

TECHNICAL NOTE

ARE THERE ENVIRONMENTAL RISKS FROM
PUERTO BARÚ TO THE GULF OF CHIRIQUÍ
AND COIBA?



PLANETA

INVESTIGACIÓN, ANÁLISIS Y PROPUESTAS PARA EL ECODESARROLLO

PLANETA PANAMÁ CONSULTORES S.A.

1. General context and international observations

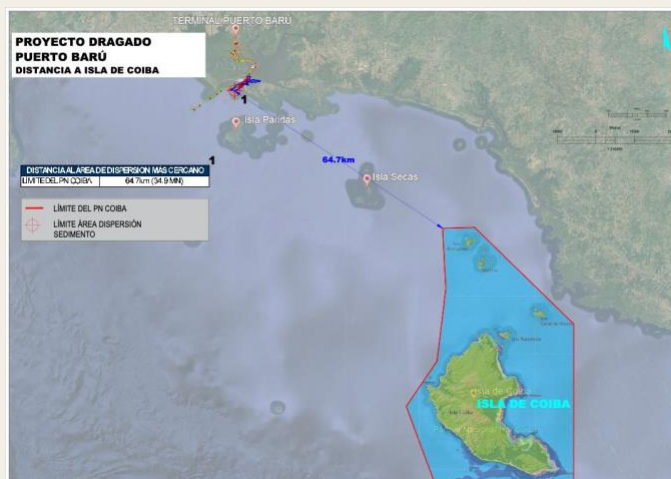
This document summarizes the analysis developed by Manuel F. Zárate P., director of the Environmental Impact Study (EIS) for Puerto Barú, prepared by Planeta Consultores Panamá SA, in response to observations made during the 47th session of the UNESCO Intergovernmental Committee for the Protection of the World Heritage. These observations requested that the Panamanian State review the project's EIA to ensure that there are no impacts on the Outstanding Universal Value of Coiba National Park. The document highlights that the Ministry of the Environment of Panama has already assessed these concerns and concluded that the project does not pose a risk to Coiba.

2. The project's study spaces

The project's environmental analysis adopts a comprehensive approach to the environmental system, considering the area of direct and indirect influence and the regional "Environmental System" comprising watersheds, marine-coastal zones and the Gulf of Chiriquí, including island and protected areas such as Coiba National Park.

Within this framework, Coiba was evaluated from the preliminary stages through water quality and regional dynamics studies; however, the results did not reveal significant impacts that would justify its inclusion as a critical factor within the Environmental Impact Study (EIS). Nevertheless, the information obtained was incorporated into the project design and environmental management measures, particularly in aspects related to dredging, navigation, and environmental monitoring.

Figure 1



Distance between the Barú Canal Deposit Site and the Coiba Island Protected Area.

3. Coiba and the dredging of Puerto Barú

The Puerto Barú project utilizes a natural tidal channel within the Chiriquí Estuarine Lagoon System, taking advantage of existing depths to minimize dredging. The channel will be deepened to 11 m ((Medium Low Water Standard MLWS) only in specific sections, maintaining a reduced navigable width compared to the natural channel. The estimated construction dredging volume is 9.6 million m³, with decreasing maintenance volumes due to the system's natural tendency to reach dynamic equilibrium. The majority of the bed sediments are composed of fine sand and silt.

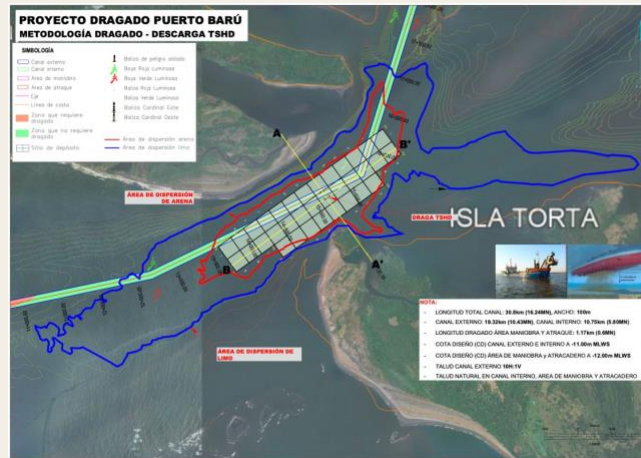
3.1. Hydrodynamics and sediment dispersion

The project's navigation channel runs through the existing estuary and is approximately 31 km long. It is clearly divided into two sections: an outer channel of approximately 19 km, primarily influenced by wave action, and an inner channel of approximately 11 km, plus an additional 1 km for the turning basin and berthing area. In the turning basin, the berthing area, and the adjacent section of the inner channel, dredging will be carried out using backhoe-type dredges assisted by tugboats, with split barges used for transporting and disposing of the dredged material.

The remainder of the channel will be dredged using mobile suction dredges, which, due to their autonomous nature, will travel directly to the disposal site to unload the material. Both the unloading by split barges and the Trailing Suction Hopper Dredger follow

similar operating procedures, and according to the calculations developed in the Environmental Impact Study (EIS), the sediments will remain confined to the area surrounding the disposal site.

Figure 2



Area of Dispersion of Sand (red perimeter) and Silt (blue perimeter)

3.2. Impact on biodiversity and salinity of the estuary

Dredging generates temporary impacts on benthic organisms in the affected areas of the seabed. However, these effects are considered reversible due to the natural resilience of the estuarine system. Undisturbed areas favor recolonization and relatively rapid recovery of the ecosystem. Numerical salinity simulations, developed with advanced software, indicate that deepening the channel does not alter the saline structure of the estuarine system.

Figures 3–4

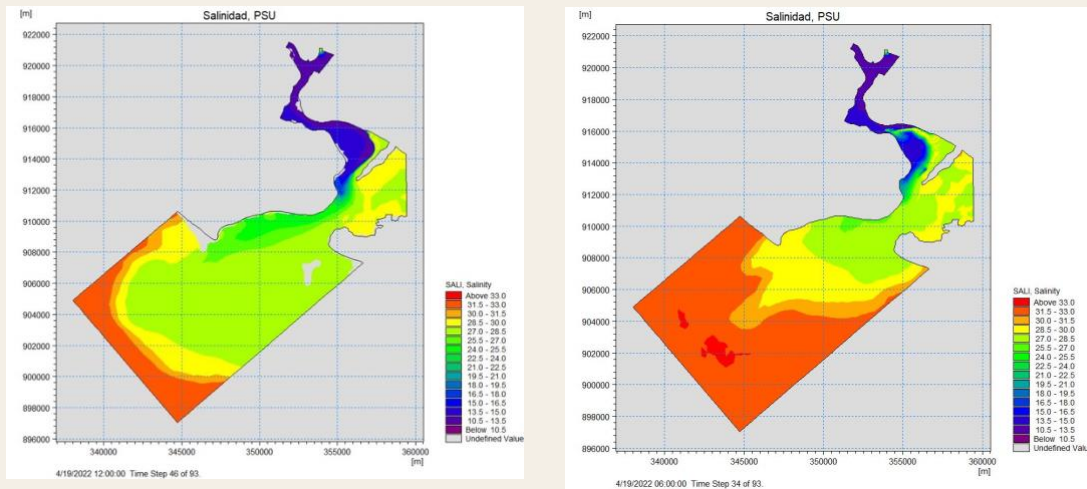


Figure 3. Post dredging tidal flow / Figure 4. Post dredging at ebb tide

3.3. Ocean Currents

Analysis of regional-scale ocean currents shows that the hydrodynamics of the Gulf of Chiriquí are dominated by west-to-east flows, with trajectories that do not favor sediment transport toward Coiba National Park. Furthermore, the distance between the sediment deposition site and the park, exceeding 60 km, along with regional circulation patterns, constitutes an additional factor limiting any potential interaction.

4. The movement of merchant ships

The project contemplates a reduced volume of maritime traffic, with a manageable average and positive control of its speed (less than 6 knots), thus minimizing the potential impacts on cetaceans.

Figure 5



Reefer Type Container Ship Project

4.1. Controlled induced swell

The residual waves generated by the boats dissipate before reaching the shores, preventing coastal erosion processes; moreover, the mangroves also act as natural elements of energy dissipation and protection of the coastal edge.

5. Conclusion

The Puerto Barú Project has been designed with an approach of integration with the natural environment, in which the identified impacts are characterized as localized, controllable, and, for the most part, reversible. Based on the technical analyses carried out, no scientific, hydrodynamic, sedimentological, or ecological evidence was identified that would establish a significant link between the project activities and Coiba National Park. Consequently, it is concluded that the project does not represent a significant environmental risk to this protected area. However, as part of the project's preventive and environmental management approach, the control, monitoring, and environmental management measures outlined in the Environmental Impact Study (EIS) will be implemented.

FULL TECHNICAL DOCUMENT

Are there Environmental Risks from Puerto Barú Project on the Gulf of Chiriquí and the Coiba protected area?

In July 2025, at the UNESCO headquarters in Paris, France, the following took place the 47th Session of the Intergovernmental Committee for the Protection of the World Cultural and Natural Heritage, an event whose objectives include reviewing decisions made in relation to cultural or natural properties declared "World Heritage". The occasion served, among other things, to examine previous agreements concerning Panama, relating to Coiba National Park and its Special Marine Protection Zone, considered one of the world's natural treasures, giving rise to decision No. 47 COM 7B.39 which, in relation to the island, requests the State Party, in its paragraph 5, to do the following:

[Se] "revise the ESIA for the proposed Port Barú port development project in the vicinity of the property, in line with the Guidance and Toolkit for Impact Assessments in a World Heritage Context, to ensure that the potential impacts on the Outstanding Universal Value (OUV) of the property, including the cumulative impacts of vessel traffic and the risk of pollution, among others, are fully considered, and to avoid any negative impacts, prior to making any decision that would be difficult to reverse."¹

Since our firm, Planeta Panamá Consultores S.A. has been responsible for the Environmental Impact Study (EIS) of this project, we have deemed it pertinent to bring to the attention of interested parties the following scientific considerations that were taken into account by the technical work team on the case, before (with the preliminary studies), during and after the approval of the Environmental Impact Study and its measures by the national authority of the Ministry of Environment, through Administrative Resolution DIEORA IA-0003-2024 from January of 2024.

¹ See document WHC/25/47.COM/17 Paris, corresponding to the 47th Session of the Intergovernmental Committee for the Protection of the World Cultural and Natural Heritage of UNESCO DIEORA IA-0003-2024 of January 2024.

In this regard, it is worth recalling that this concern was previously conveyed by UNESCO to the Ministry of the Environment in a note dated April 23, 2024, addressed to the Permanent Delegate of Panama to that entity and signed by the Director General, Lazaro Eloundou Assomo. This note was answered on May 23, 2024, as shown in the Ministry's archives, under code DM-0933-2024. Stating that, after consulting both national and international regulations – including Article 14 of the Convention on Biological Diversity of June 1992 and Law No. 44 of July 26, 2004, which creates the “Coiba National Park and dictates other provisions” – it had been concluded that the Puerto Barú project “does not” It poses a risk to Coiba National Park because no impacts on it were detected during the evaluation process.”

Having said this, we will now explain the technical reasons why Coiba Island is not included as an environmental impact factor within the Environmental Impact Study (EIS) of the Puerto Barú Multimodal Project.

1. The project studie´ s spaces

On this matter it is worth remembering that the Planeta Panamá research team, in charge of the Environmental Impact Study (EIS) of Puerto Barú, took note not only of the regular area of influence defined by the scope of the direct and indirect impacts of the project, but also, beyond that, the space called the Environmental System (Fig 1), involved in some way in the activity because of its systemic connections and exchanges with the areas of influence, which extends to the upper basins of the Chiriquí and Chorcha rivers on one side, and to the marine coastal plains of the gulf on the other, such as the tourist beaches from Barqueta to Boca Chica, the Paridas Islands area, etc.

Figure 1



Areas of direct and indirect influence and of the environmental system

Of course, the coast of the Fonseca and Tabasará basins (eastern Chiriquí) and the protected jewel of Coiba Island were also addressed, by extension, precisely because some time ago the consulting firm had participated for two years in an investigation on the water quality of its coasts and its relationship with the continental coasts of the region, under different annual climatic and marine conditions, a work commissioned by the National Secretariat of Science and Technology (SENACYT).

From this perspective, when analyzing Coiba, which was among the first sites reviewed in the preliminary studies on regional interactions and alternative project locations, it was concluded that the island did not exhibit elements of alteration sufficient to warrant its

inclusion in the Environmental Impact Study (EIS) and the initiation of procedures related to environmental permits.

Nevertheless, the information gathered was processed and taken into account in the engineering designs and environmental management of the entire project operation, incorporating precautionary measures in the details of dredging, vessel navigation, and marine and coastal monitoring, as will be discussed below.²

2. Coiba and the dredging of Puerto Barú

By way of introduction, it is worth clarifying some aspects of the project: Puerto Barú uses for the navigation of its ships a natural tidal channel belonging to the Chiriquí Estuarine Lagoon System, derived from the mouth on the coast of four rivers (Chiriquí, Chico, Chorchá, and Corrales rivers). On this map, the project is linked to a tributary of the Chiriquí River, the Chiriquí Nuevo, forming, along with the Chorchá, one of the three mouths (Boca Brava) that connect the estuary to the gulf.

Its course has an average depth of -7.5 m (MLWS), which will be deepened to -11 m along the alignment designed by the complex, and to -12 m at the turning area, by following the thalweg created by the channel's own hydrodynamics. This route conforms to the channel's bathymetric structures, meaning that approximately 59% of the total segment does not require any artificial deepening. One of the most interesting aspects of this project's design has been its focus on adhering as closely as possible to the path dictated by the water's flow, rather than altering it.

The designed channel will be 100 m wide, occupying on average 20% of the width of the existing natural channel and a length of 31 km from the access buoy in the Gulf.

The deepening dredging involves the removal of a total of 9.6 Mm³ of material from the navigation channel bottom, with subsequent maintenance activity of 0.795 Mm³ every two years (more due to the basin effect than the project itself) that tends to gradually decrease their quantities until reaching the same sedimentary dynamic stability.

² The Environmental Impact Study (EIS) was preceded by two studies before its submission and approval by the Ministry of the Environment: a Preliminary Study on regional problems and location alternatives, which consolidated the promoters' final decision for the Chiriquí River estuary site at its mouth in Boca Brava, and the Environmental Viability Study of the David Mangroves Protected Area, requested and approved in accordance with the official regulations of the Ministry of the Environment Ministry.

As part of the environmental history, it is worth adding that the site and waterway are not new to its port use. Already at the beginning of the 1970s, the place (called Puerto Cabrito) was designated as a citrus export port, using as access the tidal channel now scheduled, through dredging adjustments.

No written, properly recorded evidence of this has been found, except that in 1980 the national port authority agreed to a National Dredging Plan that included this port. However, with the field investigations carried out on the Environmental transformations of the place were documented, and testimonies were obtained from fishermen, including workers who worked with the Cítricos de Chiriquí corporation in the sphere. Port authorities stated that between 1975 and 1983, the company carried out dredging in the access channel, overseen by a Japanese engineer. However, geotechnical work conducted by our team revealed clear evidence that something similar occurred in the current channel. This was determined by analyzing several cuts that remain to this day and are not characteristic of the channel's natural hydraulics. In any case, the evidence has provided valuable information to the project regarding the resistance and resilience properties of the channel bed during the recovery of the canal's ecosystem.

2.1. Texture and quality of sediments

Along the navigation channel's route, 12 boreholes were drilled in the dredged area at depths of -12 m and deeper (reaching -19 m in some cases), from the MLWS (Medium Low Water Standard); 4 boreholes were drilled to -6 m and deeper in the marina area, also from the MLWS; and 3 surface samples were taken from intertidal areas of islets in the process of formation. Granulometric/ particle size analysis revealed that sand sediment predominates throughout the channel, with proportions exceeding 55% in most cases, falling below this figure only in a few specific instances as the channel approaches continental land, where fine granules (silt-clay) are present. Sand content reaches up to 97% in some segments as the channel approaches the coastal zone. It is therefore a high-density material, with sand at 1,940 kg/m³ and silt at 1,890 kg/m³.

Fortunately, all laboratory tests of the samples showed heavy metal and hydrocarbon contaminants within acceptable limits. Only iron and copper were found in certain segments with soils of higher clay content (near Puerto Cabrito) came out with a somewhat high percentage, but not due to human intervention but rather to the natural geological formation of the area. The copper in particular, a concentration of 129.7 mg/kg was found at the station opposite Puerto Cabrito, which is above the PEL (Probable Effect Level) in the Canadian guide. but with a geo-accumulation index $I_{geo} = 0.94$, which indicates a moderate load contaminated, acceptable by the maximum

permissible thresholds (< 1.0). In any case, the presence of this metal (copper) with a concentration typical of careful observations were sufficient to determine an area within the same estuarine system that would accommodate the precipitation of the material with a good level of adaptability, rather than throwing it out to sea where strong ocean currents would affect it will generate an uncontrollable dispersion³.

2.2. Hydrodynamics and sediment dispersion

From the point of view of dredging, the topic deserves to be analyzed in two sections different, just as the environmental study divides the channel: an Internal Channel that goes from Isla de Muertos to Puerto Cabrito, now the seat of Puerto Barú (12 km), and an External Channel (19 km) that goes from the access buoy in the gulf to Isla de Muertos.

2.2.1. The internal Channel

The inland channel has fairly limited effects on the incoming Gulf waters since it is sheltered by a semi-closed system connected to the sea only by a narrow passage (Boca Brava) that was part of the Chorcha river valley on the way to the coast, on occasion from the last climatic glaciation. The transport of suspended material in the segment is strongly conditioned by tidal movement, being non-linear with flood tides, due to the collisions of currents with continental freshwater and the unique geomorphological features of the channel, but the opposite with ebb tides, that is to say dominant linear behavior especially in the area of the ebb of the neighboring waters of Bahía de Muertos.

We clarify in this context that, in terms of design, the geometry of the channel does not change the exchange of water between the marine wetland and the open ocean. There will be no barrier effects created, because there are no accumulations or flow blockages to obstruct the natural dynamics of the river and channel. The only new element will be a volumetric increase of the bottom of the channel, when the 9.6 Mm^3 of material is extracted, increases the inflow of seawater with a constant volume and yet does not change the value of the tidal prism or the hydraulic residence time at all.³

Regarding the operation of the main dredger, a "Trailing Suction Hopper Dredger" type (TSHD or Moving Suction Dredger), it is very unlikely that the sediment plume from the extraction of solids will reach the gulf, primarily due to the technology and procedures used. The general process is by suction with a dredger head while the dredger is underway (Fig. 2) at speeds of 4 to 6 knots. This offers advantages such as minimal particle suspension because the protective hull retains the dredged material in its

³ The dominant currents within the estuary are primarily driven by tidal forces.

chamber. The dredger operates in bands, with a very controlled level of sediment leakage that tends to settle quickly, leaving large areas across the tidal channel with water in its natural state. The material is brought aboard and placed in the dredger's hopper for transport to the disposal site. It is also worth noting that no explosives are used.

Figure 2



Dredge extraction rake

The other activity that raises questions is the special slope cutting of the canal in sensitive areas, which employ the type of mechanical dredge with a shovel that operates on a barge, with the assistance of two split barges to load the material. This is necessary both because of the detailed work required for the specific modeling of the cuts are made, due to the greater hardness of the material to be dredged, which is highly compacted. These cuts are precisely adjusted to the hydrological mechanics of the tidal channel and its slopes, resulting in minimal alteration of the morphodynamic stability and a close fit.

Ideally, this process would be largely due to the natural resistance and resilience properties of the environment. They can also be used in shallow sections of the channel. The key result is that the sediment plume does not extend beyond the immediate vicinity of the channel during its journey.

2.2.2. External Channel

In the outer channel, the unloading of dredged material into the Boca Brava submarine trench, a geomorphological feature corresponding to what was once more than the extraction activity itself –it is said– a V-shaped river valley of the Chorchá River, in formation since geological times and extending along the estuary's outlet.

It so happens that with marine transgression as a result of post-glacial global warming,

characteristics have been inherited today unique features of the site that favor this activity, especially because there are no fragile ecosystems within it.

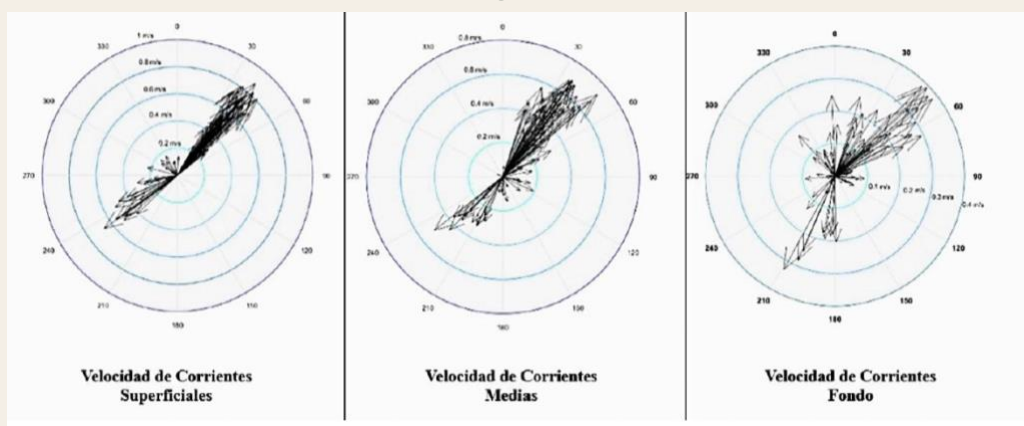
The coastal currents of the Gulf have a dominant southwest-northeast direction, which means that when the floods enter the estuary through the strait, they are especially marked by their Tidal origin are directed mainly towards the Bahía de los Muertos, revealing very characteristic behavioral variations from depths of -21 m downwards throughout the entire length of the gorge, due to the deep rocky pit described. Conversely, with the ebb tide, a current is generated towards the outer mouth of the inlet, combining the river inflow and the marine ebb. This current, upon encountering the coastal current that crosses it—including the "wind swells"—forms a retention zone, creating some sandbars on the seabed of the inlet, as well as a progradation activity on the east coast of the same; therefore there is precipitation. There is a pronounced accumulation of sediments in the area, due to differences in density and water circulation, which mitigate the transport towards the Paridas Islands.

Unlike surface hydrodynamics, below -21 m depth the trench, at -47 m, maintains a somewhat turbulent water movement, flowing in various directions due to the bottom's bathymetry, which is characterized by steep and non-uniform geomorphological features, as well as thermohaline effects⁴. The high energy during the third hours of tidal flow and ebb, and the low energy during swells, contributes to the horizontal spatial distribution of material during the first event, while facilitating its vertical deposition during the second, all of which helps to level the bottom.

This was extensively studied through dives by a team of professional technicians accompanied by an underwater drone. Essentially, the trench exhibits two water layers with distinct dynamics depending on the depth: one located above -21 m, with a fairly fixed drift, and another below -21 m, with turbulent movements flowing in various directions. These are therefore two different behaviors: one above -21 m depth, of an almost linear type, with a NE direction during flooding, an average speed of 0.61 m/s and a maximum of 1.27 m/s, or a SW-W direction during ebb, with an average speed of 0.46 m/s and a maximum of 1.36 m/s; and one below that depth, with great directional disparity of flow, low speed and diverse movements that produce resuspension of sediments at times.

⁴ See Response No. 23.A of Observation No. 23, in 1st Round of Extensions of the EIA, Preface, My Environment, p. 300

Figure 3



Results from an Eulerian current meter located at the southern entrance of the trench at a point on its upper edge, with surface current readings taken at -10 m and -20 m. The series shows how the current deforms as the depth decreases.

This condition is one of the most important advantages we might say in terms of environmental services – considered for the deposition of dredged material in the area; because it especially guarantees that any discharge of this material that occurs within the transition range between the two depth strata does not obstruct the marine dynamics of the upper stratum, nor does it affect the composition or natural turbidity of the waters of the Bahía de los Muertos (high productivity zone) and instead, works supporting a level distribution of sediment on the seabed.

Taking advantage of such opportunities in the environment, how then does the discharge of such sludge operate to ensure environmental controls?

The water surface of the dredge pit has been divided into a grid based on a projection of the -20 m isobath curve onto the surface, with 200 x 200 m² plots to alternate the dredge's discharge position according to currents and turbidity levels. This dredge has the capacity to move up to 4,000 m³ of material per trip. When the hold gates are opened, the material is released to a depth of -8.8 m, due to the draft and size of the holds. Since the heavier sediment settles by gravity to the bottom, its suction pulls the lighter sediment down to a depth of -15.8 m, which is the transition zone. From the pit, due to the density current created under the mass deployment. The following are graphical simulations of the plume dispersion.

Figure 4

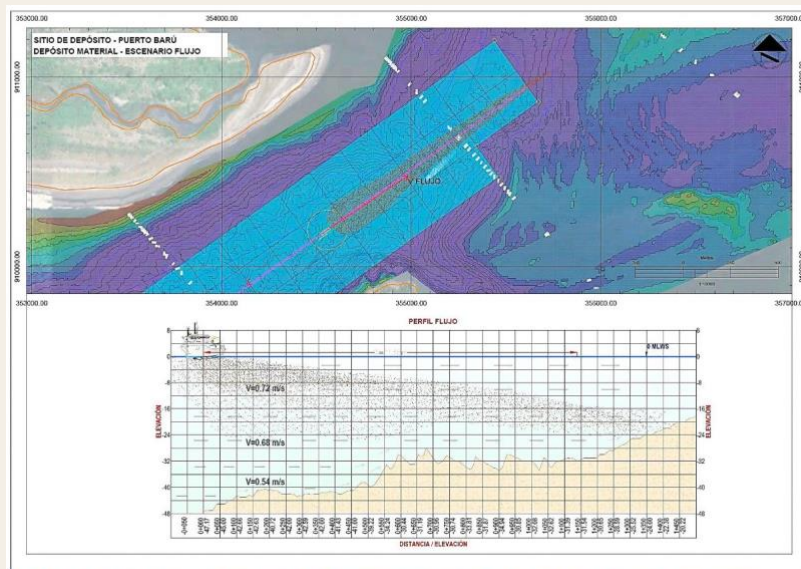


Fig 4. Modelación de la dispersión de sedimentos por el vertimiento del dragado en Boca Brava, en condiciones de marea creciente.

Modeling of sediment dispersion by dredging discharge in Boca Brava, under rising tide conditions.

Figure 5

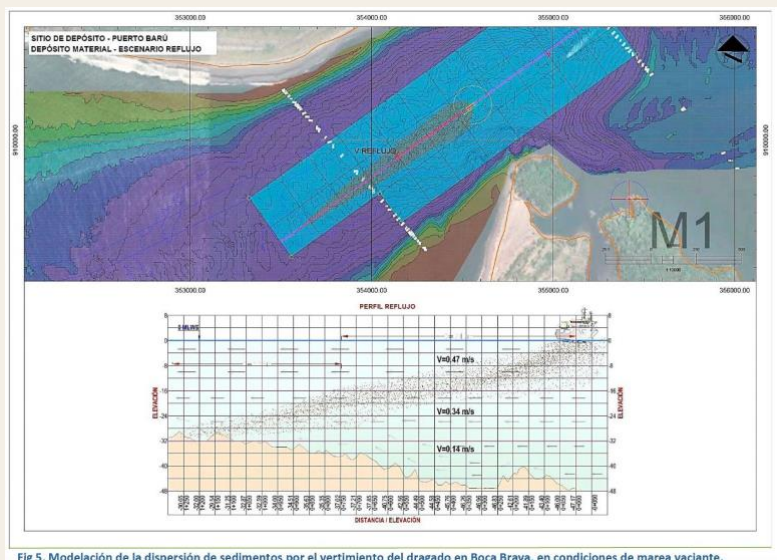


Fig 5. Modelación de la dispersión de sedimentos por el vertimiento del dragado en Boca Brava, en condiciones de marea vaciante.

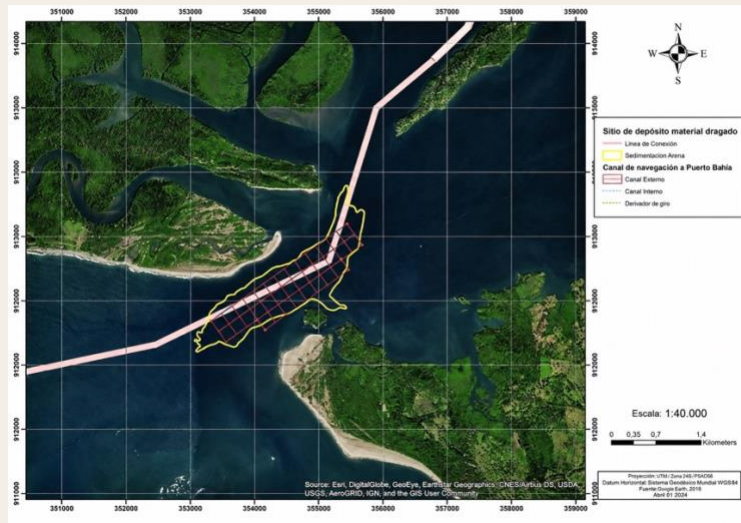
Modeling of sediment dispersion by dredging discharge in Boca Brava, under low tide conditions.

This means that if the mass fan opens completely towards -16 m with the initial influx, then the bulk of the material is precipitating within the large basin of the trench. The sedimentological dispersion graphs contained in Figures 4 and 5, produced by the consulting firm CONSULSUA – a continental firm based in Ecuador – and based on Stokes' Law and applied to a "point discharge," clearly express the dynamics of this process, using current velocities that are even above the averages for the established strata. It can be seen in great detail that the bulk of the mass descends almost entirely within the first 250 m of the source, in the direction of the current, whether it is an inflow or ebb.

Additionally, the reading allows us to appreciate other equally important aspects. For example, we can observe how the current velocity decreases in the water column within the trench area and then the maximum dispersion range at the established velocities; during rising tides, the distance in the direction of the currents does not exceed 1.14 km, and during ebb, it does not exceed 1.28 km. Also, the results of applying Stokes's equation to the entire dredging of the navigation channel are shown.

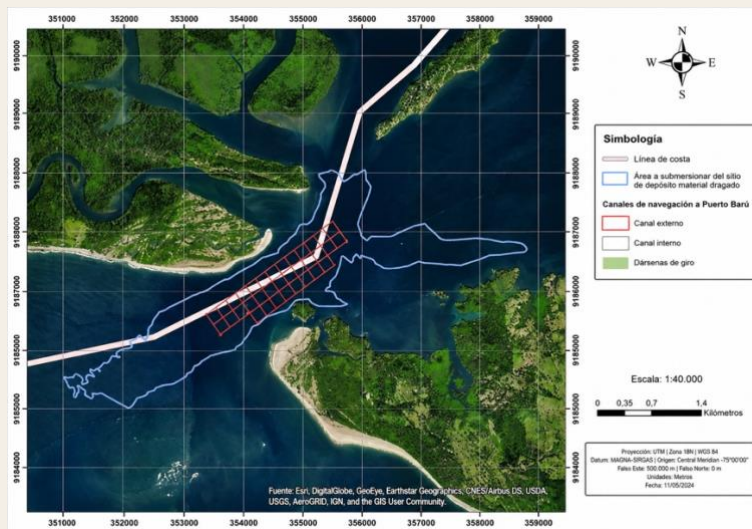
This presents, as demonstrated. Figures 6 and 7 show a total reach perimeter of 1.16 km for the sands and 4.01 km for the silts, always under the influence of the currents, their disposition not reaching the shores of the coastal areas due to the force and direction of the currents, and the turbidity curtain from the discharge does not form a door closure for the fauna, as the discharge is very local in relation to the breadth of the marine environment of the strait and is transient.

Figure 6



Outline of the total dispersion of the sands

Figure 7



Outline of the total dispersion of the silts.

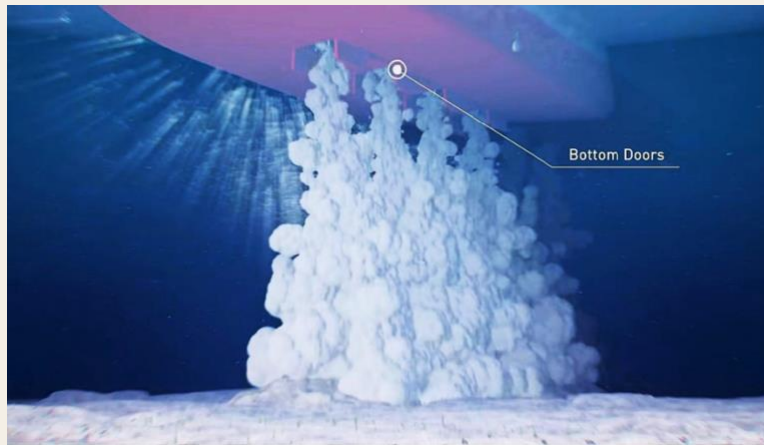
How are water transparency levels controlled during these discharges?... For the dredger, the dredging/discharge cycle takes approximately 7 hours and 20 minutes, while the sand settling time is 41 minutes and the silt settling time is 2 hours and 22

minutes, both occurring simultaneously. The water then rests naturally for 4 hours and 58 minutes before the cycle restarts. It should be noted that only one vessel is used for this activity, so there cannot be any simultaneous discharges or more than four per day, for a total daily discharge of 16,000 m³.

Another topic for analysis, as a complement to what has been discussed, is the concentration of sediment suspended during passive water transport, a task that was successfully carried out through Gaussian modeling of its deployment in space and whose results.

These results are entirely consistent with the findings in the preceding lines. If we take the threshold of 100 mg/L—which represents an acceptable average concentration of solids in the area—the changes in concentration with respect to the distance traveled, with tidal flow, are shown. The index would be reached at a distance of 700 m from the source, given a current velocity of 0.45 m/s (the most frequent). In an ebb tide, with a current velocity of 0.47 m/s (also the most frequent), the threshold would be reached at 800 m from the source. This means, then, and according to the bathymetric profiles in Figures 4 and 5, that the concentration of mass above the threshold of the marine natural system, which we could call "the black cloud," will be deposited in the depths below the -32 m isobath; and this is consistent with the Gaussian modeling performed which shows that, under the flow state, 96.2% of the material poured by The discharge precipitates almost vertically to the bottom (due to the mechanical effect of gravity and density), while 94.2% occurs during the backflow state, with the main concentration located in the first 150 m of the horizontal development of the sediment fan. (see Figure 8).

Figure 8



Modeling of discharge and fall of dredged material. Source: Jean De Nul Group

Finally, it is also worth noting that the volumetric capacity of the pit itself is 25 Mm³, which allows for the ample reception of the 9.6 Mm³ of material during the construction phase of the project and even the maximum average of 0.795 Mm³. These tanks are maintained every two years, during the first phase of subsequent maintenance until the system stabilizes. These tanks, incidentally, could accommodate other uses in the future and may not necessarily end up in the pit.

But there is an important aspect of the pit that deserves to be addressed at this point, especially regarding the precipitation of the "black cloud" of sediment below the -32 m depth line. Specifically, based on bathymetric measurements of the available space below the discharge grid, the total material from the construction phase will cover the bottom to a maximum height of 13 m, leaving a free depth of -34 m. marine waters, that is, a large part of the trench formed of rocks and sands and of course, of habitats for a good number of species, especially those of economic importance such as the croaker, snapper, and grouper. These species were monitored using echo sounders, They were recorded concentrated mostly in a depth range from -10 m to -30 m. In other words, the critical habitats in the area that support some of these pelagic species will remain open.

2.3. Impact on biodiversity

This component of the aquatic environment, which addresses, among other things, the conservation of the rich biological diversity of the protected estuary, was the

subject of meticulous studies based on the ecological function of the estuarine lagoon system as a source and refuge for marine life in the gulf and, therefore, for the island chain supported by its geographical shelf. From this perspective, the dredging brought to the forefront two important biotope factors to be analyzed, as it altered the depth of the tidal channel. One was the impact on benthic organisms in the hyporheic zone removed from the channel, and the other was the potential change in salinity due to the increased volume of seawater entering the system as a result of the deepening of the channel bed.

2.3.1. About benthos

In the Environmental Impact Study (EIS) and even subsequent documents, we have acknowledged that the hyporheic zone of the navigation channel constitutes an environmental component that receives impacts from dredging. This requires attention because dredging particularly eliminates infauna at the site of bed removal, with the worst impact falling on polychaetes, which are undeniably important for fish and macroinvertebrates. However, it is also worth clarifying that this is primarily an examination of the "intensity" of the alteration and its significance, since the linear function of the Impact Value also involves other variables such as extent, reversibility, duration, etc., all of which are relatively minor in the relativity of the system, making the total value a sum of factors with a "medium" gradient.

The truth is that large areas lateral to the dredged zone, up to the mangrove shores of the tidal channel, remain untouched (remember that only 20% of the width of the tidal channel is dredged, as well as 41% of its length), maintaining the same composition.

and natural life, a fact that empowers the system to activate its resilient capacities, producing a rapid reconstruction of the bottom ecosystems through recolonization, especially in the affected hyporheic zone ; this, undoubtedly, originating from the unaffected areas. The Environmental Baseline is conclusive on this matter, noting that the extent and health of this aquatic ecosystem allows for the prediction of a rapid

reconstruction of the dredged areas, given the great diversity and population of fauna that survives the dredging and the unchanged quality of the biotope.

There will therefore be no disappearance of benthic ecosystems, because the altered parts will be quickly reversible; moreover, it is estimated that new critical natural habitats for some riparian species may be generated in places where they did not previously exist, due to the marine wedge on the seabed, which will also contribute to

the recovery of the environment through its improved quality. Its monitoring and control are the responsibility of the monitoring program.

2.3.2. On salinity

Regarding this issue variations in the salinity of the water environment due to the widening of the natural channel bed Planeta's technical team decided to refine its criteria by using systematic modeling along the entire tidal channel, taking into account the multiple variables involved in the phenomenon. This work was carried out by the firm CONSULSUA, following the application of the MIKE 21/3 System with its hydrodynamic and ECOLab modules coupled to advection-dispersion.

SALINITY DISTRIBUTION, PRE AND POST DREDGING

Figures 9–12

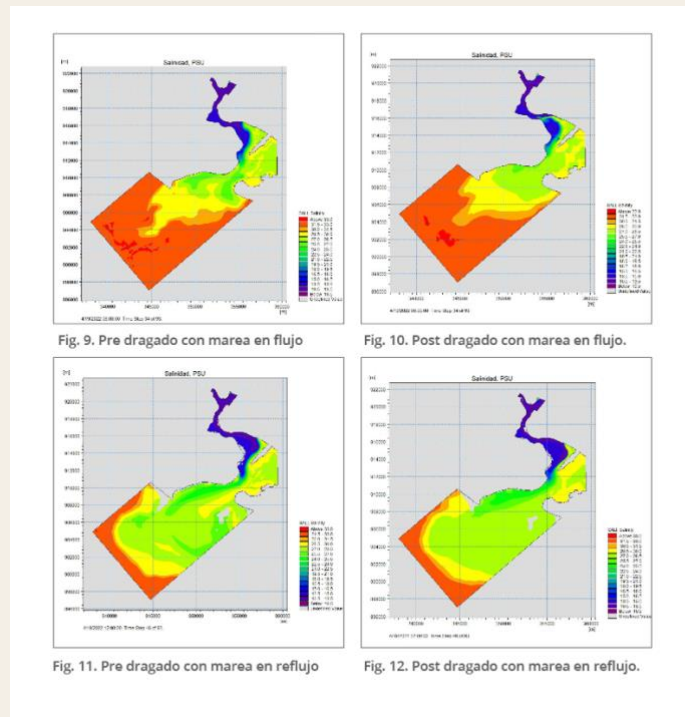


Fig 9. Fig 9. Pre-dredging with flowing tide | Fig 10. Post dredging with flowing tide

Fig 11. Pre-dredging with ebb tide | Fig 12. Post dredging with ebb tide

The modeling analyzes two specific scenarios along the waterway route due to the increase in the marine wedge and the mixing of waters: with dredging and without dredging; and the exercise. The numerical data, in summary, identifies that despite the increased channel depth (post-dredging scenario), the water column maintains a vertical stratification and horizontal distribution very similar to that observed in the pre-dredging scenario. This indicates, in particular, that the bathymetric modification does not substantially alter the vertical structure of salinity and, therefore, not the estuarine macrodynamics either. This is undoubtedly important because preserving the ecosystem's biotope conditions means preserving the foundational conditions for existing biodiversity.

And there's more!... If you carefully examine Figures 9 and 10 of the pre-dredging and post-dredging with rising tide (in flow), you'll notice an elongation of the salt wedge in the post-dredging area relative to the middle and southern coast of Isla Mono (see red circle), with levels ranging from 22.5 to 28.5 PSU, which are not present in the pre-dredging (it's lower

in the latter). This wedge follows the course of the channel opened by the dredge and dissipates towards the shores as the freshwater countercurrent rises, achieving complete mixing at the intersection known as "Cuatro Calles" (Four Streets).

These new salinity levels, resulting from the upwelling of seawater and within acceptable estuarine ranges, could potentially lead to a migration of fish species to the area that were previously absent, as well as other species consumed locally. This phenomenon is occurring in an area heavily used for trammel net fishing by local fishermen and black clam (*Anadara tuberculosa*) farmers, who have frequently reported that their peak productivity coincides with very high tides that raise the water's salinity levels.

2.4. Ocean currents and monitoring as a precaution

What has been said so far confirms, in summary, a relationship between two water systems with its own distinct identity, but in close interaction with the Chiriquí coastal region: the marine area of the Gulf of Chiriquí, open to the Pacific Ocean, and the semi-enclosed estuarine lagoon system, connected to the former by three channels (Boca de San Pedro, Boca Brava, and Boca Chica) and to the mainland by four rivers that together discharge an average annual freshwater flow of approximately 200 m³ /s into the sea. Puerto Barú exchanges its environmental processes with the gulf through Boca Brava. This means that the potential effects of the port project on ocean waters are fundamentally conditioned by the flows that pass between the two bodies of water through the strait; and if the composition, functions, and systemic structures are maintained. The original features of the estuary, as well as the connectivity between the two systems, will preserve the ecological order that sustains the gulf.

This is what the project seeks to achieve in the "socio-environmental" sphere a term used because there is no environment without society. However, caution is always necessary when working with "Complex Dissipative Systems" such as environmental ones so the technical team studied the behavior of the Gulf currents in relation to the region's two protected areas: the Gulf of Chiriquí National Marine Park, which includes the Paridas Islands, and Coiba National Park. Similarly, monitoring plans were developed to track the processes resulting from port activity and to take appropriate corrective measures in time for any risky situation that may arise; but also, currently a detailed "operations protocol" is already being designed for all dredging activity, which must be approved by the relevant state authorities and will be strictly enforced by the company contracting the activity.

With regard to these two sensitive areas, the greatest attention was then paid to safeguarding and controlling alterations at the very site of their origin especially regarding

the extent, frequency of occurrence and duration of the impacts, under a combination of scientific-technical measures and use of the environmental services of the system itself a practice widely used by the Planet Panama team, in order to stop the effect or otherwise mitigate it at the place of the action, until adjust it to levels acceptable to the receiving environment and thus guarantee a harmonious co-evolution of the parts through their natural resistance and/or resilience properties⁵.

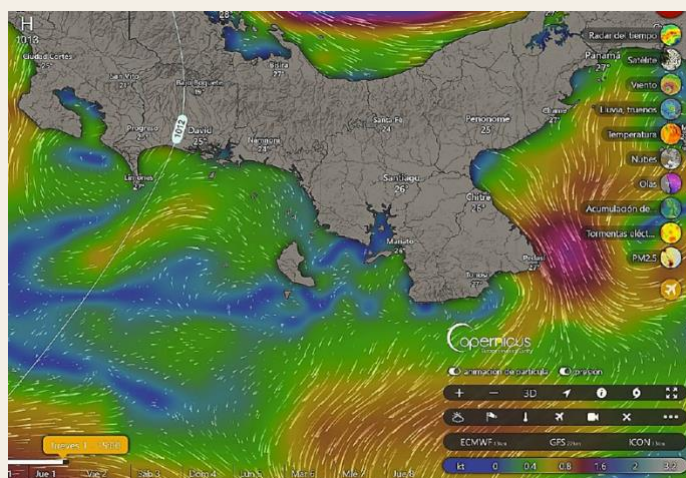
The distance from the dumping area to the parks is calculated at 9.05 km to the south for the Chiriquí Gulf Marine Park and at 64.7 km to the southeast for the Coiba National Park. Regarding the first, inspections and sweeps of the coastal area using dives. Studies conducted by the EIA team confirmed that some sediment currently reaches the western coasts of Islas Paridas, which, in our opinion, represents residual sediment that does not fully precipitate in the Boca Brava inlet with the ebb tides, aggregates of sands that arrive with the Gulf's ocean currents from the southwest. Regarding the second, in the studies carried out by our firm on the quality of marine coastal waters during the years 2009 and 2010, it was concluded that its pollution problems stem more from human intervention resulting from the island's own environmental history (it was a prison with agricultural use and a military base), than from flows from the mainland territory, although the western island side may be receiving potential effects from the San Juan and Tabasará river basins.

It must be taken into account – as stated in the most recent study of currents for the mathematical modeling of salinity – that the hydrodynamics of the Gulf of Chiriquí is dominated by a west-east flow current coming from Costa Rica.

Additionally, the area receives the persistent contribution of the North Equatorial Countercurrent (Wyrtki, 1965). This system advects water masses northeastward off the coast of Puerto Armuelles (with speeds of 0.21 to 0.42 m/s), then adopts an eastward trajectory parallel to the coast as far as Isla Sevilla (0.10 to 0.15 m/s), finally resuming an eastward component until it extends south of Isla Coiba.

⁵ Planeta Panamá Consultores works with the environment by considering it as a complex system, under the consideration of three fundamental pillars that support the mechanics and life cycles of its factors. These environmental factors are: composition, function and functionality, and structure. Understanding the properties, movement, and connections of these elements, based on thermodynamic principles, means understanding their capacity to accommodate a project, as a foreign body grafted onto a different system, exchanging mass and energy.

Figure 13



Most frequent ocean currents of the Gulf of Chiriquí. Source: Copernicus 01/08/24

This pattern, the most frequent (see Figure 13), naturally experiences seasonal variations modulated by the magnitude and direction of wind stress (IGNTG, 2007). While our preventive management measures for dredged material discharges in Boca Brava are aimed at containing the dispersal plumes within the system itself, strict monitoring plans regarding water flows entering and leaving the lagoon system form an inevitable complement to these measures; and there are two that are fundamental: the David Mangrove Monitoring.

The potential trajectory of this important ecosystem for the project itself and for the biodiversity of the estuarine lagoon system, a task that will be carried out by the country's Center for Research, Training and Entrepreneurship (CIFEm) in conjunction with Louisiana State University and the Faculty of Agricultural Sciences of the University of Panama, and the Gulf Coastal Marine Ecosystem Monitoring Plan, which covers from Playa Barqueta to Isla Seca and is currently in its final expanded design and approval by the competent State authorities.

In addition, we have a program that originated within the communities themselves and which the project is supporting through CIFEm in order to avoid infringing upon their autonomy. This program is the Community Early Warning Brigades, comprised primarily of community users of the estuary and, therefore, of volunteers interested in protecting the resources they manage. Citizen participation is a fundamental factor in the reorganization of the environmental system under the project, and within this framework, the early warning

system for impactful events caused by the interaction of the complex with the environment, whether anticipated or unforeseen, is of paramount importance for the adjustment processes.

This network, developed in collaboration with the local population, organized and trained through appropriate education on indicators and procedures, and led by technical personnel, is essential for maintaining an effective prevention and control program.

3. Ship traffic

As an introduction, it is worth remembering that the port project consists of only two docks, which span a total of 500 meters along the edge of the esplanade adjacent to the waterway, intended for medium-sized ships, such as "Reefer" vessels.

Figure 14

PARÁMETRO	DIMENSIÓN / TONELAJE
Eslora Total (LOA)	192.0 m
Manga	30.0 m
Calado Máximo	11.0 m
Calado para el Proyecto	11.0 m



Type of vessel: Reefer Container Ship

The aim is essentially to provide a necessary service to the increase in domestic and regional cabotage trade – both within the country and across the Pacific coast of the continent – which is becoming increasingly important and significant due to the restructuring of the global supply and consumption market, the growth of trade within the continent driven by the pressure of its economic integration, and the connectivity this demands of maritime transport.

It is a project that enhances the value of the national coastal marine resource, providing a technologically advanced and environmentally sustainable service to continental containerized cargo, bulk cargo of supplies for the country, liquids from the production of edible oils and fuels from the entire western region of the isthmus, and finally to low-density (maximum of 500 passengers) international cruise ships for responsible tourism, which already frequently anchor off the coasts of both Coiba Island and the Paridas Islands, within their protected parks without adequate care facilities.

Figures 15–16



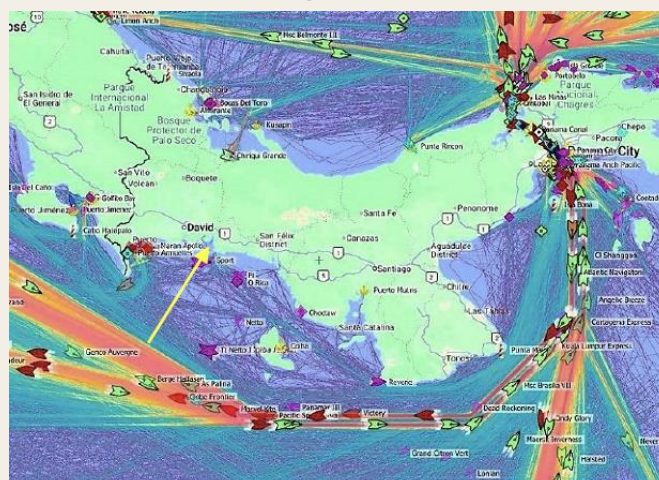
Fig 15. Cruise ships in the Paridas Islands 1 Fig 16. Cruise ships in the Paridas Islands

These ships, required by the project to comply with the ship classification with “Class Certificate” will have a modus operandi regulated by the Authority Maritime Authority of Panama (AMP) as well as by the port corporation itself –in its corresponding jurisdiction–, as soon as they point the course towards the canal approach route. From the access point in the gulf to the docking pier, they will be guided by a pilot in the ship's command post, monitored by tugboats along the entire navigation channel, and their speeds will be limited (≤ 6 knots) from the moment they reach the Entry Buoy at kilometer marker 0+000 of Boca Brava Bay. Offshore, they must comply with the regulations established by the relevant national and international organizations.

Offshore, vessels already operate under the regulations of the IMO and the Panama Maritime Authority (AMP), as well as the restrictions imposed on ships transiting to the

Panama Canal or navigating toward Puerto Armuelles en route to the Petroterminal port. Puerto Barú, for its part, does not significantly increase this traffic; even at peak operations, it is expected to average no more than 1.7 vessels per day, simply because that is the maximum operational capacity of the complex. Other movements, mostly within the estuary itself, will continue to be carried out by local fishermen and tourist boats, which are already highly active in the area and will undoubtedly benefit from the services provided by the project's marina component. It should also be noted that there is no conflict among port cargo operations, tourism, and artisanal fishing activities, as vessel routes and movements have been adjusted to accommodate the requirements of these other activities, in coordination with representatives of those sectors.

Figure 17



Ship transit routes to the Panama Canal

However, the navigation of ships to port centers through the tidal channels of mangrove estuaries will always raise concerns among stakeholders, especially regarding ecosystems; this is understandable. In response to these concerns, the Planeta team refined its analysis in many specific areas, some of which are worth highlighting.

3.1. Induced waves and sediment resuspension

Regarding this effect the waves induced by the ship's movement of water beneath its hull concerns have focused primarily on the mangrove forest, whether due to erosion or the progradation of soils along the canal banks and in its intertidal zones. This led to an analytical evaluation of the various wave patterns in the natural water bodies of the environment resulting from navigation. of the ship, its dimensions and speed, through mathematical

modeling based on Boussinesq's Law (1872), which belongs to fluid mechanics. The study established that, even in the worst-case scenario, its danger can be controlled by the ship's speed, whose maximum limits were determined to be between 4 and 6 knots according to the distance between the ship and the shores, and the curvature the present meanders⁶. With this, the natural capillary swell of the tidal channel waters generally of aeolian origin dissipates the ship's wave due to its greater amplitude and sustained height, combined with the energy loss of the induced wave over the distance traveled; and finally, it diffuses it before reaching the affected shore. That is to say, at these speeds, there will be no changes in the normal swell in the shallow areas bordering the channel. This has also been verified live with the movement of ships in the port network of Guayas, Ecuador, through ships much larger than those budgeted for Puerto Barú, moving at speeds of 10 knots and in a narrower channel.

Regarding the resuspension of sediments with the movement of the ship, it is of course possible that it may occur in dredged segments (they have the shortest depth); but it is expected that in this circumstance it will have a very insignificant impact on the hyporheic ecosystem. In practice, what is most likely to cause this soil removal is the impact of water on the seabed due to the shear force of the ship's propellers; however, the ship has a remaining 1 m of clearance with respect to the lowest point of its hull – and the propellers are undoubtedly much higher – and it is assumed that it will always travel with the tide in its favor after the first third of the rising tide – there is enough time for its entire journey – which in the worst case raises it to no less than 2.27 m above the bottom; if this is added to the low authorized speed, there is no reason to consider a compromising propeller rotation.

This is a good opportunity to add something about the mechanics of sediment movement in the channel. The resuspension of bottom sediments is a natural and recurring phenomenon in the estuary, to which the behaviors of the area's aquatic species have certainly adapted. These arise from estuarine turbulence caused by the combination of the rising tides against the freshwater runoff from rivers, the topography of the channel, the density difference between the two interacting waters, and the sedimentary layer of the bed all play a role.

The vertical paths taken by the two water currents as they meet, along with the geometry of the riverbed, play a particularly important part, as the type of sediment present can cause resuspension.

⁶ The study concluded that the edge of the navigation channel (100 m wide) must never be located less than 50 m from the shoreline of the tidal channel

at low tide. This was also approved during joint fieldwork conducted with representatives of the fishing communities.

Thus, during a journey under the full sun on a dry season day, one might encounter a sharp divide between clear and highly turbid waters. of the channel (Figures 18 and 19); and likewise, alongside the clear waters of Bahía de Muertos, a strong resuspension of sandy sediments from the bottom can be found in the Boca Brava strait and its entrance inlet, to the point that the surface transparency does not exceed 2 m in distance in the Secchi Disk, something that is taken into account for the Operations Protocol of the dredging activity.

Figures 18–19



Fig 18. Murky waters at the Cuatro Calles site | Fig 19. Clear waters 1.9 km downstream from the site

3.2. Ship traffic and sensitive marine species

In this matter, it is important to first consider the low volume of ships traveling to the port. This is not the case of the 38 ships per day that transit the Panama Canal (we emphasize that there will be no designated space for ship berths within the estuary).

This issue of the risks to marine species has been widely discussed among the public and has been explained in its various aspects in several previous public documents; therefore, we do not believe it necessary to repeat what has already been said. However, it is worthwhile to recall some points made regarding cetaceans, especially since their movements encompass the entire gulf.

Regarding accidents and noise, it's important to remember that bottlenose dolphins entering

the estuary preferentially move towards Bahía de Muertos and not towards the Chiriquí Nuevo tidal channel, our navigation channel. Humpback whales, on the other hand, travel further east along the Gulf and do not enter the estuary (they don't even reach Boca Brava inlet); that is, they are outside the navigation route. Nevertheless, it's important to know that strict measures have been established regarding vessel guidance and speed, and consequently, controls on engine speed and noise levels, all with the aim of preventing accidents and to prevent interference between communication frequencies between species.

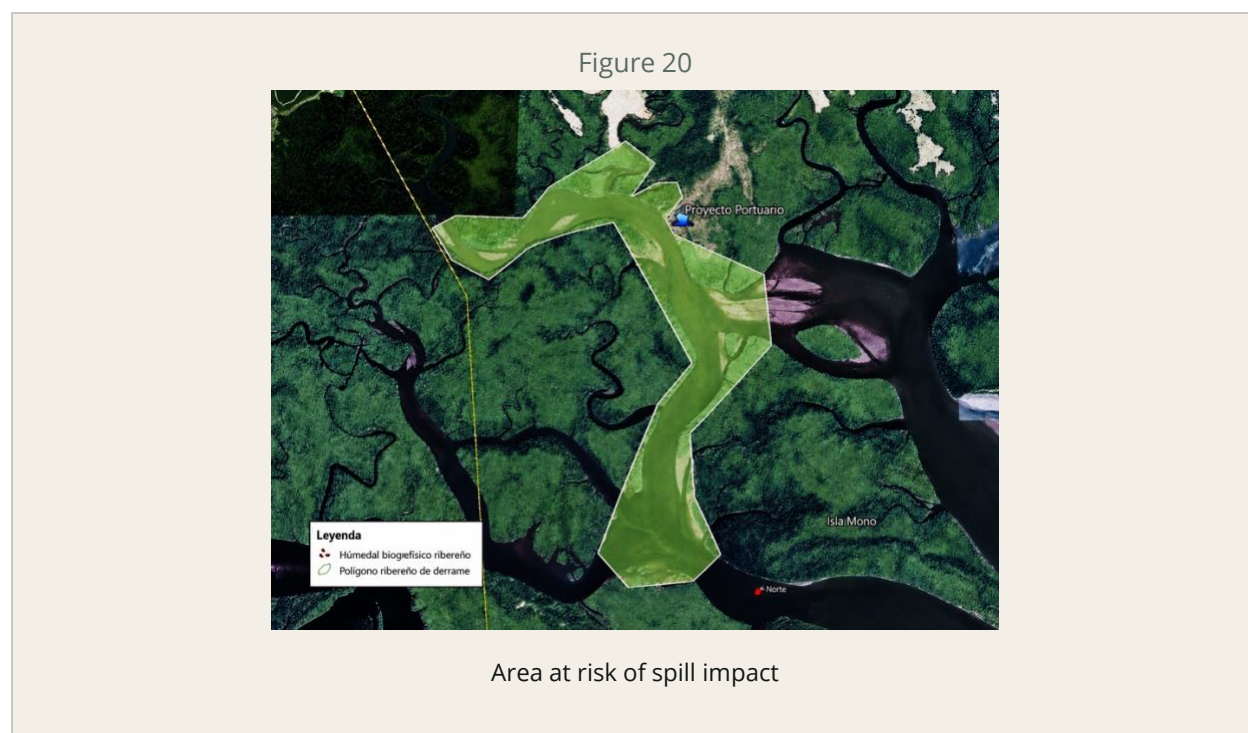
As already stated, the speed of all vessels within the canal area has been defined as between 4 and 6 knots; and outside the Entrance Buoy, the IMO standard for ships in the Panama Canal will apply, a regulation that to date has yielded highly effective results. Furthermore, it is important to note that thorough studies in acoustic ecology were conducted crossing frequency and noise power based on equal-loudness curves between emissions of ship-type and selected species from the marine environment and it was established that, certainly, the low speed of the engines is fundamental in the control of interference.

Another concern has been the turbidity caused by sediment concentration in the Boca Brava channel due to dredged material discharges, as this is a dolphin entrance to the estuary. It's important to remember that the discharges into the channel represent a very localized and short-lived impact (estimated at 2 hours and 20 minutes). Since dolphins are highly mobile in the area, it is expected that they will seek a suitable space at the time, as one exists, and will return just as it currently does in the face of high turbidity dynamics.

3.3. Emergencies due to possible hydrocarbon spills

Spills of hydrocarbons or other pollutants are addressed in the Environmental Impact Study (EIS) accordingly: as a risk, meaning subject to a probability of occurrence. The port will handle hydrocarbons and edible oils for regional distribution, so the movement and storage of these products inevitably leads to "exposure to the event," which contributes to the "Hazard" value of the incident. The study considered these aspects in its risk analyses and prevention, control, and contingency measures, clearly differentiating between the various types of fuels and oils, the receiving media (water or soil), and the different possible spill accident scenarios. These can be found in the Impact and Risk Assessment chapters of the approved Environmental Impact Study (EIS), under codes R-EA-02 ("Water pollution by hydrocarbons and wastewater") and R-EA-04 ("Soil pollution by waste and polluting materials"), and in the Environmental Management Plan under code MR-02 ("Prevention and control of surface water pollution by hydrocarbons"), MR-04 ("Prevention and control of soil contamination"), and the subheading "Emergency and Contingency Plans" with regard to

Annex 28, “Contingency plan for hydrocarbon spills” and its complement Annex 28.1, in the parts B, E, F and G.



By synthesizing the spatial reach within the estuary under the worst-case scenario, a vulnerability polygon was established, primarily considering the dock site as the source of the event, as well as other potential accident scenarios, narrower areas of the channel, currents, and sharp bends in meanders. The area affected by the resulting impact, encompassing the impact of full tides, totaled no more than approximately 790 hectares, all within the estuary (Figure 20). This means that the impact does not extend beyond the estuarine system, and all of this is easily manageable with existing national and international protocols. We would also like to add that the project will have its own specialized spill control unit on-site.

3.4. Management of liquid and solid waste

Regarding liquids, the first thing to highlight is that, as this is a project seeking certification as a “Green Port”, all port operations related to the movement of ships through the navigation channel, docking at piers, and loading and unloading procedures must comply with the regulations of the MARPOL Framework, Directive 73-77, and the International Convention for the Prevention of Pollution from Ships and Port Activities.

In this regard, it is agreed that bilge water, due to its contents, will be subjected to the international protocols signed by the country; these will be collected and treated by specialized companies that provide this service to the ports of Panama and may never be dumped into the estuarine environment, all of which is stated in the approved EIA. Regarding solid waste, apart from that generated by ordinary users. Those who will undoubtedly disembark from ships, particularly cruise ships, are among those affected by the project. All waste from the project will first undergo separation and sorting in a unit specifically established for this purpose. Non-recyclable waste will be taken to a facility for pre-treatment, including crushing and compaction, before being sent to the David City landfill. Industrial and recyclable waste will be sent to specialized companies for processing.

The facility for solids consists of two plants located within the grounds of the complex, which reduce the volume capacity by 80% and up to 50% of the weight, all without generating gaseous waste or black smoke chimneys, since the process is not done by burning systems or similar, but by crushing, compaction and suction dehydration.

4. Conclusion

The Puerto Barú project is not a "Potential Danger" to Coiba National Park, meaning that the park faces serious dangers that could have detrimental repercussions on its essential characteristics. Even less so is it a "Proven Danger," meaning that the park faces a proven, concrete, and imminent danger. This can be clearly verified in the referenced public document, the Environmental Impact Study (EIS) approved by the Ministry of the Environment, since the arguments presented throughout its pages clearly demonstrate that no effect, impact, consequence, or risk arises from an alleged potential danger and proven that it will remotely damage this park; this is because, essentially, despite the alterations in the estuarine lagoon system – which contains the David Mangroves Protected Area – the composition of the system, the functions and functionality of its environmental factors and the structure of its components are preserved in time and space, and this is what "sustainable development" means in its fullest sense.

It should be noted in this context, and as an appendix, that the Municipal Council of the District of David, upon approving Agreement No. 21 of June 6, 2007, which "adopts provisions for the protection of the environment and mangroves on the coasts of the District of David," designated the District's mangroves as a protected area with the specific purpose of protecting and conserving the ecosystems of this important wetland, and nothing else. Regarding the tidal channel—which will provide ships with access to the port and is located

within the protected area—neither the municipal agreement nor the proposed management plans address this issue.

Subsequent proposals have included prohibitions on navigation in the estuaries or dredging of the riverbed. However, this project gave special attention to the sustainability of the system, considering that, due to the type of vessels used, a closed estuary and its mangroves form the best protective shield. This necessitates working with the mangroves, not against them, under scientifically based management plans for their conservation.

It is this, along with all the environmental care put into the project, that allows us to affirm, in a context of systemic relationships with the gulf, that the island chain of the coastal marine territory is not only safe from any threat due to Puerto Barú, but it also benefits from the intensive monitoring that will be given to the entire lagoon system using the most advanced technologies available. The truth is that if we preserve this biodiversity haven for our neighboring community, its health as a center will be strengthened feeding capacity and the capacity of their reproductive habitats, we can be sure that by maintaining connectivity between the parties, we will also be guaranteeing the life and health of that great beneficiary, the Gulf, which exchanges mass and energy with it at all times.

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