the approval of the decree and incorporate the operational aspects in the Environmental Management Guide (INVIAS) to standardize procedures and facilitate communication between the regulatory framework and practice in dredging projects. This activity has priority as it ensures that any beneficial use of dredged material projects is executed in a manner that is safe for humans and the environment.

In the meantime, the conceptual designs described in deliverable 5 (Chapter 3) could be further developed. Figure 5-1 shows how the decision tree developed in deliverable 4 (chapter 3) can be implemented throughout the project cycle. Some steps may need to be more iterative than the figure shows, due to new information or study results. However, this can help clarify when actions and decisions need to be taken. Therefore, the priority progresses through a normal project cycle.

This chapter provides an overview of the main issues and actions to be considered in the different stages of the development of a dredged material use project. To this end, it takes as a reference the conceptual designs presented in this report and makes suggestions for their follow-up. The analysis is approached from different perspectives: social, governance, technical, economic and environmental. The table also incorporates the decision tree presented in deliverable 4 (chapter 3) and shows how the steps and decisions on material quality are articulated with the stages of the project and with the other aspects considered.

Our reference: 1 – Date: March 25, 2026

Table 5-1 Overview of next steps for developing conceptual designs into implementable and feasible projects.

THE DECISION TREE	PROJECT PHASE	SOCIAL/GOVERNANCE	TECHNICAL/ENVIRONMENTAL	COST-EFFECTIVE
Supply and demand	**Formulation of plans and projects**	It is recommended that the formulation of the projects be developed in an articulated manner with the related institutional and community actors, following the following stages: identification of actors, socialization and mapping of interests, and participatory design and consultation. The objectives, key actions, expected outputs and indicators proposed for each of these stages are detailed in the governance context of this report.	Collect and characterize information on the physical, chemical, and biological quality of the materials to be dredged and at the disposal site. Identify missing information to be obtained through pre-studies or include these studies in the scope of the maintenance dredging project before moving on to the next phase. Deliverable 3 (chapter) (Assessment of the physical and chemical quality of sediments dredged in the access channel to the port area of Barranquilla) can serve as a first base, as it describes the next steps to gather more information on the quality and quantity of the dredged material in the access channel of Barranquilla.	Align the project for the use of dredged material with the technical and operational guidelines generated by public policy on the use of dredged material. This ensures that the private sector becomes the strategic actor for the use of dredged material in coastal protection.
	Pre-feasibility	In the pre-feasibility stage, social and governance aspects should be oriented towards the identification of risks, opportunities, and enabling conditions before moving on to studies of a higher level of detail. The main objective of this phase is to determine the social viability and governance of the project. In the social component, the delimitation of the area of influence, the characterization of the general socioeconomic context, the preliminary analysis of the social impacts and the initial evaluation of the social acceptability of the project must be considered. For its part, the governance component must contemplate the mapping of actors and power analysis, the identification of the preliminary institutional and regulatory framework, the assessment of governance risks, the design of early participation and socialization strategies, as well as the identification of conditions for the social sustainability of the project.	It should be clearly established whether the sediments meet the characteristics and conditions necessary for use under the NBS approach defined for the project. The organizations involved in this process could be, in the case of Barranquilla: CORMAGDALENA, INVEMAR, the Humboldt Institute, the Colombian Geological Service, IDEAM and laboratories duly certified by this entity. In addition, the Ministry of Environment and Sustainable Development must provide recommendations on the possible beneficial uses of the dredged maintenance material so that a cost-benefit analysis of such applications can be carried out. To determine the suitability of the dredged material, a decision tree was presented in the report of Deliverable 4 (chapter 3) (Formulating procedural guidelines to determine the feasible and suitable uses of dredged marine sediments in Colombia, including nature-based solutions) to evaluate the physical, chemical and biological characteristics in general terms and by specific use.	Characterize the market around the use of dredged material (uses, quality requirements, applications, quantities, areas where it will be developed). Quantify the costs and benefits for each of the uses of the dredged material discussed in Chapter 4 of this document.
Permits and Licenses	**Environmental and social impact and feasibility assessment**	It is recommended that a comprehensive and participatory evaluation of the positive and negative impacts on the sociocultural, environmental and economic components be carried out, incorporating in a structured manner the perceptions of local communities and institutional actors. This exercise should be aimed at identifying risks, opportunities, and management measures that optimize benefits and prevent, mitigate, correct, or compensate for the negative impacts associated with the project. The evaluation must consider, among other aspects, territorial dynamics, local uses, practices and knowledge, the technical feasibility of the interventions, the costs of implementation, operation and maintenance, as well as the criteria of sustainability, governance and social appropriation in the short, medium and long term. In this phase, it is essential for the competent environmental authorities to identify, assess and validate the environmental impacts, within the framework of their legal and mission	The beneficial use of the proposed dredged material must not affect the current ecosystems defined in the Coastal Environmental Units and the social impact must be evaluated by the participation of the community where the beneficial use will be carried out. An environmental impact assessment will be conducted to better understand the risks, possible alternatives and mitigation measures. In particular, it will be necessary to thoroughly assess whether and how contaminated dredged material can be used. In the annexes to the reports of Deliverable 1 (Information, experiences and lessons learned in the licensing, operation, monitoring and control of maritime dredging activities in the Netherlands, as well as in the determination of the requirements for approving uses of dredged marine sediments in the Netherlands) and Deliverable 2 (Analysis of the parameters and procedural steps of the Netherlands and other countries, to determine the quality requirements of dredged marine sediments for their beneficial uses.	Define public and private financing tools for business development around the use of dredged material in coastal protection. Calculate the actual demand for the dredged material for each of the potential uses for coastal protection.

Our reference: 1 – Date: March 25, 2026

Table 5-1 Overview of next steps for developing conceptual designs into implementable and feasible projects.

THE DECISION TREE	PROJECT PHASE	SOCIAL/GOVERNANCE	TECHNICAL/ENVIRONMENTAL	COST-EFFECTIVE
Permits and Licenses	**Environmental and social feasibility and impact assessment**	competencies, in order to ensure the coherence of the process with current environmental regulations, territorial planning instruments and the adequate protection of associated ecosystems.	Include lessons learned to support the determination of threshold values in Colombia for beneficial uses of dredged marine sediments) detailed tables with specific threshold values for each pollutant are included.	Alinear el proyecto de uso del material de dragado con los lineamientos técnicos y operativos, generados por la política pública sobre el uso de material de dragado. Lo anterior permite garantizar que el sector privado se convierta en el actor estratégico para el uso del material de dragado en la protección costera.
Permits and Licenses	**Design and engineering**	In the design and engineering stage, it is key to integrate social and governance aspects from the beginning to ensure technical feasibility, social legitimacy and sustainability over time. Social aspects to be considered: social characterization of the area of influence, social perception of the project, potential social impacts, equity and inclusion approach. Governance aspects to be considered: participation and consultation, institutional and regulatory framework, conflict management, transparency and access to information, sustainability and co-responsibility.	Propose three (3) alternatives for use in accordance with the guidelines of the Ministry of Environment and Sustainable Development to select the best option with the social, governance, economic and environmental analyses that allow the design and recommendations for the work to be carried out with the beneficial use of the dredged maintenance material.	Generate a public-private alliance and academia for the use of dredged material in the coastal protection of Barranquilla, as a measure that is part of climate adaptation.
Beneficial use	**Implementation and monitoring**	The active participation of communities and entities in the implementation of projects must be guaranteed. Within this stage, it is recommended to develop the following actions: formation of monitoring committees, periodic evaluation meetings, linking of local labor, training processes and documentation of good practices.	Prepare a risk matrix for the contracting entity and the contractor company (dredger).	Generate a business implementation strategy, based on available quantities, costs, prices, margins and marketing strategy.
Beneficial use	**Monitoring and evaluation**	The active participation of communities and entities in the implementation of projects must be guaranteed. Within this stage, it is recommended to develop the following actions: formation of monitoring committees, periodic evaluation meetings, linking of local labor, training processes and documentation of good practices.	Establish measurement indicators and characterize the site before beneficial use and subsequent evaluation of the results.	Follow-up to the marketing strategy on the use of dredging material for coastal protection.

The steps described above constitute an important input to advance the use of dredged material, since they allow understanding the supply through the analysis of availability (quantity) and quality (chemical and physical characteristics), as well as assessing the demand through market studies and interaction with stakeholders.

Within the scope of this project, conceptual designs were made that highlight the need for specific environmental studies, such as environmental impact studies, hydrodynamic modeling and ecotoxicological studies, among others.

In general terms, it is necessary to carry out a system analysis along the entire coastline to understand the morphological dynamics and problems along the coast, especially those associated with erosion and flooding processes.

Thus, the conceptual designs presented are a first step, to be complemented by a comprehensive system-scale assessment, together with a detailed analysis of supply and demand, supported by field evaluations. For its part, the decision tree developed in this project is proposed as a guidance tool to assist decision-makers in determining the suitability of the material for different uses and identifying alternatives for the most appropriate beneficial use.

Our reference: 1 – Date: March 25, 2026

6. References

Our reference: 1 – Date: March 25, 2026

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7. Appendices

7. Appendices

7.1 Appendix A: Barranquilla Port Concessions

The port area of Barranquilla is defined as the Magdalena River from kilometer 0 to kilometer 22 (location of the Pumarejo Bridge), including the eastern and western banks up to Via 40 and the PIMSA terminal at kilometer 38 (Malambo). According to the inventory, there are 28 port terminals under CORMAGDALENA's concession in this port area.

Table 7-1 includes contractual information, such as the concession contract number, the term of the contract (start date - end date) for each of the port companies in this zone.

Table 7-1 Contractual information of concession contracts Barranquilla port area. Source: Unión Temporal Serman Saenz- Steer -INP, 2024, with information from Supertransporte and ANI.

#. (ID)	PORT COMPANY	NO. CONTRACT	START DATE	END DATE
(53)	SP. Aquamar S.A. (Contrato 045)	45 – 2011	25-Jan-11	25-Jan-31
(54)	SP. Aquamar S.A. (Contrato 046)	46 – 2011	25-Jan-11	25-Jan-31
(55)	SP Bocas De Ceniza S.A.	23 – 1998	21-Aug-98	21-Aug-28
(56)	SP Del Caribe S.A.	3 – 0035 – 2007	23-Aug-07	23-Aug-37
(57)	SP Integral De Colombia S.A. Sodintec S.A.	42 – 2010	2-Jun-10	2-Jun-40
(58)	Sociedad Portuaria Marinas Del Caribe S.A.	47 – 2011	13-Dec-11	12-Dec-31
(59)	SP. Michellmar S.A.	43 – 2010	20-Jul-10	2-Jul-30
(60)	SP. Monómeros Colombo Venezolanos S.A. (Contrato 026)	026 –2004	11-Mar-04	11-Mar-24
(61)	SP. Monómeros Colombo Venezolanos S.A. (Contrato 027)	027 – 2004	24-Apr-11	17-Mar-34
(62)	SP Omniport S.A. (Antes SP Pizano SA)	32 – 2006	26-Dec-06	27-Dec-26
(63)	SP Palermo S.A. (Contrato 028)	028 – 2004	29-Jun-04	28-Jun-24
(64)	SP Parques Urbanos S.A	019 – 1997	12-Sep-97	23-May-21
(65)	SP. Portmagdalena S.A.	3-0001-2013	30-Dec-13	29-Dec-33
(67)	SP. Regional de Barranquilla S.A. (Contrato 008)	008-1993	8-Nov-93	8-Nov-33
(68)	SP. Regional de Barranquilla S.A. (Contrato 039)	39 – 2009	22-Jul-09	21-Jul-29
(69)	SP. Río Grande S.A. (Contrato 029)	029- 2004	29-Dec-04	28-Dec-24
(70)	SP. Río Grande S.A. (Contrato 031)	031 – 2006	10-Aug-06	9-Aug-36
(71)	SP. Riomar S.A. (Antes Pescamar S.A.)	38–2008	2-Jul-09	1-Jul-30
(72)	SP. Riverport S.A.	30 – 2006	2-May-06	1-May-36
(73)	SP Terminal De Mallorquín S.A.	36 – 2007	14-Nov-07	13-Nov-37
(74)	SP Terminal Las Flores S.A.	3-0037-2008	15-Apr-08	15-Apr-28
(75)	Palermo Sociedad Portuaria S.A. (Contrato 034)	34 – 2007	14-Feb-07	14-Feb-37
(76)	SP. Barranquilla International Terminal Company S.A. – Bitco	41 – 2010	3-May-07	2-May-37
(77)	Compañía De Puertos Asociados S.A. Compas S.A.	40 – 2009	27-Feb-09	26-Feb-29
(78)	Sociedad Portuaria Siduport	44-2010	30-Dec-10	29-Dec-30
(79)	SP. Vopak Colombia S.A. (Barranquilla)	003-1993	30-Jun-13	29-Jun-33
(110)	Sociedad Portuaria Novo Porto S.A.	3-0004-2014	26-Nov-14	25-Nov-34
(80)	SP Química Internacional S.A.	NR	22-Feb-93	26-Dec-34

Taking into account the description in the table above on the contractual information and the status of the port companies, we present the following:

- **In force:** 20 in force, 12 are operating (1 under construction and 11 built) and 8 are not operating (3 built, 2 under construction and 3 not built). Of the operating concession contracts, 33% offer a specialized service from 4 concessions, of which 3 are public and 1 private, and the remaining 67% from 8 multi-property concessions, of which 7 are public and 1 private.
- **Non-current:** 8 non-current concession contracts, 1 constructed and 7 unconstructed.

Most of the concessionaires' terminals are private single-use or dedicated terminals, which handle cargo that they own. However, the majority of cargo is handled by multi-user or public terminals, which means that they handle third-party cargo. The main products handled are general cargo, bulk cargo, coal, liquids and containers.

Of the contracts that are in force and not operating, the following is described:

- Aquamar S.A.'s SP does not have infrastructure built in the adjacent area and neither in the public use area, therefore, it is not operating.
- SP. Omniport S.A. (formerly SP Pizano SA) is not operational because it is in the pre-operational phase; therefore, no docking activities are being carried out. Given the natural configuration of the terrain, it is not necessary to carry out any type of adaptation or undertake major infrastructure works, except for the installation of a mobile pier for crew embarkation and disembarkation.
- SP. Palermo S.A. is not in operation, since according to the final report of the Inter Magdalena Consortium, the Concessionaire executed the entire technical and financial scope of its investment plan.

- The port companies of Rio Grande 029 and Rio Grande 031, both have a dock, but are still under construction.
- Sociedad Portuaria Del Caribe S.A. has only completed phase I of the land development project, and phase II of the project has yet to be executed.
- SP Terminal De Mallorquín S.A. does not have an approved investment plan and has not executed it.
- SP Terminal Las Flores S.A., the concession did not grant infrastructure or equipment, only areas for public use.
- Of the contracts that are not in force, the following is described:
    - SP. Aquamar S.A. 046, the contract has been terminated in advance due to an arbitration ruling, while the contract of SP.
    - Integral de Colombia S.A. Sodintec S.A., was terminated by mutual agreement.
    - SP Parques Urbanos S.A. was completed on May 23, 2021.
    - SP. Bocas de Ceniza S.A. has expired. The contractual term with Sociedad Portuaria Parques Urbanos S.A. has expired.
    - SP. Siduport did not make the investments that were included in its Investment Plan; therefore, the Port Terminal submitted a request to Cormagdalena to terminate the concession contract by mutual agreement between the parties.
    - SP. Química Internacional S.A. did not make the investments that were included in its Investment Plan; therefore, the Contract with the Grantor was terminated by mutual agreement.
    - SP. Novo Porto S.A.'s contract was terminated early.
    - Sociedad Portuaria Regional de Barranquilla S.A. was terminated early by mutual agreement.

Of the terminals currently in operation, there are five terminals specialized in: passengers, bulk monomers, liquid chemical products, hydrocarbons and fishing. The rest are multipurpose, such as liquid and solid bulk, containers, general cargo, coal, coke, among others.

Below, in Figure 7-1, the information is shown in the figures through a visualization of the concessioned public use assets and adjacent areas in the port area of Barranquilla.

Figure 7-1 Delimitation of concessioned public use property and adjacent areas. Barranquilla port area. Source: Unión Temporal Serman Saenz- Steer - INP, 2024, with information from ANI and Cormagdalena, 2024.

7.2 Appendix B: Characterization of the Coastal Environmental Unit (UAC) of the Magdalena River in the port area of Barranquilla.

7.2.1 Abiotic Environment

- **Climatology and meteorology**

Average maximum temperatures in the north of the UAC vary between January-April and July-August, while the lowest temperatures are observed between May-June and September-December, reaching up to 33° C. In the south, there is a monomodal pattern with high temperatures between April and September. Precipitation ranges from 0.3 to 9.5 mm during the dry season (January-March) and from 3.7 to 256 mm in the wet season (April-December), decreasing from June to September. Relative humidity averages 70%, with higher values during the wet periods. Evapotranspiration reaches about 1700 mm/year, coinciding with drought periods. Winds show maximum magnitudes in February and March and lower values from May to November, with a predominantly south-southwest direction. The climatic classification is warm dry.

- **Hydrology, water uses and water use conflicts**

The port area of the port of Barranquilla is located within the hydrographic subzones Ciénaga de Mallorquín, Ciénaga Grande de Santa Marta and Directos al Bajo Magdalena between Calamar and the mouth of the Caribbean Sea (mi). According to the UAI, it is between very high and critical because the basin has exhausted its surface water availability to meet the water requirements of economic activities. Water use conflicts are evident in this zone due to high demand and low surface water availability.

- **Air and noise pollution**

The annual PM10 concentrations are not exceeded in accordance with the air quality standard. The air quality index during the year is between "good" and "acceptable", where it indicates possible respiratory symptoms in sensitive population groups (Corpomag, 2023). In terms of noise pollution, the maximum permissible limit for daytime hours is not met; in hotel occupancy zones, these levels exceed the established decibels.

- **Geology**

In Figure 7-2 Map of geological units of the Barranquilla Port Zone. Source: Unión Temporal Serman Saenz- Steer - INP, 2024 based on (SGC, 2015) and (INVEMAR, 2008) Figure 7-2 shows the geological units of the Barranquilla Port Zone.

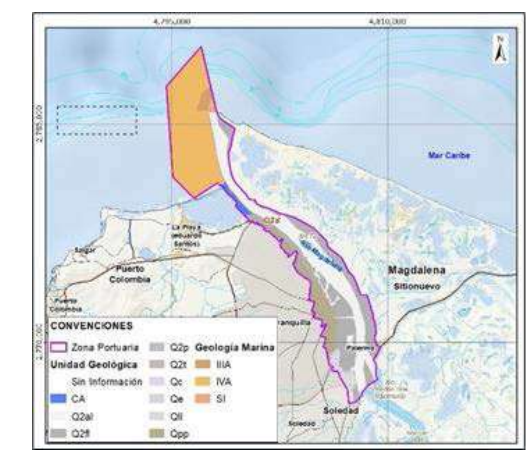

Figure 7-2 Map of geological units of the Barranquilla Port Zone. Source: Unión Temporal Serman Saenz- Steer - INP, 2024 based on (SGC, 2015) and (INVEMAR, 2008).

- **Geomorphology**

The following figure shows the geomorphological units of the Barranquilla Port Zone.

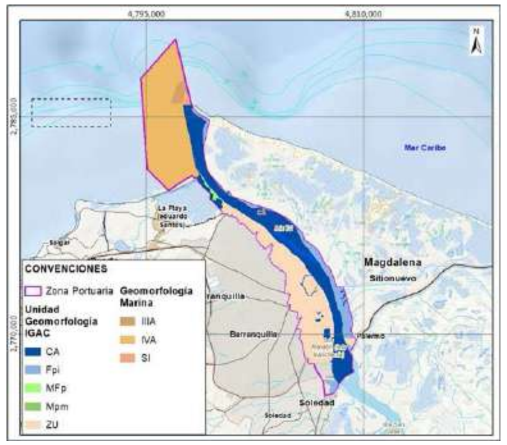

Figure 7-3 Map of geomorphological units of the Barranquilla Port Zone. Source: Unión Temporal Serman Saenz- Steer - INP, 2024 based on (IGAC, 2017) and (INVEMAR, 2011).

- **Hydrogeology**

The following figure shows the hydrogeologic units of the Barranquilla Port Zone.

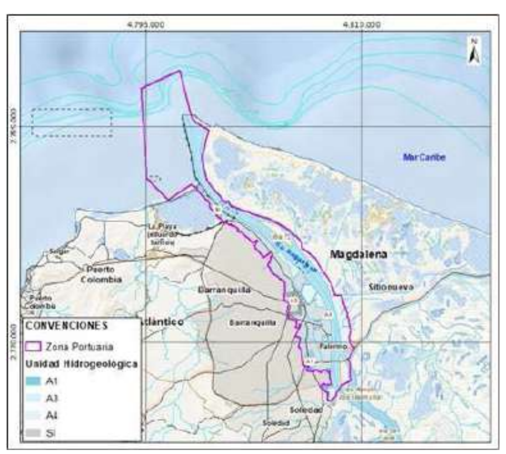

Figure 7-4 Map of hydrogeological units of the Barranquilla Port Zone. Source: Union Temporary Union Serman Saenz-Steer - INP, 2024 based on (INGEOMINAS, 2003).

7.2.2 Biotic Environment

- **Land Cover**

For the Barranquilla port area, marine coverage is the most extensive, covering 2,827.13 hectares, representing 39.15% of the total. The river occupies 1,727.71 hectares, equivalent to 23.92%. Coastal marshes cover 196.51 hectares, or 2.72%, while aquatic vegetation on water bodies has an area of 92.90 hectares, representing 1.29%. Natural grasslands cover 137.45 hectares, or 1.90%, and low dense forest occupies 34.04 hectares, corresponding to 0.47%. Coastal lagoons cover 61.59 hectares, or 0.85%, while marshy areas cover 57.23 hectares (0.79%). Natural sandy areas cover 15.33 hectares, representing 0.21%, and lagoons occupy 0.49 hectares, or 0.01%. Finally, beaches cover a minimal area of 0.02 hectares, or 0.00%.

Artificialized territory is the main anthropized cover, with 1,702.02 hectares, representing 23.57% of the total. Crop and pasture mosaics occupy 138.07 hectares (1.91%), and crop, pasture and natural spaces mosaics cover 131.90 hectares (1.83%). Mosaics of pasture and natural areas cover 99.78 hectares (1.38%). Table 7-2 shows the land cover for the Barranquilla Port Zone.

Table 7-2 Coverages in the Barranquilla port area

COBERTURA	ÁREA HA	%
Bosque denso bajo	34,04	0,47
Laguna	0,49	0,01
Laguna costera	61,59	0,85
Marino	2827,13	39,15
Mosaico de cultivos y pastos	138,07	1,91
Mosaico de cultivos, pastos y espacios naturales	131,90	1,83
Mosaico de pastos con espacios naturales	99,78	1,38
Pantano costero	196,51	2,72
Pastos	137,45	1,90
Playas	0,02	0,00
Rio	1727,71	23,92
Territorio artificializado	1702,02	23,57
Vegetación acuática sobre cuerpos de agua	92,90	1,29
Zonas arenosas naturales	15,33	0,21
Zonas pantanosas	57,23	0,79
	7222,19	**100,00**

The following figure shows the location of the land cover units within the polygon of the Barranquilla Port Zone.

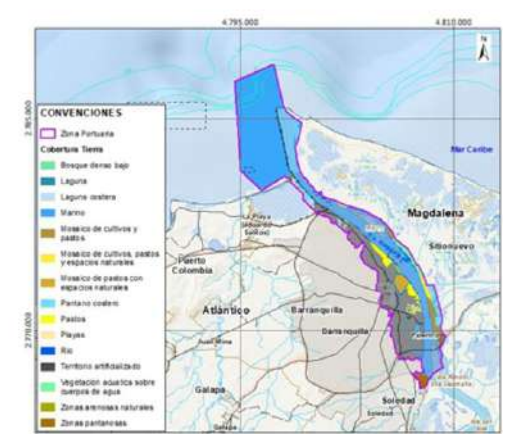

Figure 7-5 Land Cover Units in the Barranquilla Port Zone

- **Protected Areas**

The following figure shows the location of the National Natural Park Via Salamanca Island Park with respect to the polygon of the Barranquilla Port Zone.

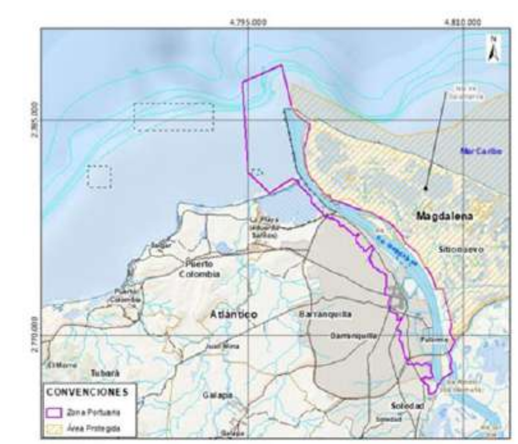

Figure 7-6 Location of the PNN Protected Area Via Salamanca Island Park

7.3 Appendix C: Diagnosis of the Coastal Zone between Castillo de Salgar, Punta Roca and Ciénaga de los Manatíes.

The stretch between Castillo de Salgar and Playas del Country is classified as an actively receding coast, with average erosion rates of 1.5 to 3.5 meters per year, reaching more than 5 meters in unprotected areas. Although works such as the spurs have stabilized specific sectors, they do not solve the regional sediment deficit, leaving neighboring areas exposed, such as the Archdiocese sector. The technical literature warns that major interventions, such as the proposed marina at Castillo de Salgar, could further alter coastal transport, so comprehensive solutions are required at the regional scale and not isolated measures.

In the Punta Roca sector, coastal vulnerability is accentuated by soft rock geology susceptible to marine erosion and by wave patterns that shift sediments to the southwest. This natural instability has been aggravated by human intervention, including unplanned urbanization that overloads slopes and shell extraction that eliminates natural protective barriers. Despite being diagnosed as a high threat zone, there is a fragmentation of specific data on local retreat rates and a lack of concrete coastal defense or management plans for this specific point.

Finally, in the Ciénaga de los Manatíes it suffers critical deterioration marked by marine intrusion, mangrove loss and hypersalinity, caused by the obstruction of its connection with the León stream and the disorderly urban expansion that has reduced its buffering capacity. To mitigate its ecological collapse, experts recommend restoring water exchange and controlling anthropogenic sedimentation through continuous monitoring.

The following figure shows the location of the mouth of the Magdalena River and the three sectors under study. Later, in different chapters, the results of a research of studies, articles, documents carried out by INVEMAR (Institute of Marine and Coastal Research), CRA (Corporación Autónoma Regional del Atlántico: Home), Universidad del Norte, articles, among others, are presented.

7.3.1 Erosion of Castillo de Salgar and Salgar beach.

The town of Salgar, in the municipality of Puerto Colombia, is located within one of the most dynamic and fragile stretches of the Colombian Caribbean coast. The technical evidence compiled by university studies, particularly those developed by the Universidad Nacional and the Universidad del Norte, shows that coastal erosion in this sector does not respond to a specific or recent phenomenon, but to a regional morphodynamic process active since the mid-20th century, intensified by anthropic interventions and by the reorganization of the sedimentary system associated with the Magdalena River.

The study by Vargas (2012), based on multi-temporal analyses of coastline between 1935 and 2009 using remote sensing and GIS, shows that the coast between Punta Sabanilla and Puerto Colombia—where Salgar is inserted—has experienced a sustained migration of sand bars and beaches in a northeast-southwest direction. This process has generated a progressive loss of beach width, the fragmentation of old sand bars and the direct exposure of coastal slopes, which coincides with INVEMAR's most recent diagnoses of chronic sedimentary deficit in this stretch of the coast.

From a geomorphological point of view, Salgar is characterized by a mixed coastline, where sandy beaches of low stability alternate with rocky outcrops associated with outcrops of the La Popa Formation. Vargas (2012) identifies that these lithological units present low mechanical strength, with poorly compacted sandstones and clays that, when exposed to direct wave action, develop simultaneous processes of basal marine erosion and mass removal. This condition explains the high vulnerability of the Castillo de Salgar sector, where the presence of isolated reef blocks generates coastal ledges that temporarily resist erosion, but induce wave energy concentration on the adjacent flanks, accelerating the erosion process and retreat of the coastline.

The dynamic analysis carried out in the studies reviewed confirms that the erosive behavior of Salgar is mainly controlled by the dominant coastal transport, induced by incident waves from the northeast and persistent coastal currents to the southwest. The historical migration of marine sand bars is evidence that much of the available sediment moves out of the Salgar beach system, with no possibility of natural replenishment. This pattern is consistent with the conceptual models of INVEMAR and DIMAR, which indicate that the North Atlantic coastal system currently functions as an open system with net sediment loss.

Anthropic influence has been a determining factor in the acceleration of these processes. Vargas (2012) points out that the channeling of the Magdalena River in Bocas de Ceniza profoundly altered the regional distribution of sediments, favoring deposition in deep areas and reducing the effective contribution to the Atlantic beaches. In addition, the intensive occupation of the coastal edge in Salgar and in the Country beaches sector, where the construction of houses, roads and rigid structures on denuded marine terraces has increased the overburden on the coastal slopes and reduced the natural wave dissipation capacity. Evidence of landslide processes associated with these overloads is recurrent in the intervened sectors.

More recent studies by the Universidad del Norte, such as that of Anaya (2022), reinforce this diagnosis by pointing out that the current coastal dynamics in Salgar correspond to a highly unstable morphodynamic state, where extreme wave events—associated with cold fronts and swells—generate abrupt retreats of the coastline, without clear recovery phases. This behavior confirms that the sector's beaches have lost their natural resilience and depend, in practice, on artificial interventions for their permanence.

This is the context of the protection works carried out on the Country and Salgar beaches by the Governor's Office of the Atlántico and the Mayor's Office of Puerto Colombia. The spur-type structures have allowed stabilizing specific sectors and recovering beach widths locally, but they do not modify the regional sedimentary imbalance. The studies warn that without a periodic artificial filling scheme and without longitudinal continuity of the works, the erosive processes tend to move to neighboring sectors, maintaining the problem on a regional scale.

In the case of Castillo de Salgar, the academic literature agrees that any intervention should prioritize the protection of the foot of the slope from marine scour and the control of surface drainage, rather than the development of major infrastructure such as marinas. Available studies indicate that a poorly located marina could further alter coastal transport and generate additional erosive impacts downstream, which is why the Government has not moved forward with its implementation without conclusive hydrosedimentological studies.

Finally, in the sector associated with the Archdiocese, the technical diagnoses of the CRA and the patterns identified by Vargas (2012) show that this is an area inserted within the same active erosive system, characterized by the absence of functional beaches and direct exposure of infrastructure to waves. The lack of interventions to date is not due to the absence of a diagnosis, but to the technical complexity of acting in a coastal system that requires comprehensive and not punctual solutions.

In summary, the integration of INVEMAR, DIMAR and CRA studies confirms that erosion in Salgar is a structural process, controlled by the regional coastal dynamics, the sediment deficit induced by the Magdalena River and the high anthropic intervention of the coastal edge. From a coastal engineering perspective, any effective solution must be conceived on a regional scale, combine hard and soft works, and incorporate continuous monitoring of the coastline, since isolated interventions only offer temporary relief in the face of a highly active morphodynamic system.

The behavior of the coastline through multi-temporal studies by DIMAR-CIOH Caribe, based on analysis of aerial photographs and satellite images (1954-2022), classify the Castillo de Salgar - Playa de Salgar stretch as a "coastal zone". Salgar - Playa de Country as a coast in active retreat, with average erosion rates ranging from 1.5 m/year to 3.5 m/year in open sectors and punctual values higher than 5 m/year in areas without control structures. INVEMAR also found that the sector may have mean sea level increases between 2.8 and 3.6 mm/year for the Colombian Caribbean.

7.3.2 Coastal erosion in Punta Roca

Morphodynamic characteristics: Punta Roca is part of the rocky platform of the North Colombian Caribbean. Geologically, the La Popa Formation (Miocene-Pliocene) outcrops, composed of calcareous sandstones with intercalations of reef limestones. In particular, the La Popa unit Qpp3 consists of "white and yellow sands with levels of clays and large lumps of reef limestones" of medium to coarse grain, "friable and friable". This soft lithology favors marine erosion. Morphologically, Punta Roca is characterized by a rocky cliff adjacent to narrow sand and shell beaches. The dominant swell comes from the northeast, generating coastal currents to the southwest that transport sediments from the mouth of the Magdalena River towards Punta Roca. This pattern has led to the accumulation of sand bars and beaches to the southwest, shaping the coastal morphology of the sector. The coast of Punta Roca presents dynamic sandy barriers (bars and mobile beaches) together with carbonate rock escarpments susceptible to scour, in a framework of rapid coastal migration.

Regarding the possible causes of coastal erosion, available data show a clear process of coastal retreat in Punta Roca and neighboring areas. Multitemporal studies in Puerto Colombia report "large retreats in its coastline" attributable to intense marine erosion and landslides on slopes saturated by built-up overburden. It is estimated that the continuous migration of sediment from the NE to the SW could, which directly affects the Punta Roca shoreline. Although there are no published point measurements for Punta Roca alone, the CRA documents that between 2004 and 2025 the shoreline in the nearby Ciénaga de los Manatíes receded significantly, with loss of mangrove and widening of the lagoon; satellite images from 2016 vs. 2025 show increased water mirror and lighter tonality of the terrain, indicative of marine intrusion in the coastal bar. In addition, INVEMAR reported "inadequate" marine-coastal water quality conditions in Punta Roca (high concentrations of suspended solids and nutrients) during field assessments, reflecting the high sediment load and organic matter mobilized by erosion (Invemar Informe Del Estado de Los Recursos Marinos de Colombia - 2010).

Human impacts have amplified coastal erosion in Punta Roca. Unregulated urbanization along the coastal strip (housing construction) increases runoff and overloads coastal slopes, generating mass removal and exposing soils to marine attack. Recent studies denounce the indiscriminate extraction of mollusk shells on the beaches of Punta Roca, an activity for decorative uses that eliminates the natural "refuge" of fauna and sediment-stabilizing materials. In this regard, it is noted that "by removing them, problems such as coastal erosion are exacerbated". Fragmentation and foundations on the coast reduce sand accumulation spaces and damage coastal vegetation (mangroves, herbaceous species) that act as a protective barrier. In the Punta de Roca sector, unplanned occupation has locally intensified erosion processes.

The erosion phenomenon in Punta Roca is complex and requires integrated approaches. The official and academic sources consulted (INVEMAR, CRA, Universidad del Norte, Atlántico) coincide in the general diagnosis: Punta Roca is a sector of high coastal vulnerability with clear erosive tendencies. However, specific information is fragmentary. Many studies cited (e.g., Vargas 2012, Rivillas-Ospina et al.) cover the Puerto Colombia coastline as a whole or contiguous sectors (Ciénaga de Mallorquín), so localized retreat and dynamics data for Punta Roca in particular are lacking. This complicates the quantification of current erosion rates. Furthermore, although natural (high tides, storm surges, ENSO events) and anthropogenic causes are recognized, their relative weight at the site is not always distinguished. The measures proposed lack solid coordination: for example, despite the high risk warning, there is no concrete published plan for coastal defense or management works. In addition, regulatory instruments (POMCA Atlántico, Plan de Ordenamiento Territorial) need to be better integrated with coastal management. In summary, erosion in Punta Roca requires a rigorous coastal adaptation strategy, supported by updated technical data and the commitment of environmental and planning authorities.

7.3.3 Erosion and environmental degradation of the Ciénaga de los Manatíes.

The Ciénaga de los Manatíes is a shallow coastal lagoon located on the northwestern border of the department of Atlántico, in the jurisdiction of the municipality of Puerto Colombia. This body of water is located in sub-basin 1401-1 of the Atlantic coast basin, characterized by an elongated shape and a sand bar of approximately 0.63 km that separates it from the Caribbean Sea, which historically regulated its hydraulic dynamics between freshwater inflows from runoff and seasonal marine pulses from the Caribbean (Ariza-Pérez, D. & I. M. León-Luna, M. 2020. Spatio-temporal variation of the phytoplankton community of the Ciénaga de los Manatíes, Atlántico, Colombia. Cymbella 6(2): 63-77).

The deterioration of the Ciénaga de los Manatíes has been accompanied by significant morphodynamic and ecological changes. Multitemporal monitoring carried out by the Corporación Autónoma Regional del Atlántico (CRA) has shown a reduction of the mangrove forest associated with the water body, as well as a change in its coloration observable through satellite images, which is interpreted as marine intrusion and loss of depth of the water mirror. These observations coincide with the process described by experts, according to which the connectivity between the León stream and the marsh was obstructed by civil works and drainage alterations, causing a transformation of the original estuarine dynamics towards a regime dominated by higher salinity and a reduction of habitat for species linked to less saline conditions.

Although exclusive technical studies for the Ciénaga de los Manatíes are less abundant than for other major lagoon systems (such as the Ciénaga de Mallorquín or the Ciénaga Grande de Santa Marta), the zoning updated by INVEMAR and CRA classifies this wetland within zones of high coastal vulnerability. This is due to the combination of erosion of the adjacent coastline, loss of hydrophilic vegetation (mangroves), and changes in the hydrological dynamics generated by the alteration of river channels and drainage in the region (Update and adjustment of the diagnosis and zoning of mangroves in the coastal zone of the Department of Atlántico, Colombian Caribbean. INVEMAR. June 2005).

In addition to these natural factors, the degradation of the Ciénaga de los Manatíes is strongly influenced by anthropogenic pressures. The expansion of riverside constructions such as cabins and clubs around the marsh has reduced the natural vegetation cover and diminished the wetland's capacity to buffer changes in salinity and sedimentation. Environmental experts have pointed out that this informal occupation not only alters the landscape, but also contributes to the loss of biodiversity and the institutional invisibility of the ecosystem, making it difficult to monitor and manage in a participatory manner.

Although the Ciénaga de los Manatíes is a lagoon ecosystem and not a coastal ecosystem per se, its situation is closely linked to the coastal erosion process and the coastal dynamics of the North Atlantic. Technical publications on coastal erosion in the Colombian Caribbean, prepared by INVEMAR, show that erosion not only affects beaches, but also contributes to the modification of coastal lagoons and bodies of water associated with the coast, displacing sediments that influence the morphology of the sand bars and, therefore, the connection between lagoon and sea. This means that well-studied changes in coastal transport and erosion patterns by INVEMAR can be reflected in the dynamics of adjacent marshes such as Los Manatíes.

Management and mitigation of the deterioration of the Ciénaga de los Manatíes requires, according to available technical sources, an integrated and multidimensional approach. Assessments by the CRA and environmental experts agree on the need to restore water exchange between freshwater sources and the Caribbean Sea, recover mangrove cover, control anthropogenic sedimentation sources, and design drainage systems that allow functional connectivity throughout the year. This also implies the rehabilitation of fluvial corridors such as the León stream and the creation of long-term monitoring programs for salinity, dissolved oxygen and physicochemical water parameters, possibly in alliance with networks such as REDCAM developed by the CRA and INVEMAR for coastal and lagoon environmental monitoring.

Technically, the phenomenon of degradation of the Ciénaga de los Manatíes can be interpreted as a combination of processes of siltation, hydraulic alteration, saline intrusion, and loss of riparian vegetation, exacerbated by coastal erosion and coastal occupation. If comprehensive measures based on continuous scientific monitoring and territorial planning aligned with the natural dynamics of the system are not implemented, this lagoon ecosystem could continue to lose ecological functionality and its capacity to act as a biological and physical buffer against extreme climatic events.

Our reference: 1 – Date: March 25, 2026

7.4 Appendix D: Google Earth imagery for cost benefit analysis

Illustration 7-1: Erosion area - 2030

Table 7-3: Coordinates of Erosion Areas 2030

X	Y	Z	NAME
-74,92254117	11,03846118	0	Line Measure - 2030 #12
-74,9349147	11,02039694	0	Line Measure - 2030 #13
-74,93644197	11,01991165	0	Line Measure - 2030
-74,9268393	11,02474299	0	Line Measure - 2030 #2
-74,92833543	11,02373324	0	Line Measure - 2030 #3
-74,92975515	11,02260844	0	Line Measure - 2030 #5
-74,93153249	11,02195595	0	Line Measure - 2030 #6
-74,93297425	11,02141108	0	Line Measure - 2030 #7
-74,92418802	11,02684248	0	Line Measure- 2030 #8
-74,921741	11,02924463	0	Line Measure - 2030 #9
-74,92113936	11,03288717	0	Line Measure - 2030 #10
-74,92133686	11,03577102	0	Line Measure - 2030 #11
-74,92294914	11,02805971	0	Area - 2030

Illustration 7-2: Erosion Area - 2040

Table 7-4: Coordinates of Erosion Areas 2040

X	Y	Z	NAME
-74,92401402	11,02674865	0	Line measure - 2040
-74,93635265	11,01957987	0	Line Measure - 2040 #1
-74,93476159	11,0200893	0	Line Measure - 2040 #2
-74,93284052	11,02109149	0	Line Measure - 2040 #3
-74,93141973	11,02162842	0	Line Measure - 2040 #4
-74,92957615	11,02230091	0	Line Measure - 2040 #5
-74,92814372	11,02344379	0	Line Measure - 2040 #6
-74,92662708	11,02446542	0	Line Measure - 2040 #7
-74,925256	11,02563522	0	Line Measure - 2040 #8
-74,92390155	11,02678934	0	Line Measure - 2040 #9
-74,92143691	11,02906837	0	Line Measure - 2040 #10
-74,92074598	11,03142242	0	Line Measure - 2040 #11
-74,92078943	11,03285496	0	Line Measure - 2040 #12
-74,92059821	11,03439046	0	Line Measure - 2040 #13
-74,92098514	11,03577473	0	Line Measure - 2040 #14
-74,92218424	11,03846377	0	Line Measure - 2040 #15
-74,92267897	11,02800553	0	Area 2040

Illustration 7-3: Erosion Area 2050

Table 7-5: Coordinates of erosion areas 2050

X	Y	Z	NAME
-74,93623042	11,01913937	0	Line Measure - 2050 #1
-74,93456936	11,01967641	0	Line Measure - 2050 #2
-74,9326771	11,02066157	0	Line Measure - 2050 #2
-74,93126184	11,02119863	0	Line Measure - 2050 #3
-74,92935115	11,02190068	0	Line Measure - 2050 #4
-74,9279038	11,02304691	0	Line Measure - 2050 #5
-74,92636094	11,02407832	0	Line Measure - 2050 #6
-74,92353878	11,02634251	0	Line Measure - 2050 #7
-74,92102672	11,02882895	0	Line Measure - 2050 #8
-74,92017894	11,03134773	0	Line Measure - 2050 #9
-74,92032788	11,03280436	0	Line Measure - 2050 #10
-74,92001881	11,03435972	0	Line Measure - 2050 #11
-74,92051898	11,03579527	0	Line Measure - 2050 #12
-74,92172554	11,03847936	0	Line Measure - 2050 #13
-74,92144382	11,0290085	0	Area 2050

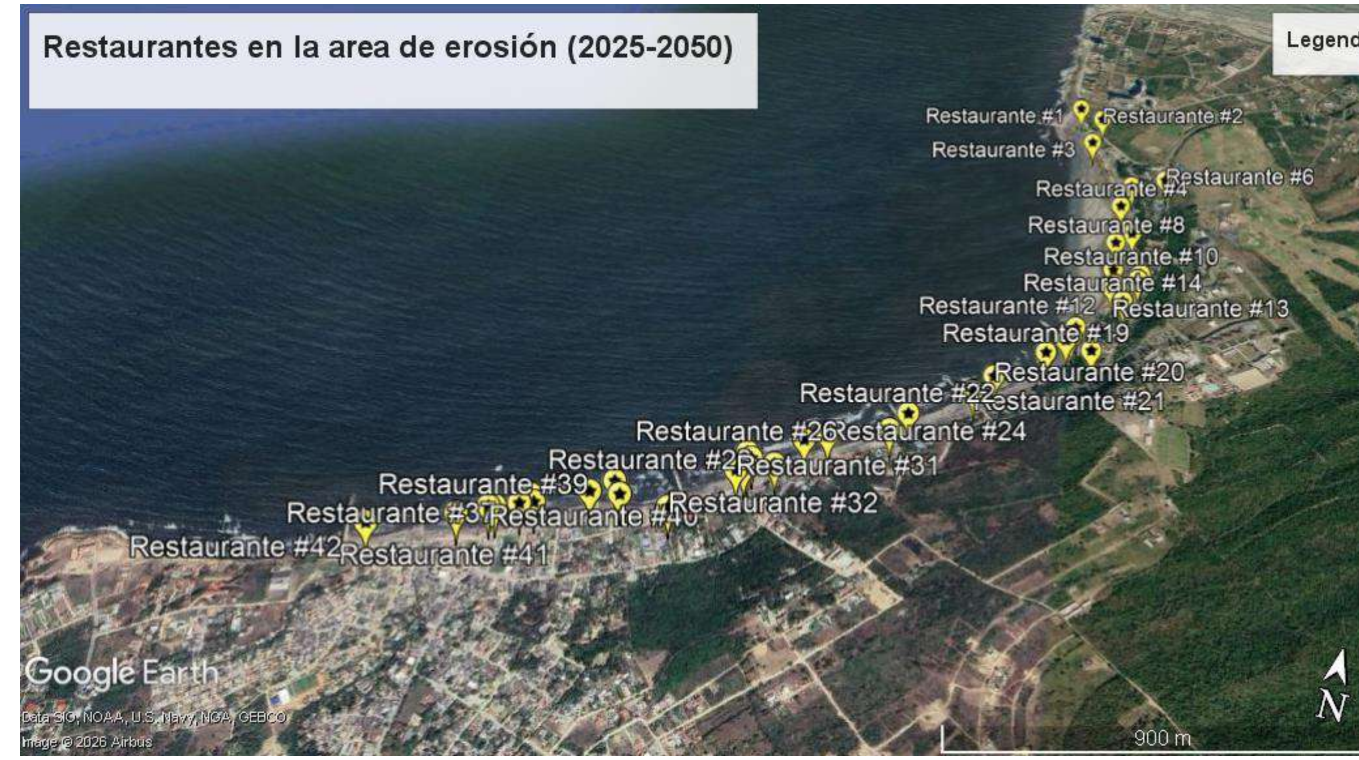

Illustration 7-4: Erosion Area Restaurants (2025-2050)

Table 7-6: Coordinates of Restaurants in the Erosion Area (2025-2050)

X	Y	Z	NAME
-74,92191211	11,03839514	0	Restaurante #1
-74,92128943	11,03799773	0	Restaurante #2
-74,92153135	11,03678176	0	Restaurante #3
-74,92070124	11,0340588	0	Restaurante #4
-74,92042694	11,03499637	0	Restaurante #5
-74,9195299	11,03549619	0	Restaurante #6
-74,92039929	11,03297065	0	Restaurante #7
-74,92080705	11,03249265	0	Restaurante #8
-74,92084846	11,0313956	0	Restaurante #9
-74,92017071	11,03138111	0	Restaurante #10
-74,92023981	11,03115492	0	Restaurante #11
-74,92078766	11,03082399	0	Restaurante #12
-74,92086583	11,03069362	0	Restaurante #13
-74,92059932	11,03026834	0	Restaurante #14
-74,92169463	11,02904566	0	Restaurante #15
-74,92179192	11,02869988	0	Restaurante #16
-74,92190484	11,0285516	0	Restaurante #17
-74,9213017	11,02835125	0	Restaurante #18
-74,9223441	11,02802872	0	Restaurante #19
-74,9234813	11,02695148	0	Restaurante #20
-74,92389925	11,02633945	0	Restaurante #21
-74,9252685	11,02532284	0	Restaurante #22
-74,92561215	11,02474133	0	Restaurante #23
-74,9269291	11,02423562	0	Restaurante #24
-74,92741088	11,02398502	0	Restaurante #25

Table 7-6: Restaurant Coordinates in the Erosion Area (2025-2050)

X	Y	Z	NAME
-74,92855331	11,02333629	0	Restaurante #26
-74,9284329	11,02319379	0	Restaurante #27
-74,92790732	11,02315274	0	Restaurante #28
-74,92848116	11,02295685	0	Restaurante #29
-74,92853307	11,02285596	0	Restaurante #30
-74,92869146	11,02279422	0	Restaurante #31
-74,92985315	11,02147211	0	Restaurante #32
-74,93094828	11,0215501	0	Restaurante #33
-74,93115818	11,02186078	0	Restaurante #34
-74,93159446	11,02146805	0	Restaurante #35
-74,93277381	11,02106748	0	Restaurante #36
-74,93294761	11,02080318	0	Restaurante #37
-74,93266227	11,02090622	0	Restaurante #38
-74,93342626	11,02060492	0	Restaurante #39
-74,93355632	11,02056231	0	Restaurante #40
-74,93415099	11,02023721	0	Restaurante #41
-74,93589724	11,0195511	0	Restaurante #42

Ilustración 7-5: Viviendas en el área de erosión (2025-2050)

Table 7-7: Coordinates for housing in the erosion area (20202 - 2050)

X	Y	Z	NAME
-74,92051176	11,03255322	0	V1
-74,92060797	11,03250556	0	V2
-74,92044876	11,03267527	0	V3
-74,92054639	11,03233398	0	V4
-74,92063212	11,03203608	0	V5
-74,92061196	11,03145828	0	V6
-74,92050858	11,03140094	0	V7
-74,92034544	11,03123488	0	V8
-74,9205024	11,03116173	0	V9
-74,92051044	11,03098324	0	V10
-74,92072239	11,03038533	0	V11
-74,92101375	11,03090073	0	V12
-74,9205115	11,03084644	0	V13
-74,92063197	11,03029212	0	V14
-74,92068854	11,03016011	0	V15
-74,92098286	11,03021983	0	V16
-74,92109861	11,03031635	0	V17
-74,92073494	11,02999568	0	V18
-74,92086509	11,02977067	0	V19
-74,92160185	11,02984821	0	V20
-74,92177987	11,02997321	0	V21
-74,92178685	11,0295998	0	V22
-74,92119417	11,02993285	0	V23
-74,92089877	11,02960011	0	V24
-74,92118867	11,02959798	0	V25
-74,92127939	11,02976	0	V26
-74,92135162	11,02955008	0	V27
-74,92100676	11,02939826	0	V28
-74,92116985	11,02928697	0	V29
-74,92169043	11,02941657	0	V30
-74,92102401	11,02921984	0	V31
-74,92165011	11,02912363	0	V32
-74,92179145	11,02876701	0	V33
-74,92189788	11,02855406	0	V34
-74,92130887	11,02842491	0	V35
-74,92161235	11,0281529	0	V36
-74,9217151	11,02799921	0	V37
-74,92250493	11,02789115	0	V38
-74,92228104	11,02752522	0	V39
-74,9222392	11,02745078	0	V40
-74,92232094	11,02741609	0	V41
-74,92227647	11,02737012	0	V42
-74,92252267	11,02726241	0	V43
-74,92279183	11,02715687	0	V44
-74,92295972	11,02715926	0	V45
-74,92287661	11,02701701	0	V46
-74,92319529	11,02694955	0	V47
-74,92342421	11,02702599	0	V48
-74,92352953	11,02692172	0	V49
-74,92361263	11,02642927	0	V50
-74,9236616	11,02652338	0	V51
-74,92374023	11,02663689	0	V52
-74,92420296	11,02612211	0	V53
-74,92446926	11,02609804	0	V54
-74,92430697	11,02586109	0	V55
-74,92449793	11,02583687	0	V56

Table 7-7: Housing coordinates in the erosion area (20202 - 2050)

X	Y	Z	NAME
-74,92482759	11,02572716	0	V57
-74,92472222	11,02558051	0	V58
-74,92497224	11,02537256	0	V59
-74,92522978	11,02534465	0	V60
-74,92573793	11,0249781	0	V61
-74,92594029	11,02490862	0	V62
-74,92603098	11,02491908	0	V63
-74,92592129	11,0248188	0	V64
-74,92634923	11,02464941	0	V65
-74,926421	11,02457631	0	V66
-74,92585509	11,02455785	0	V67
-74,92575422	11,02445032	0	V68
-74,92543121	11,02440518	0	V69
-74,92561488	11,02441453	0	V70
-74,92686237	11,02456238	0	V71
-74,92678022	11,02384542	0	V72
-74,92724249	11,02414858	0	V73
-74,92698812	11,02398808	0	V74
-74,92713155	11,02378216	0	V75
-74,92785843	11,0239776	0	V76
-74,92729189	11,02355861	0	V77
-74,92798369	11,02341633	0	V78
-74,92818625	11,02307748	0	V79
-74,92794368	11,02318931	0	V80
-74,92804327	11,02287283	0	V81
-74,92849474	11,02291905	0	V82
-74,92872642	11,02303802	0	V83
-74,92905509	11,02292468	0	V84
-74,92914367	11,02290752	0	V85
-74,92869201	11,02257673	0	V86
-74,92811511	11,02266596	0	V87
-74,92835027	11,02261627	0	V88
-74,92893317	11,02249649	0	V89
-74,92906258	11,02241941	0	V90
-74,92939757	11,02219488	0	V91
-74,92958649	11,02237497	0	V92
-74,92993629	11,02225973	0	V93
-74,92958863	11,02206269	0	V94
-74,92927022	11,02184291	0	V95
-74,92982295	11,0218482	0	V96
-74,92946413	11,02173064	0	V97
-74,93045435	11,02182173	0	V98
-74,93073374	11,02176934	0	V99
-74,93115368	11,02112929	0	V100
-74,9309682	11,02158209	0	V101
-74,93146025	11,0213418	0	V102
-74,93186289	11,02105408	0	V103
-74,93177473	11,02117747	0	V104
-74,93202755	11,02110732	0	V105
-74,93181079	11,02132233	0	V106
-74,93202841	11,02123835	0	V107
-74,93206885	11,0209751	0	V108
-74,93166305	11,02144576	0	V109
-74,93184831	11,0215502	0	V110
-74,93217532	11,02136629	0	V111
-74,93179932	11,02094118	0	V112

Our reference: 1 – Date: March 25, 2026

Table 7-7: Coordinates of dwellings in the erosion area (20202 - 2050)

X	Y	Z	NAME
-74,93229727	11,02074675	0	V113
-74,9324791	11,0209457	0	V114
-74,93258333	11,02067188	0	V113
-74,93264213	11,02087008	0	V114
-74,93260703	11,02123444	0	V115
-74,93276962	11,02108653	0	V116
-74,93245715	11,02051299	0	V117
-74,93239363	11,02062914	0	V118
-74,93286561	11,02043726	0	V119
-74,93288497	11,02060755	0	V120
-74,93310622	11,02087756	0	V121
-74,93326647	11,02023352	0	V122
-74,93332765	11,02047254	0	V123
-74,93356416	11,02056156	0	V124
-74,93353568	11,02031007	0	V125
-74,93349887	11,02017423	0	V126
-74,93373285	11,02007668	0	V127
-74,93394563	11,02014289	0	V128
-74,9342709	11,02026884	0	V129
-74,93412255	11,02024115	0	V130
-74,93402711	11,01993222	0	V131
-74,93422332	11,01993481	0	V132
-74,93423899	11,02006551	0	V133
-74,93405875	11,02005286	0	V134
-74,93429085	11,01985932	0	V135
-74,93430877	11,01997496	0	V136
-74,93443234	11,02024704	0	V137
-74,93439914	11,01998106	0	V138
-74,93449861	11,01998227	0	V139
-74,93448056	11,01984293	0	V140
-74,93463169	11,02000359	0	V141
-74,93462703	11,01984367	0	V142
-74,93500004	11,01998199	0	V143
-74,93500397	11,0198313	0	V144
-74,93436221	11,01957146	0	V145
-74,93467536	11,01956906	0	V146
-74,93484456	11,01983836	0	V147
-74,93471239	11,01944941	0	V148
-74,93481071	11,01950472	0	V149
-74,93490947	11,01949915	0	V150
-74,93489385	11,01939749	0	V151
-74,93515544	11,01931472	0	V152
-74,93519289	11,01986318	0	V153
-74,93518421	11,01946345	0	V154
-74,93519656	11,01973807	0	V155
-74,93527462	11,01978578	0	V156
-74,93535565	11,01970187	0	V157
-74,93543563	11,01980813	0	V158
-74,93547055	11,01966112	0	V159
-74,93534431	11,01927143	0	V160
-74,93562959	11,01963328	0	V161
-74,93565061	11,01974441	0	V162
-74,93552956	11,0193687	0	V163
-74,93569154	11,01976897	0	V164
-74,93571497	11,01961515	0	V165
-74,93584851	11,01962987	0	V166

Table 7-7: Housing coordinates in the erosion area (20202 - 2050)

X	Y	Z	NAME
-74,93609429	11,01962456	0	V167
-74,93553719	11,01946992	0	V168
-74,93565325	11,01924654	0	V169
-74,93572392	11,01914224	0	V170
-74,93599468	11,01932889	0	V171
-74,93617367	11,01955382	0	V172
-74,93601374	11,01908411	0	V173
-74,93588128	11,0197532	0	V174
-74,93610197	11,01975262	0	V175
-74,93340144	11,02058619	0	V176
-74,92975105	11,02232559	0	V177
-74,92948313	11,02263065	0	V178
-74,9284919	11,02356678	0	V179
-74,92842686	11,02321171	0	V180
-74,92795831	11,02388196	0	V181
-74,92321007	11,02720007	0	V182
-74,92144973	11,02999627	0	V183
-74,92138865	11,03015763	0	V184
-74,92127108	11,03038936	0	V185
-74,92113566	11,03079633	0	V186
-74,92142404	11,03805625	0	V187
-74,92043527	11,03299574	0	V188
-74,92030888	11,03336243	0	V189
-74,92002668	11,03349039	0	V190
-74,92028536	11,03473528	0	V191

Our reference: 1 – Date: March 25, 2026

Illustration 7-6: Hotels in the erosion area (2025-2050)

Table 7-8: Hotel coordinates in the erosion area (2025 - 2050)

X	Y	Z	NAME
-74,92115103	11,03024535	0	Hotel #4
-74,92555109	11,02510042	0	Hotel #5
-74,92620119	11,02471262	0	Hotel #6
-74,92748408	11,02402686	0	Hotel #7
-74,92785269	11,02352758	0	Hotel #8
-74,92894877	11,02248292	0	Hotel #9
-74,92956509	11,02215568	0	Hotel #10
-74,93228741	11,02093689	0	Hotel #11
-74,92080573	11,03533953	0	Hotel #1
-74,9206211	11,03453344	0	Hotel #2
-74,92145036	11,03736778	0	Hotel #12
-74,92071175	11,03338739	0	Hotel #3
-74,92109565	11,0364026	0	Hotel #13
-74,93021621	11,02162339	0	Hotel #14
-74,93127976	11,02104857	0	Hotel #15
-74,92123427	11,0376788	0	Hotel #16
-74,93233406	11,02097037	0	Hotel #16

7.5 Appendix E: Technical requirements for proposed NbSs

NbS	SEDIMENT PHYSICAL REQUIREMENTS	SEDIMENT CHEMICAL REQUIREMENTS
Sand engine	Fine to medium-fine sand	Do not exceed Action Level 2
Erosion prevention: Geotextile tubes	All types	Dependent on leaching (Water Quality Act)
Erosion prevention: artificial breakwater	Low organic matter content	Do not exceed Action Level 2
Mangrove restoration	Silt, clay, peat	Dependent on mangrove growth, but should not exceed Action Level 2 unless contained
Earth slope - Embankment material	Clay	Do not exceed Action Level 2 or soil quality thresholds

7.6 Appendix E: Technical Requirements for Proposed BwNs

ABBREVIATION	DESCRIPTION
BwN	Building with Nature
COT	Total Organic Carbon
Comagdalena	Regional Autonomous Corporation of the Magdalena River ("Magdalena River" is the historical name used during the colonial era).
CONAMA	National Council for the Environment (Brazil)
CONPES	National Council for Economic and Social Policy (Colombia)
DCS	Sediment Quality Guidelines
DNP	National Planning Department (Colombia)
HAP	Polycyclic Aromatic Hydrocarbons
INVIAS	National Roads Institute (Colombia)
INVEMAR	José Benito Vives de Andreis Institute of Marine and Coastal Research
MinAmbiente	Ministry of Environment (Colombia)
MinTransporte	Ministry of Transport (Colombia)
PCB	Polychlorinated Biphenyls
PNDM	National Maritime Dredging Plan (Colombia)
NbS	Nature-Based Solution(s)

Our reference: 1 – Date: March 25, 2026

Colophon

POLICY AND TECHNICAL ADVICE ON BENEFICIAL USES OF DREDGED MARINE SEDIMENTS IN COLOMBIA, INCLUDING NATURE-BASED SOLUTIONS. DREDGED MARINE SEDIMENTS IN COLOMBIA, INCLUDING NATURE-BASED SOLUTIONS. DEVELOPMENT OF A THEORETICAL CASE STUDY FOR THE USE OF DREDGED MARINE SEDIMENTS FROM THE PORT AREA OF BARRANQUILLA FOR THE PORT AREA OF BARRANQUILLA, FOR THE EXECUTION OF ENVIRONMENTAL PROTECTION WORKS THROUGH NBS.

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