An aerial night photograph of a city, likely Santa Fe, showing a dense urban landscape with numerous illuminated buildings and streets. A large body of water, possibly a river or harbor, is visible in the foreground, with several boats docked. The city lights create a vibrant, colorful scene against the dark night sky.

PROTECTION OF NATURAL SLOPES AND REDEVELOPMENT IN THE PORT OF SANTA FE

CEGM3000

MULTI-DISCIPLINARY PROJECT

MP393

PROTECTION OF NATURAL SLOPES AND REDEVELOPMENT IN THE PORT OF SANTA FE

MP393

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Project Duration

09-2025 - 11-2025

Faculties

MSc Biomechanical Engineering, MSc Technical Medicine, MSc
Offshore and Dredging Engineering, MSc Civil Engineering,
MSc Strategic Product Design



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Preface

This report is the result of the Multidisciplinary Project (CEGM3000) at Delft University of Technology. The project was carried out by a team of six students from different disciplines, combining technical, design, and management perspectives.

The assignment focused on the Port of Santa Fe in Argentina and aimed to develop a sustainable and resilient vision for its future. The main goal was to design an integrated concept that combines slope protection with the redevelopment of the Amarras waterfront, creating a public area that reconnects the port with both the city and the river.

This report is intended to serve as an advisory document for the Ente Administrador del Puerto de Santa Fe (EAPSF), providing a strategic and technical foundation for future development steps in the port area. The proposed designs and analyses aim to support decision-making on sustainable waterfront redevelopment and riverbank protection. In addition, the report outlines a long-term vision and roadmap for the port's transformation, offering guidance for future projects that enhance connectivity, environmental quality, and social and economic vitality, ensuring that the port continues to develop as an integrated and resilient part of the city.

We would like to express our sincere gratitude to our TU Delft supervisors, Dr. Ing. J.A. Antolinez, Prof. Dr. Jenny Dankelman, Dr. Mariëlle Walraven, Prof. Mr. Dr. Ir. Sicco Santema, Dr. Ir. Abraham Gebremariam, and Dr. Ir. Jeroen Hoving, for their continuous guidance, valuable feedback, and encouragement throughout the project.

Special thanks also go to the technical team of Ente Administrador del Puerto de Santa Fe (EAPSF), in particular Catalina de la Vega and Estéban Franco, for their kind support during our time in Santa Fe and for bridging both cultural and language barriers during the research phase. We would further like to thank Mg. Ing. Pablo Arreco and José Grau from the University of Buenos Aires for their expert advice and for sharing their local knowledge and experience, which greatly enriched our work.

Buenos Aires, October 2025

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Abstract

The Port of Santa Fe was once a major hub for both domestic and international trade, but changing river dynamics have reduced its accessibility and economic importance. As a result, the port now faces the challenge of redefining its role and exploring new functions that reconnect the port with the public. The Dyke 2 waterfront in the Port of Santa Fe, is currently in a deteriorated and underdeveloped state, lacking essential public facilities, accessible green spaces, and safe access to the river. Most importantly, the site faces severe riverbank instability, confirmed by a calculated Safety Factor (SF) of 0.67.

This report presents an integrated vision and technical design for the sustainable redevelopment of the project site area, commissioned as an advisory document for the Ente Administrador del Puerto de Santa Fe (EAPSF). The project employed a strategic track, guided by four pillars, and a slope protection track, using a Multi-Criteria Decision Analysis (MCDA) to select a solution, resulting in a design containing both technical stability and a public urban concept.

The resulting urban concept, *The Santa Fe Riverside Park*, serves as a project embodying the strategic vision. The design integrates adaptive infrastructure, including stepped terraces and docking places, engineered to accommodate significant seasonal river fluctuations. This concept is supported by the delivery of a 15-year long-term roadmap. The unstable slope is protected using an ecosystem-friendly Articulated Concrete Block mattress system, improving the calculated sliding SF from 0.67 to 1.9, and achieving an erosion SF of 2.10.

Finally, the report provides the Port Authority with a strategic foundation of recommendations to realise the project.

Summary

The port of Santa Fe is facing a moment of transition that requires coordination between productive activities and the diverse ambitions of stakeholders for urban development. Within the port, the project site on Dyke 2 is currently in a deteriorated and underdeveloped state: it lacks essential public facilities, accessible green spaces, and safe access to the river. At the same time, the project site faces a serious technical risk: the instability of the riverbank slope. A calculated safety factor (SF) of 0.67 confirms that the driving forces exceed the opposing forces, indicating critical instability.

To address these combined strategic and technical challenges, the project was structured around three interrelated components: 1) identifying a suitable slope stabilization solution, 2) designing the project site as an attractive public space, and 3) developing a long-term vision at Port level. The methodology consisted of two parallel tracks; a strategic track and a technical track. Both followed a synchronized three-phase structure: Research & Analysis, Concept Development, and Detailed Concept. The strategic track focused on establishing a port vision, structured around four guiding pillars, and translating it into an integrated urban design for the Dyke 2 site. The technical path systematically evaluated stabilization alternatives through Multi-Criteria Decision Analysis (MCDA). The MCDA assessed solutions based on five criteria clusters: protection, ecosystem, constructability, costs, and usability, ensuring that the final integrated design achieved both technical stability and alignment with the Port's spatial ambitions.

The integrated approach resulted in a design that addresses both the site's technical and spatial challenges. The geotechnical analysis led to the selection of an Articulated Concrete Block mattress system as the most suitable solution to address the site's slope instability. The proposed design improves the slope stability from the initially critical SF of 0.67 to 1.9 for sliding, based on the same calculation method, and achieves an additional erosion SF of 2.10 for surface protection.

The proposed design of the articulated concrete block mattress has an open-cell structure, which allows for plant growth and thus ecological enhancement. The estimated cost of the stabilization solution is approximately USD 4.05 million.

The final urban design proposal, *The Santa Fe Riverside Park*, serves as a pilot project for the strategic vision developed for the Port of Santa Fe. This vision, formulated prior to the site design, is built around four guiding pillars, *Connectivity & Sustainable Mobility*, *Attractive & Livable Environment*, *Co-existence*, and *Economic & Cultural Vitality*, which together address the main challenges identified in the problem definition. The Riverside Park integrates all four pillars within the design. It combines public spaces, green infrastructure, and direct access to the river to reconnect citizens with the water, as is desired by the Port Authority. This is done by including elements such as a viewing tower and a docking place in the design which enhance a connection with the water.

In addition, the report concludes with a set of recommendations and future steps to guide implementation. These include exploring eco-friendly concrete alternatives, refining site data and slope modeling, and defining clear guidelines for the park's long-term use and management.

The project provides a realistic reference for future decision-making and investment in the redevelopment of the Port of Santa Fe.

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1. Introduction

This chapter introduces the overall context and objectives of the project. It outlines the background and motivation for addressing the transformation of the Port of Santa Fe, framing the project within broader spatial, technical, and strategic challenges. The chapter also defines the main direction of the research and establishes the foundation for the analyses and design approach developed in the following chapters.

1.1 Background

Santa Fe, the capital of its namesake province in northeastern Argentina, has long been defined by its port, which historically connected the fertile Pampas region to the Paraná River and international markets. The location of the port of Santa Fe can be seen in Figure 1.1. Inaugurated in 1910, the Port of Santa Fe became a strategic hub in Argentina's inland trade network during the country's early 20th-century economic expansion driven by agricultural exports. Its monumental infrastructure still reflects this industrial legacy.

However, recurring national and local crises, and the river behaviour causing poor access to the port, have since affected port operations, prompting renewed discussions on its future role. A turning point came in 2005 with the demolition of the enclosing wall, which reopened the riverfront to the city and initiated a new phase of urban redevelopment. A masterplan developed in the 2000s set the course for a multifunctional waterfront that balances production with public access. Today, the port has evolved into a vibrant leisure and commercial district, featuring key attractions such as the Casino Santa Fe, Los Silos Hotel, and Ribera Shopping Mall, where recreation, tourism, and contact with the riverfront define its contemporary identity.

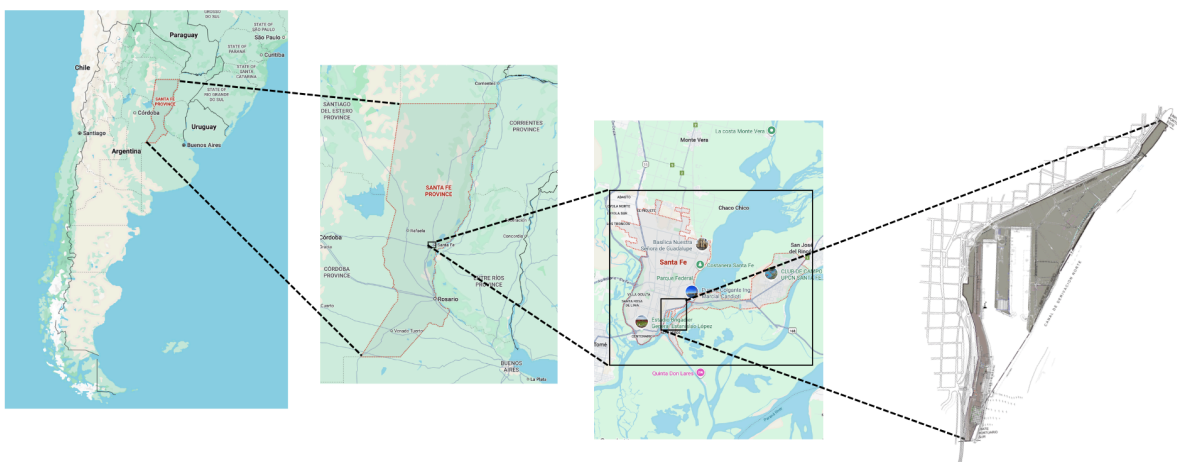


Figure 1.1: Map of the port of Santa Fe in the Santa Fe Province, Argentina

In parallel with these transformations, institutional changes also reshaped the port's governance. In 1993, the Ente Administrador Puerto Santa Fe (EAPSF) was established as a non-state public entity (see Figure 1.2 and 1.3), following the transfer of the port from national to provincial jurisdiction. Since then, the EAPSF has functioned as the Port Authority, responsible for managing daily operations and guiding the port's development (Citroni, 2024). From this point onward, it will be referred to as the "Port Authority."



Figure 1.2 and 1.3: Office of Port Authority situated in the Port of Santa

1.2 Project brief

As mentioned in the background, the Port of Santa Fe is in a moment of transition. The port currently still serves as a logistics hub, however, there is growing pressure to reconsider its role within both the city and wider region. This is because the capacity of the industrial hub has been reduced due to sedimentation and limited dredging possibilities. Partly as a result, the port is no longer purely industrial: residential towers, hotels, and recreational facilities have been developed along the waterfront.

Consequently, the port faces technical challenges related to riverbank protection and stabilization. In several areas, structural reinforcement is absent. Addressing this issue requires an integrated redevelopment approach that combines technical and spatial dimensions. On the technical level, durable stabilization is essential to ensure the safety and longevity of future developments. On the spatial level, the transformation of the undesignated waterfront into an attractive public space. Ultimately, these efforts must be embedded within a comprehensive, long-term vision that positions the port as a resilient and multifunctional urban asset.

1.3 Scope

This project will be carried out for the Port Authority and focuses on the redevelopment of the project site at Dyke 2 and the adjacent slope of the Port of Santa Fe. The project focuses on the redevelopment of the project site at Dyke 2 and the adjacent slope of the Port of Santa Fe. The scope includes defining spatial strategies that ensure technical stabilization, enhance public accessibility, and strengthen the port's connection to the city. The aim is to translate the broader vision for the port into concrete design interventions at the project site.

Within this context, the project consists of three interrelated components:

- Slope stabilization: identifying sustainable stabilization strategies that are suitable for the specific site slope and therefore well-adapted to the dynamics of the Paraná River and the Northern Diversion Channel.
- Project site design: designing the project site as an attractive public space that aligns the long-term vision to stimulate river tourism.
- Port-level vision creation: developing a long-term vision for the Port of Santa Fe, based on stakeholder interviews and contextual analysis, to guide future decision-making.

The project scope includes slope stability calculations, cost estimates, and a detailed site design, supported by 3D modeling and material specifications. However, the project remains at the pre-implementation stage. Therefore, the work focuses on developing technically and spatially feasible design solutions for the project site area, without proceeding to construction documentation or implementation planning.

1.4 Research questions

Each interrelated component holds an underlying research question and therefore results into the three following questions:

1. How can the slope in the Dyke 2 project area be naturally protected and developed?
2. How can the Dyke 2 project site be redeveloped to make it attractive for visitors, investors, and residents while coexisting with its port functions?
3. How can the Port of Santa Fe become connected to the city and surrounding areas?

1.5 Methodology

This section outlines the methodology applied throughout the project, which is visualized in Figure 1.4. The figure visualizes how the process was divided into two parallel tracks: a strategic methodology, focused on developing a long-term vision for the port and urban design of the project site, and a technical methodology, focused on the stabilization of the slope.

Both tracks follow a similar three-phase structure:

- Phase 1: Research and analysis: understanding the context through data collection, literature review, and stakeholder input.
- Phase 2: Concept development: translating insights into potential design and stabilization concepts.
- Phase 3: Detailed concept: refining the chosen concept into a coherent and technically feasible proposal.

To ensure alignment between the both tracks, daily collaboration was organized through a shared Excel task management system. This Excel was used to assign responsibilities, monitor progress, and plan short-term deliverables. To maintain coordination, a rotating leadership system was implemented. Each day, one team member acted as ‘president’, responsible for opening and closing the workday, listing the tasks, and setting priorities.

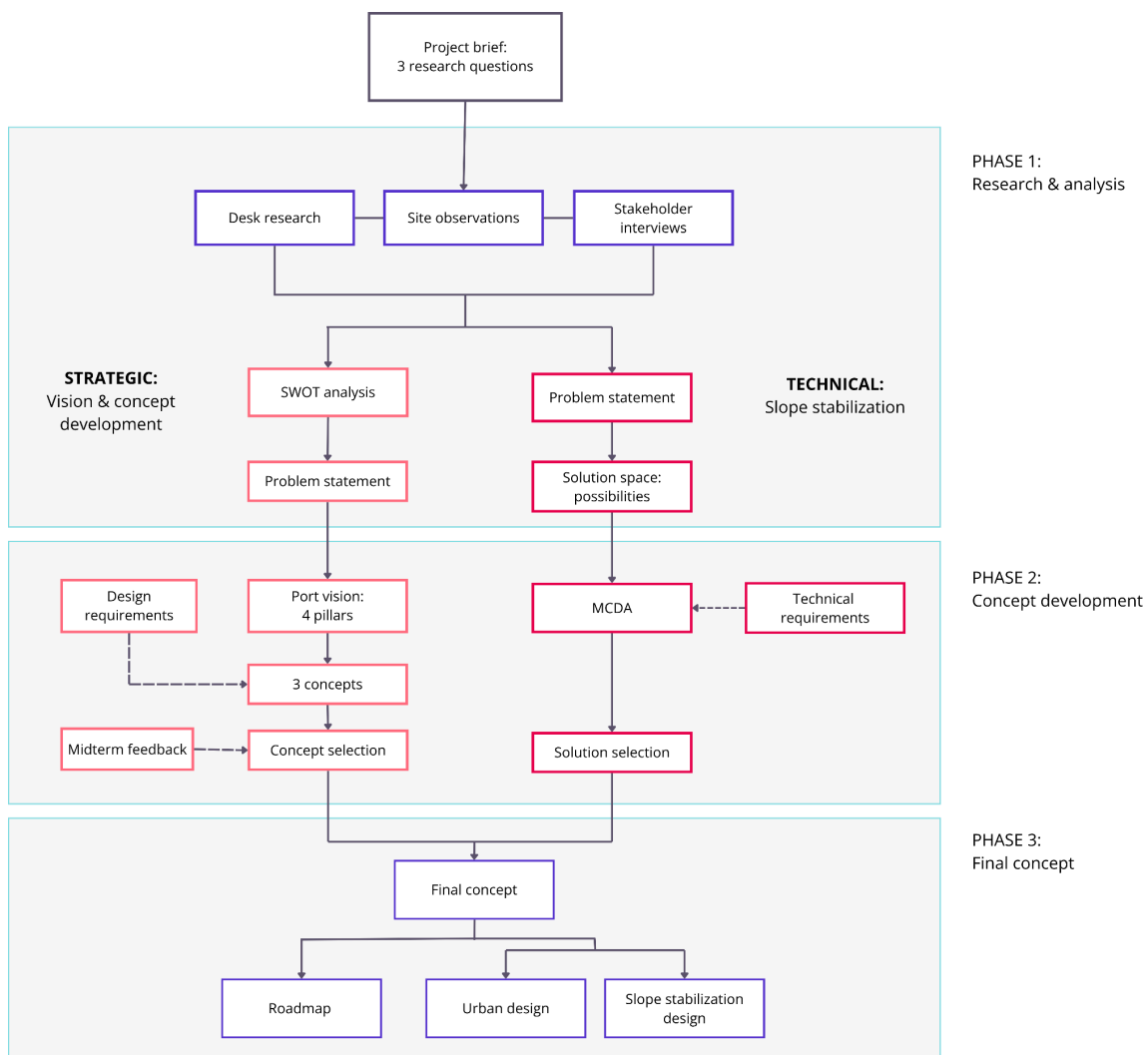


Figure 1.4: Overview of the used methodology

1.5.1 Strategic methodology

The strategic methodology, as can be seen in pink on the left track of Figure 1.4, guides the development of both the port vision and the urban design for the Dyke 2 project site.

Phase 1: Research and analysis

The first phase aims to gain an understanding of the urban, economic, and socio-political context of the port and its surroundings. Desk research and site observations are conducted to analyze the area and its existing land use. In parallel, semi-structured interviews were held with stakeholders to identify key issues and ambitions. The collected data were summarized in a SWOT analysis, which formed the basis for the problem statements.

Phase 2: Concept development

In this phase, the findings from Phase 1 are translated into a long-term strategic vision for the Port of Santa Fe. Four guiding pillars are derived from this vision. Based on these pillars, several urban design directions for the project site are developed, exploring different spatial scenarios. In a mid-term presentation for the Port Authority, the different concepts are presented in order to gather feedback.

Phase 3: Detailed concept

Based on feedback and evaluation of the concepts, one integrated design direction is selected for further development. In this final phase, the proposal is worked out in detail, with an accompanying CAD model and 3D visuals. The urban design proposal for the project site is integrated together with the technical design for slope stabilization.

1.5.2 Technical methodology

The technical methodology, as can be seen in red on the right track of Figure 1.4 focuses on the engineering and stability aspects of the slope in the Dyke 2, which is part of the project site. The process follows the same three-phase structure as the strategic track, ensuring coordination between the technical feasibility and spatial design.

Phase 1: Research and analysis

The first phase aims to understand the geotechnical and hydrological conditions of the site. Literature research and interviews were conducted to analyze river dynamics, climate influences, and soil characteristics that affect slope stability. Site observations are conducted to gain a clear picture of the waterfront and current stabilization measures. Consequently, possible solutions for the waterfront are reviewed to identify potential stabilization strategies. The insights from this phase are summarized in a technical problem statement.

Phase 2: Concept development

In the second phase, the stabilization strategies identified during Phase 1 are further explored and compared, ranging from soft bioengineering solutions to hard structural interventions. These alternatives are systematically evaluated through a Multi-Criteria Decision Analysis (MCDA). The analysis results in the selection of the most suitable stabilization approach for the specific site conditions.

Phase 3: Detailed concept

In the final phase, the selected stabilization strategy is developed into a detailed technical design, including cross-sections, technical drawings, and supporting calculations. The design is visualized in a 3D visualization, and material specifications and cost estimations are defined to assess financial feasibility. The final stabilization design is then integrated with the urban design proposal to ensure

technical coherence and visual alignment across the project site.

A large, white, classical-style building with a clock tower and a flagpole in the foreground. The building features arched windows and doorways, and a prominent clock tower with two clock faces. A flagpole with a flag is visible on the left side of the building. The scene is set against a clear blue sky.

PHASE 1

Research & analysis

Introduction of Phase 1

Phase 1 forms the analytical foundation of the project. It focuses on understanding the spatial, social, and physical conditions shaping the Port of Santa Fe and its surroundings, in order to identify the key challenges that guide the project's strategic and design direction.

This phase results in three main analytical components:

- An urban analysis of the city, port, and project site, examining spatial structure, accessibility, and governance to identify opportunities for urban integration and redevelopment.
- A technical analysis of the river and slope conditions, assessing hydrodynamic processes, soil composition, and slope stability to understand the physical risks and inform sustainable stabilization measures.
- A synthesis through SWOT analyses and problem definition, combining findings from both analyses into two SWOTs and three problem statements that define the strategic, spatial, and technical challenges of the port's redevelopment.

Because these components operate at different but interrelated levels, Phase 1 is structured into three chapters.

Chapter 2 addresses the urban analysis of the city, port, and project site. Chapter 3 focuses on the technical river and slope analysis. Chapter 4 consolidates these insights into the SWOT and problem definition, forming the bridge toward the strategic and design development presented in Phase 2.

2. Urban analysis: city, port and project site

This chapter serves as the orientating phase of the study, aimed at defining the problem statement through an analysis of the city, the Port of Santa Fe, and the project site. It examines the area's spatial, historical, political, and economic context, as well as its connectivity and stakeholder dynamics. By understanding these interrelated factors, the chapter establishes a comprehensive foundation for identifying key challenges and opportunities that shape the project's direction.

2.1 Location analysis

This section outlines the geographical and functional context of the Port of Santa Fe, examining its urban integration, spatial structure, and diverse uses. It concludes by focusing on Dyke 2, the specific site selected for the proposed urban design project.

2.1.1 Surrounding areas of the Port

Figure 2.1 shows the Port of Santa Fe in green. The port is surrounded by the city of Santa Fe and the waterfront. To the west lies the historic city center of the city (in purple), which serves as the commercial, residential, and cultural heart of Santa Fe. Across the river to the east lies Alto Verde (in orange) which is a low-income residential neighborhood that has historically been connected to the port through labor and daily mobility. This neighborhood is accessible by a car bridge up north.

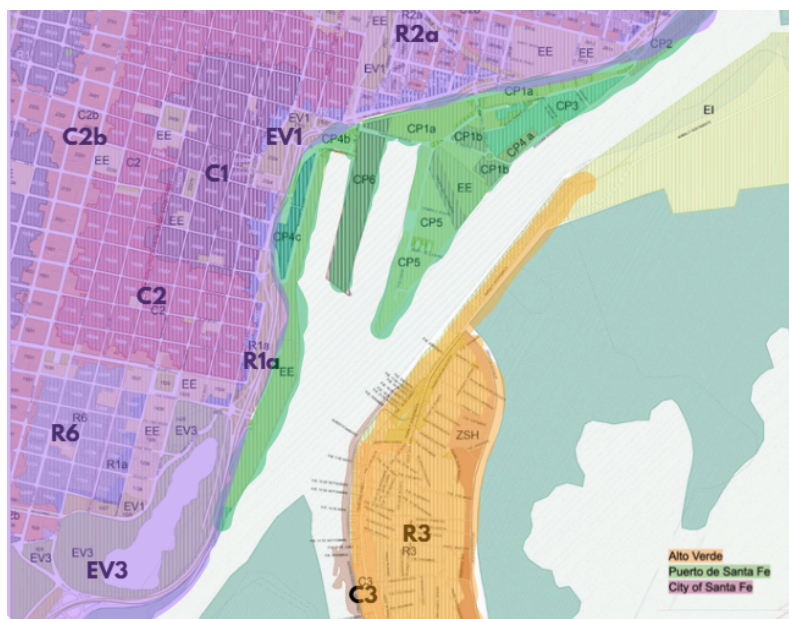


Figure 2.1: Areas surrounding the Port of Santa Fe

The central districts of Santa Fe include the C1 Microcenter, the traditional downtown with commercial, administrative, and cultural functions, and the C2 Macrocenter, which extends the central area with residential and mixed urban uses. The network of C2b primary roadways links these districts to the port and to other parts of the city. Other important functions in the center include public green spaces (EV1, EV3) and dense residential areas (R1a, R2a, R6).

Alto Verde was estimated to have around 10.000 inhabitants in 2021 (Alto Verde City, 2021). Figure 2.1 shows three key land-use categories: C3 Neighborhoods, which represent the main residential areas;

R3 Low-density integration zones, characterized by scattered housing and exposure to environmental risks; and ZSH Water security areas, which highlight the community's exposure to flood risks. This structure reflects Alto Verde's identity as a lower-income district with limited infrastructure and strong dependency on the river.

This mix of functions shows that the port is not only used for logistics and industry, but also has residential, commercial, and leisure areas. The port terminals connect Santa Fe to regional export routes; and apartments, hotels, and cultural facilities are being used daily by city residents and other visitors. For people from Alto Verde, the port corridor is also an important route into the city.

2.1.2 Port of Santa Fe

This section examines the Port of Santa Fe in more detail. The port itself covers a total area of 72 hectares, of which 54 hectares form part of the city-port area, for residential and commercial use, and 18 hectares are assigned to the operational port area, including the terminals for export.

The Port of Santa Fe consists of two different docks and dykes, as can be seen in Figure 2.2. Dyke 1 has mainly commercial and hotel activities, housing a casino, shopping mall and restaurants. Dyke 2 combines residential and commercial activities, including restaurants and recreational facilities along the waterfront. Approximately 10% of the area is covered by green spaces. In the northern part of Dyke 2 there are office buildings as well as the industrial areas, including the Raízen oil storage (Shell) terminal. Other industries in this area mainly consist of construction and electrical companies.



Figure 2.2: Overview of the docks and dykes in the Port of Santa Fe

The entire port area, including the two Dykes, is divided into multiple functional zones. The two most important zones, the Port Area and Port City will be elaborated below.

Port area

The grey areas highlighted in Figure 2.3 represent the Port Area, where the port's operational activities are concentrated. On the west side it accommodates the operational facilities of the port, including the container and general cargo terminal, the agro-bulk terminal and the multipurpose terminal. These are public terminals, which means that operations, management and administration are done by the EASPF. The private terminal of Raízen oil storage is on the east side, next to the Northern Diversion Channel.



Figure 2.3: Overview of Port Area zones

Port city area

The areas highlighted in red, green, and purple in Figure 2.4 are designated as the Port City. The red area houses a mix of commercial, industrial, sporting, and residential activities and the purple area houses educational and institutional functions. The green areas consist of parks or grassfields that are available for future parks.

This analysis shows how groups of people and functions coexist in the Port of Santa Fe within a relatively compact urban port environment, ranging from industrial operators and commercial companies to port residents.



Figure 2.4: overview of Port City zones

2.1.3 Dyke 2 area

Project site

The project site is located along the southern edge of Dyke 2, along the Santa Fe River for approximately 630 meters. In Figure 2.5, the Raízen oil storage terminal can be seen in the foreground and the project site is located behind it along the riverbank. Residential towers stand at the tip of the dyke. The image provides a good aerial view of the slope.



Figure 2.5: Surroundings of the site - Raízen oil storage terminal in the front

This waterfront strip, designated as green space, is currently in a deteriorated state, as seen in Figures 2.6 and 2.7. It has the potential to be transformed into a public access area, which could also boost tourism.



Figures 2.6 and 2.7: Project site images

Site context

The site is situated directly opposite the Liceo Municipal “Antonio Fuentes del Arco”. This institution offers programs in visual arts, music, dance, and languages. The broader area of Dyke 2 contains several residential blocks, such as Amarras Center Torre IV, sports facilities including tennis courts, a number of offices and restaurants, and several spaces for designated green areas that need to be developed. Slightly further north, heavy industry and the Raízen oil storage facilities dominate the port landscape. In Figure 2.8 the specific functions of Dyke 2 are shown.



Figure 2.8: Functional land use map of Dyke 2

Municipal green space - adjacent to the project site

In front of the Liceo Municipal lies a large green area, situated between the institution and the project site, see Figures 2.9 and 2.10. This area has great potential as a public recreation space, but is currently underdeveloped. Interviews and site inspections revealed that residents, employees, and students currently lack sufficient outdoor amenities, such as seating, park infrastructure, or shade.

As shown in Figure 2.8, this green plot is owned by the Municipality, not by the Port Authority, which makes its future plans uncertain. Nevertheless, contractual obligations stipulate that the area must retain its green function, preventing it from being developed for residential or commercial purposes. Although this area lies outside the scope of the current project, its location next to the project site makes it an important space to acknowledge.

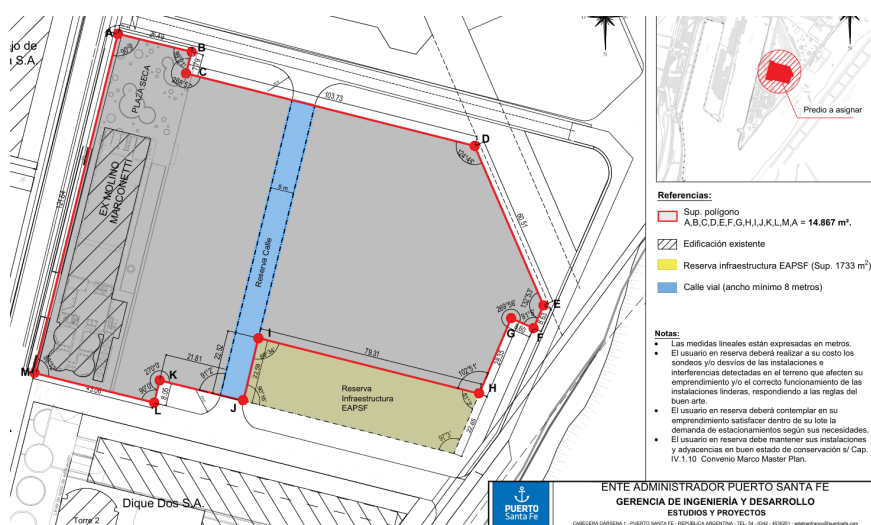


Figure 2.9: Photo of the green area adjacent to the project site (reserved for green use)



Figure 2.10: Photo of the green area adjacent to the project site (reserved for green use)

Industrial activities

In addition to the presence of residential functions along Dyke 2, industrial activities remain active in the area. The Raízen oil storage terminal is only a short distance from the project site. Figure 2.11 shows the project slope (highlighted in yellow), located between the high residential towers of the Amarras complex (on the right) and the Raízen oil storage terminal in the foreground.



Figure 2.11: Project slope highlighted in yellow, located between residential towers and the Raízen oil storage terminal on Dyke 2

For safety reasons, current regulations prohibit construction directly next to the Raízen oil storage terminal within a limited radius, which must be taken into account in the development of the project site. The concession contract for the Raízen oil storage terminal expires in 2030. It is currently uncertain whether the site will continue to be used for industrial purposes or whether new land uses will be possible after that date. In addition to the Raízen oil storage terminal, the northern part of Dyke 2 is home to various other industrial and office-related activities, such as sawmills and port-related service companies.

2.2 Connectivity with the Port of Santa Fe

This section examines the physical connections between the Port of Santa Fe and the city, addressing both land-based and, possibly, fluvial transport. It also examines the social connection between the Port of Santa Fe and its surrounding cities. It highlights the historic role of rail and road access, the current dominance of cars, and limited well developed facilities for pedestrians and cyclists. As well as

the port's strategic yet challenging position on the Paraná River, shaped by sedimentation, low water levels, and emerging initiatives for recreational and passenger transport.

2.2.1 Land-based connection

The transport connection between the Port of Santa Fe and the city center is defined by several key routes and modes of transit:

Trains

Rail transport once played a major role in connecting Santa Fe's port with agricultural production from the hinterland. The city was served by large stations such as Mitre and Belgrano (Wikipedia, 2024a, 2024b), which made it an important hub in national logistics. Over time, however, the network declined due to underinvestment, competition from road transport, and railway privatization. By the early 2000s, passenger services had disappeared, leaving much of the infrastructure underused.

Buses

Public buses connect the port with the city center and Alto Verde. The main bus routes are line 9, which connects the port with the city center and other neighborhoods, and line 13, which passes through the port on its route connecting the Alto Verde neighborhood with the city center. Bus stops are available at various points along the main streets, this can be seen in Figure 2.12.

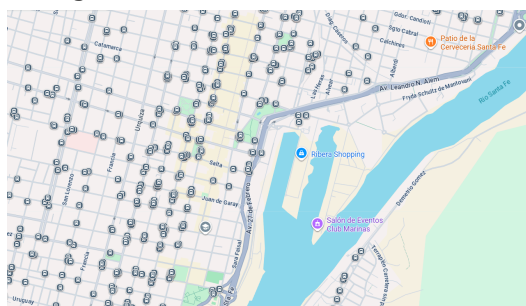


Figure 2.12: Bus stops along the port

Cars

Cars are the dominant mode of transport connecting the Port of Santa Fe to the city center. The two main access roads carry a significant amount of traffic which can be seen in Figure 2.13, ranging from large trucks to passenger cars. In recent years, traffic has increased due to the construction of new residential and commercial areas, while the road infrastructure has not kept pace. In addition, free public parking spaces are available within the operational port area. As a result, many drivers leave their cars within the port area and continue their journey into the city, creating additional congestion in the port.

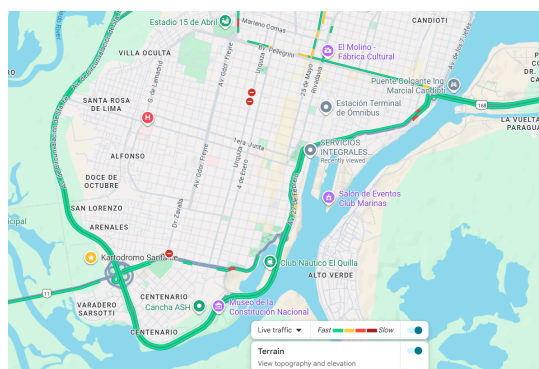


Figure 2.13: Main roads along the port

Pedestrian and bike lanes

The infrastructure for non-motorized transport has distinct characteristics, defined by a lack of continuous, dedicated facilities. Without protected bike lanes or uninterrupted sidewalks, pedestrians and cyclists must navigate an environment primarily designed for vehicles. This journey requires crossing major, multi-lane intersections. Furthermore, access to the waterfront itself is fragmented and discontinuous, as any potential path is interrupted by fences, active port operations, and private lots. At the same time, Santa Fe city offers a free shared-bike service, Las Bicis, for its citizens, encouraging cycling as a practical means of transport despite these limitations. There are many “bicipuntos” (bike docking/pick-up stations) around the city (Santa Fe Capital, 2023).

2.2.2 Fluvial connections

The Port of Santa Fe has been an important point for both regional and international shipping, because it is the last upstream port accessible to oceangoing vessels on the waterway of Paraná to Paraguay (Predict Wind, n.d.). The port currently handles a variety of cargo, including grains, oilseeds, construction materials, and other goods (Santa Fe Provincia, n.d.). Throughout its history, it has maintained its role as a public-use port, a function it continues to serve today. But, according to the president of the port, many citizens of Santa Fe are no longer very familiar with the water.

Access and operations

Cargo ships must enter through an access channel that connects the port to the Paraná River. This indirect connection reduces efficiency, as the channel is prone to sedimentation and would require constant dredging and maintenance to remain navigable, a process considered economically unviable due to its high cost. As oceangoing vessels have grown in size, and the need for dredging has increased accordingly, the decline of traffic to Santa Fe has therefore accelerated.

The port's operational capacity is highly dependent on the water level of the Paraná River. In recent years, prolonged periods of low water, known locally as "la bajante", have limited the cargo capacity of vessels, often forcing ships to reduce their load or rely more heavily on barges for regional transport (Heath, 2024). During severe low-water events, Argentine grain ships have been forced to cut cargo by up to 25% (Bronstein & Heath, 2021).

Recreational transport

In addition to large commercial vessels, the Port of Santa Fe also hosts smaller boats. At Dyke 2, moorings are available through spaces like the Club Marinas Puerto Santa Fe, which offers facilities for sailing, motorboats, and other recreational activities (Merino, 2018). The nearby Hotel Puerto Amarras also provides private docking options (Hotel Puerto Amarras, n.d.).

In 2023, a passenger boat for over 60 people was in operation at Dyke 2, highlighting the potential for excursions and tourist transport on the river (Loyarte, 2023a). Also, a major investor has existing plans for organizing river tours along the coast of the city, mainly focussing on city history and nature.

According to the director of cooperation and international trade, there are also plans to introduce public fluvial transport over the Paraná, a project plan based on the *Businú* concept of Colombia (Minister of Transport Colombia, 2025). The concept envisions a connection between two locations in Alto Verde and the port, this can be seen in red in Figure 2.14 below. However, investors are still required to make this project a reality.



Figure 2.14: Connected fluvial transport in stakeholder plan

2.2.3 Social connections

This section explores the social connections of the Port of Santa Fe with its surrounding neighbourhoods Alto Verde and Santo Tomé.

Alto Verde

As mentioned, the Port of Santa Fe is located between the historic city center, the Paraná River, and the neighborhood of Alto Verde. Its position makes it both a link and a barrier between these areas. Alto Verde, right next to the port, is one of the most underdeveloped low-income neighborhoods in the city. This is very different from the port itself, which has long been tied to wealth and trade. The neighborhood originated as a settlement for workers involved in the construction of the harbor, particularly the access channel. Dredging operations were carried out during the harbor's artificial development (Mendizabal, 2025). With the official opening of the Port of Santa Fe in 1910, more families, mostly dockworkers from the nearby community of Colastiné, settled there. (Crece El Vínculo Entre El Puerto Santa Fe Y Alto Verde, 2024).

Alto Verde is a riverside neighborhood of Santa Fe with around 10,000 inhabitants. However, through valuable conversations we heard that there are even more people (~10,000) living there illegally. Historically, it developed with limited infrastructure and small residential lots, and it has frequently been perceived as an isolated and marginalized district within the city. The relationship between Alto Verde and the Port of Santa Fe is one of direct physical proximity but functional and social separation. According to the director of cooperation and international trade, although crossing the river by boat is illegal, many citizens of Alto Verde still do so. This highlights the need for an official means of river transport.

The sense of separation between the port and the community is intensified by the port's internal division. While the active industrial area remains non-residential, the section of the old docks across from the Alto Verde coast has been transformed into one of the city's most affluent districts. This redevelopment accentuates the contrast and social divide between the new wealthy hub and the nearby working-class neighborhood of Alto Verde. With modernization and automation reducing the area's economic dependence on the port, a private investor emphasized the importance of rebuilding social connections. He noted that providing employment opportunities for Alto Verde residents, supported by education programs, could foster social recovery and create mutual benefits for both the city and the port.

Santo Tomé

A couple of kilometers south of Santa Fe lies the city of Santo Tomé. While not directly next to the port, it is strongly connected to Santa Fe and aims to develop a more active economic and cultural role in the region.

The mayor of Santo Tomé, who has served for the past 20 months, described Santo Tomé as “three cities in one”: a middle-class area, a lower-income district, and a northern zone where the wealthier population resides. Investments are now being made to better connect these neighborhoods and foster greater social integration. He explained that most cultural, educational, and social activities such as studying, nightlife, football matches, and major events still take place in Santa Fe’s provincial capital, leaving Santo Tomé functioning largely as a “sleeping city.” The current administration is actively working to change this image by making Santo Tomé more dynamic and independent, while also strengthening the city’s connection to the city of Santa Fe.

2.3 Political situation

This section examines the political and institutional framework of the Port of Santa Fe. It outlines the role of the Port Authority, the composition of its Board of Directors, and the influence of provincial leadership.

2.3.1 Institutional structure of the Port Authority

As mentioned, the Port of Santa Fe is managed by the Port Authority. While financially and administratively independent, they remain under the authority of the provincial government, making it both a technical body and a political actor. Its core responsibilities include:

- Managing port infrastructure and (public) terminals
- Working with concessionaires and developers on new projects (private contract holders).
- Coordinating with the Municipality on urban planning, traffic, and tourism
- Autonomous public entity created by provincial law
- Reports to the Governor / Ministry of Production
- Subject to national trade and customs regulation

At the center of its governance model is the Board of Directors, composed of nine members representing diverse stakeholders from both the public and private sectors. The Board is chaired by a president, appointed directly by the governor of Santa Fe. The current president, Leandro González, is responsible for the port’s strategic direction and for supervising major investments. Day-to-day operations are carried out by the Port Authority’s technical and administrative departments.

The remaining eight members of the Board represent key constituencies:

1. Province of Santa Fe
2. Municipality of Santa Fe
3. Water Transport Companies and/or Maritime Agencies
4. Exporters
5. Producers
6. Port Terminals
7. Importers
8. Port-Sector Workers

2.3.2 Provincial influence & political landscape

The provincial government of Santa Fe provides the wider political framework within which the port operates. The province follows the classic separation of powers, *trias politica*; with the executive, legislative, and judicial branches. The governor, currently Maximiliano Pullaro, has particular influence

over the port through the appointment of the Port Authority president (Leandro González). This creates a direct political link between provincial leadership and port governance.

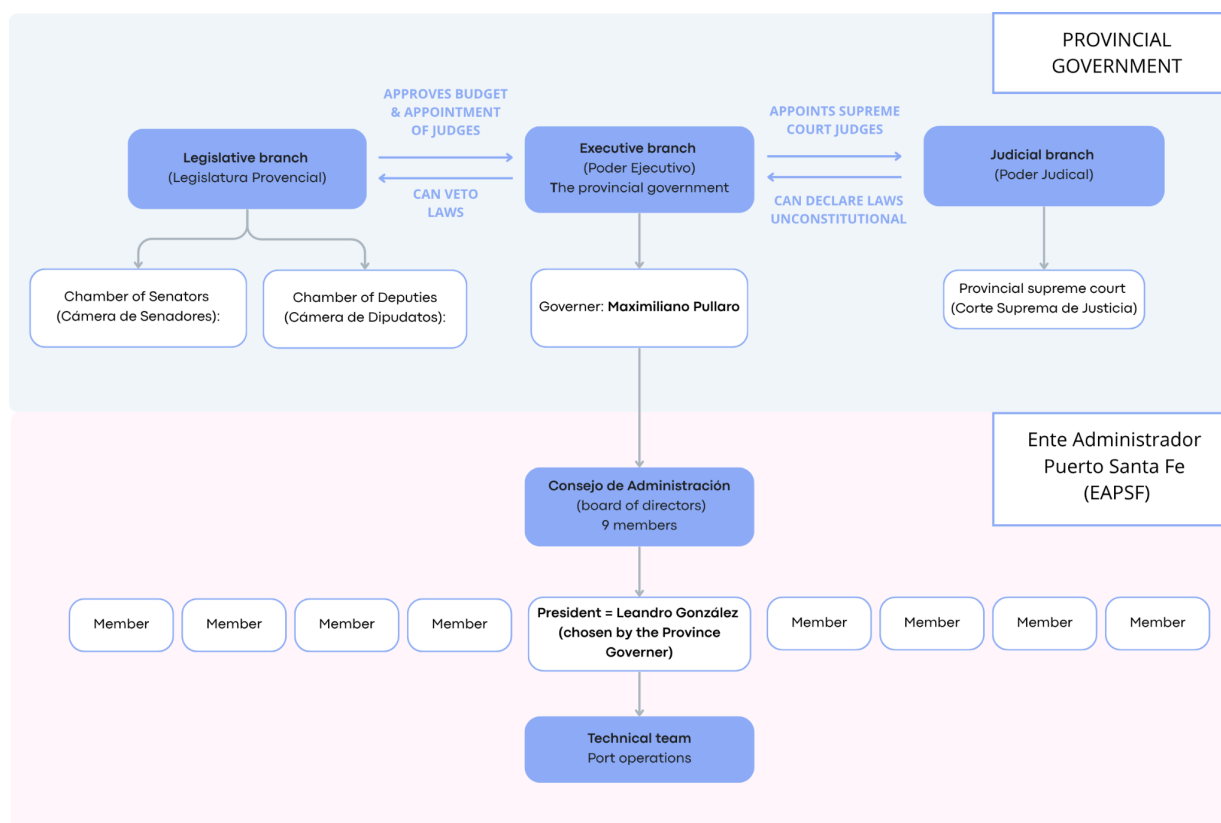


Figure 2.15 Governance structure of the Port of Santa Fe

In Figure 2.15 an overview of the relationships in this political landscape is shown. In summary, the Governor sets a goal and he then appoints a President to execute that goal. The President then manages the Board, where he must negotiate with representatives from the city, unions, and businesses who are all focused on their specific interests.

Because the President has the Governor's backing and a tie-breaking vote, the provincial government still has a big influence on the Port Authority. Because decisions at the port depend on balancing provincial politics with the often conflicting interests of exporters, transport companies, and workers agreements are slow to reach. This makes it difficult to plan major investments and to set out a clear long-term vision for the port's role in Santa Fe and the wider region.

The mayor of a nearby city explained that the current government is a coalition of parties. The governor belongs to the Radical Party, which has existed for more than 120 years. Despite their political differences, their cooperation and relationship remain good. However, he feels that when it comes to advancing projects such as tenders, there is a need for a guiding factor or vision to provide direction. At present, he feels that a strategic outlook is missing, particularly in opportunities like leveraging fluvial transport for the city's development.

The president of the port explained that the municipality prioritizes its citizens, while the private sector focuses on its own interests. The port can decide what they want to do with the land of the port by suggesting a plan to the municipality, but the province can decide to sell the land.

2.4 Project approval process and regulations

This section outlines the regulatory and approval framework for projects in the Port of Santa Fe. It explains the step-by-step process from preliminary proposals to concession contracts, and highlights the key legal instruments and requirements.

The development of projects in the Port of Santa Fe follows a clearly defined process in which the contract itself represents the final stage of a broader evaluation framework. Before a concession agreement can be signed, any interested party must first submit a preliminary project proposal to the Port Authority. This submission includes written and graphic documentation, detailed plans equivalent to municipal building permits, investment budgets, schedules, and environmental considerations. The technical team of the Port Authority evaluates the proposal, may request adjustments, and subsequently forwards it to the board of directors for approval. Only after municipal authorities have also provided their approval can the binding contract be signed, enabling project execution.

The contracts concluded by the Port Authority then formalize the conditions already framed by this process. They generally follow a standard structure, covering the duration of the concession, the concession fee, permitted uses, investment obligations, guarantees, insurance requirements, and sanctions in the event of non-compliance. However, the core substantive requirements are not negotiated case by case, but derive from overarching frameworks such as the Convenio Marco Master Plan, the Urban Planning Regulations (Port of Santa Fe, 2024) and the Habitability Code/Ordenanza 11.748 (HONORABLE CONSEJO MUNICIPAL, 2021). These instruments define the permitted land uses, urban indicators (e.g. F.O.S. (land occupancy factor) and F.O.T. (floor area ratio), building heights), safety and accessibility standards, and environmental obligations. Contracts therefore act as the legal instruments that bind each project to these wider rules, ensuring that private developments align with the strategic objectives of the port and the city.

2.4.1 Key requirements

While the concession contracts provide the legal framework for private developments in the port, the substantive requirements for project approval and execution are drawn from a broader set of regulations and guidelines.

Mobility and Circulation

- Projects must ensure safe and efficient internal circulation.
- Vehicle and pedestrian routes inside concession areas are required to follow uniform signage and design standards approved by the Port Authority.
- Each development must provide sufficient parking spaces for staff, clients, and suppliers, reducing pressure on public infrastructure.
- Projects located next to common-use spaces, such as streets, sidewalks, or green areas, are obliged to adapt to them, without blocking or privatizing access.

Integration with the Urban-Port Context

- Projects must showcase and reinforce the port landscape and identity.
- Architectural and urban design should reference port symbols such as cranes, railways, and containers.
- Proposals must ensure connectivity and access, including:
 - Safe pedestrian paths.
 - Adequate vehicle circulation.
 - Landscaping that integrates with surroundings.
 - Strong links between the port, the waterfront, and the city.

- Developers must preserve and incorporate cultural and architectural heritage, reinforcing the long-term identity of the Ciudad Puerto district.

Technical and Construction Responsibilities

- Making underground electrical connections consistent with port standards.
- Connecting to the Port's sewer network (Desagües Cloacales) and contributing proportionally to shared infrastructure such as pumping stations and main sewer lines.
- Carrying out complementary works, most notably the stabilization and filling of riverbank slopes (taludes) where relevant.
- If the concession borders the waterfront, maintaining the coastal edge entirely at their own expense, compensating the Port Authority against liability.
- Preserving non-built areas as green zones, kept free of commercial use and in hygienic condition.
- Dedicating at least 5% of the total project investment to improvements in common-use infrastructure outside the concessioned plot.

Environmental Management

Projects carry environmental responsibilities that extend beyond their own plots. Users are liable for any contamination of land, water, or air, and must provide systems for waste management, fire prevention, and safety. In addition, each development has to consider an Environmental Management Plan (Guía de aspectos ambientales, n.d), covering:

- Sustainable design (e.g. permeable sidewalks, renewable energy, rainwater reuse, green roofs and walls).
- Efficient use of water and energy.
- Forestation, prioritizing native species and compensating removals by planting three new specimens for each one extracted.
- Spill prevention in water areas and effluent/emission control.
- Comprehensive solid waste management (reduction, separation, recycling; no incineration).
- A contingency plan for environmental or safety emergencies.

Zoning Requirements

Projects in the Puerto City zone must comply with the zoning regulations established in Ordenanza 11.748 (Honorable Consejo Municipal, 2021), which define land uses, building indicators, and height restrictions for each sector. The specified area of this project falls under CP5: Residential Sports & Hotel area which has to follow the rules $FOS = 0.40$, $FOT = 3.5$, Max height = 45 m (south end only).

2.5 Economic situation

This section examines the economic situation at national, provincial, and local levels, and its implications for the Port of Santa Fe. It considers Argentina's economic volatility, the province and city's export base, and the port's role in fuel, grain, and trade, while contrasting Santa Fe with Rosario.

2.5.1 Economy of Argentina

In recent years, currency volatility has emerged as a major challenge for Argentina's and thus Santa Fe's economy. Sharp fluctuations in the Argentinian peso (ARS) have directly increased the cost of imported goods and production inputs, driving inflation across urban consumption baskets. For a city that depends on imported goods, these shifts weaken purchasing power and put pressure on household budgets (Yapur et al., 2025). Businesses, in turn, often adjust by raising prices to cover rising costs, which further amplifies inflationary pressures and deepens economic uncertainty at the local level.

2.5.2 Economy of the Province and city of Santa Fe

The province of Santa Fe contributes around 8% of Argentina's national GDP and approximately 23% of national exports, making it one of the country's economic powerhouses (Wikipedia, 2022).

The Santa Fe city, with more than half a million inhabitants, concentrates a significant share of this activity due to its position as not only a river port, but also an administrative, educational, industrial, commercial hub.

The economic base of Santa Fe is highly diversified, which can be seen in Figure 2.16. At the provincial level, the primary sector represents about 10% of output, the secondary sector 22%, and services 68% (Wikipedia, 2022).

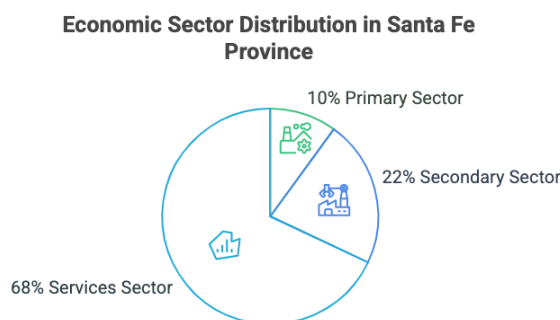


Figure 2.16: Economic Sector Distribution in Santa Fe Province (Wikipedia, 2022)

The city level reflects this structure; agro-industrial processing remains crucial. Manufacturing activity includes automotive and machinery production, while services dominate in logistics, trade, education, and public administration. Exports from the region are strongly oriented towards manufactures of agricultural origin, which account for nearly two-thirds of the total. Soy flour and refined soybean oil alone represent more than half of provincial exports (UNR, n.d.).

2.5.3 Economy of the Port of Santa Fe

The Port of Santa Fe is a strategic hub balancing energy logistics and agricultural exports while facing operational, financial, and infrastructural challenges that point toward a potential shift from industry to tourism and small-scale transport.

2.5.3.1 Terminal overview

The Port of Santa Fe has become a key hub for both energy logistics and agricultural exports, though its operations face challenges. Firstly, the private terminal of Raízen oil storage will be introduced, after that we will discuss the public terminals of the Port of Santa Fe.

Raízen Argentina S.A.

The company operates warehouses in Dyke 2 and accounts for the majority of port activity. Around 10 ships dock monthly, with 8 belonging to Raízen, mainly distributing fuel to western Argentina. Its reliance on Santa Fe grew after the 2022 closure of Puerto Vilelas in Chaco due to low Paraná River levels, showing the port's strategic resilience (Tejero, 2022; Galli, 2019).

Grain Terminal

Focused on grain exports (wheat, corn, sorghum, soy), the terminal has seen rapid growth: 60,000 tonnes in 2020, 80,000 tonnes in 2021, and 133,180 tonnes in the first half of 2025, over six times more than 2024. Storage silos often reach capacity, underscoring both its importance and infrastructure limits (Santa Fe Provincia, 2020; Santa Fe Provincia, 2021; Rosario Plus, 2025).

Container and General Cargo Terminal

Built with a 270 m dock, 5 m depth, and capacity for Panamax-size vessels, it reopened in 2021 with barge links to Puerto La Plata. The container terminal, which began operating in 2021, consolidated two activities in 2022 (Vallejos, 2023). However, by 2024–2025 the terminal appears inactive again most of the year. Causes include low traffic, competition from Rosario, fluctuating river levels, and irregular barge services (Portal oficial del Estado Argentino, n.d.; RMF, 2021; Redacción Agroverdad, 2025).

Multipurpose Terminal

After several years of inactivity following the end of its concession in 2015, the multipurpose terminal of the Port of Santa Fe resumed operations in late 2021. Owned and managed by the Port Authority, the facility was refurbished with an extended dock, a new container crane, and upgraded handling equipment. The terminal operates through public–private cooperation, with logistics partners such as Newport Management running a regular barge service to TecPlata Port in La Plata every fifteen days, facilitating both imports and exports from regional industries (De Desarrollo, 2023).

As a comparison, in 2023 Rosario exported 42.4 million tonnes of grains, making it one of the busiest grain ports in the world (Hanrahan, 2024). The Agrograneles Terminal in Santa Fe exported 133,000 tonnes in the first half of 2025 (Rosario Plus, 2025), a big increase for Santa Fe, but still very small compared to Rosario. Rosario's advantage is not just in volume but also in infrastructure. The Paraná River near Rosario is dredged for Panamax-size vessels, giving them reliable access (Wikipedia, 2025). The Port of Rosario has many specialized terminals, large storage facilities, and modern loading systems. This setup lowers costs, speeds up operations, and makes the port more resilient to market ups and downs (Atlantic Project Cargo, 2025).

It seems that existing infrastructure for industrial activities is largely unused in Santa Fe. In order to make the Port of Santa Fe an industrial hub again it would require enormous investments to compete with nearby cities that already benefit from the Paraná River.

2.5.3.2 Commercial analysis

The analysis in the sections above suggest that there might be room for a shift from industrial activities to tourism and smaller-scale river transport. This is further supported by the following statistics:

1. Financial Performance of EAPSF (2023-2024)

The 2024 accounts of the Port Authority reveal both improvements and structural weaknesses. Total revenues decreased by 8% in 2024, reaching ARS 4.26 billion. This was mainly due to a 69% collapse in the port terminal services (–ARS 0.86 billion). By contrast, Puerto Ciudad Master Plan (Port of Santa Fe, 2024) contributions grew by over 20% (+ARS 0.5 billion), which highlights its role as the port's main and most stable income stream.

Operating costs decreased by 15%, generating an operating income of ARS 218 million after years of deficits. However, heavy financial and inflation-adjustment losses led to a net deficit of ARS 364 million, almost triple the loss of 2023. In short, EAPSF improved its operations, but reliance on the Puerto Ciudad Master Plan and continued financial losses underline ongoing liquidity problems and the fragility of Santa Fe's public terminals (Ente Administrador Puerto Santa Fe, 2025).

2. Tourism Economy Insights from Hotel Los Silos

Not much data is available about tourism in the Port of Santa Fe specifically. However, the Hotel Los Silos, located within the port's historic silos, provides recent data that can offer an indication of tourism trends in the area. The hotel's annual occupancy ranges between 60%

and 63%, with a notable peak in guests arriving from April through December. Each year, around 23,000 individuals book a stay at the hotel. The majority of these guests are divided into three categories: 42% are tourists, 43% are corporate travelers, and 15% are there for the casino. Most visitors come from within Argentina, making up 90% of the guests. The remaining 10% is made up of international visitors. This reflects the tourism potential within the port area. While international tourists are currently few, there's room for growth in this segment (Hotel Los Silos, 2025).

2.6 Stakeholders analysis

This Section provides an overview of the stakeholders relevant in the context of Puerto de Santa Fe. The analysis is based on desk research, interviews, the development of a stakeholder map and a power-interest grid.

2.6.1 Relationships & value between stakeholders

The stakeholder relationships map can be seen in Figure 2.17, it positions the Port Authority at the center, illustrating its coordinating role within the port ecosystem. It visualizes public and private sector actors alongside local stakeholders, grouped into different categories, as shown in the legend. Key ambassadors and interviewed stakeholders are also identified to indicate their influence within this complex network.

The relationships between these actors take on different forms and levels of engagement, generating different forms of value, including financial investment, collaboration, and innovation. This stakeholder map provides a simplified overview of this value exchange, where the connecting arrows visualize interdependence and collaboration between actors. A high-resolution version is included in Appendix A.

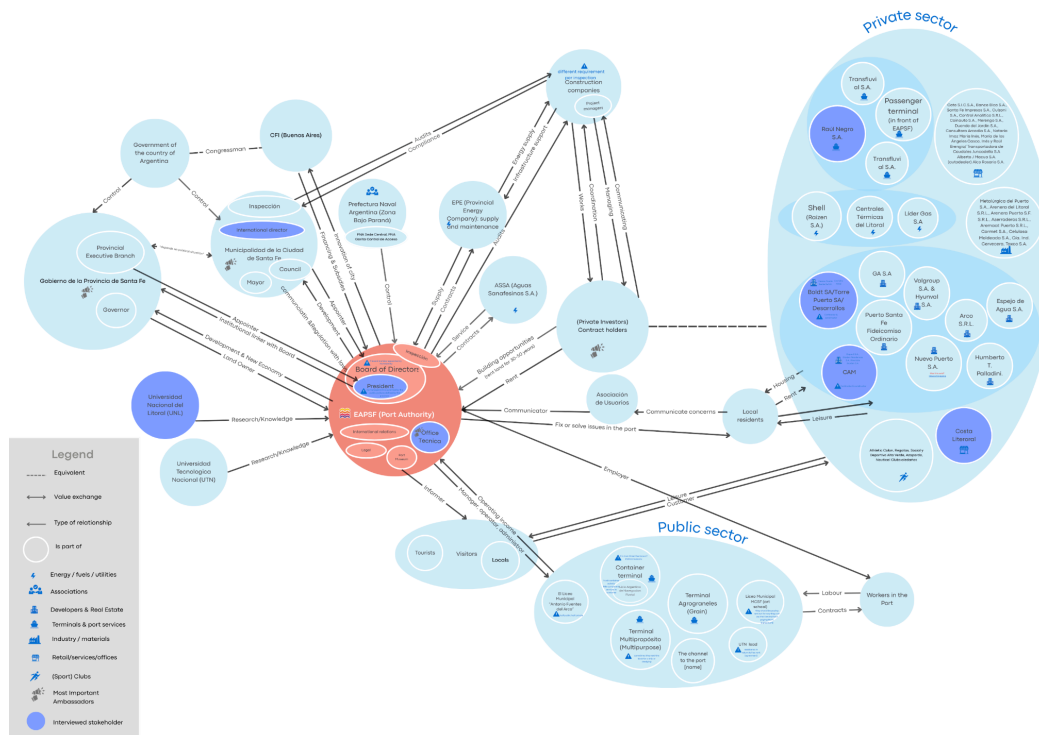


Figure 2.17: Stakeholder relationships map within context of the EAPSF

2.6.2 Stakeholder power-interest grid

To categorize and prioritize stakeholders based on their power and interest, the most important actors from the stakeholder map were placed in a power-interest grid which can be seen in Figure 2.18.

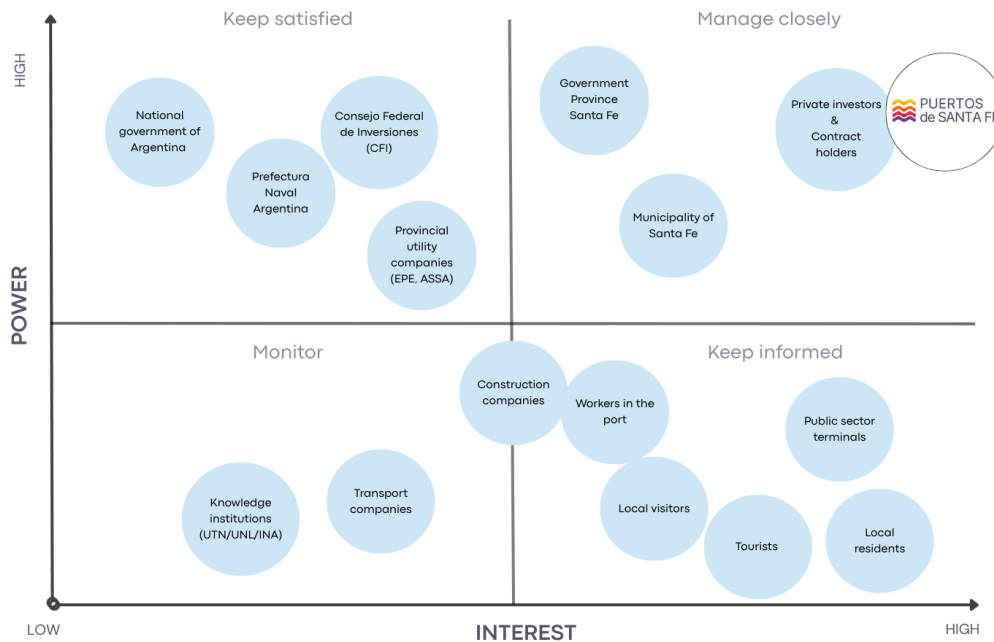


Figure 2.18: Power-Interest Grid within the Port of Santa Fe

From this analysis, three key ambassadors, right-above box, emerged. The first is the province of Santa Fe, which owns the port land and has decisive authority over the Port Authority, as the chair of the board of directors is appointed by the provincial governor. The port is financially dependent on the province to some extent, as the provincial government occasionally provides funding to the port. However, this only occurs when the proposed projects align with the provincial agenda, limiting the frequency and predictability of such support.

A second influential actor is the Municipality of Santa Fe, which provides local legitimacy by linking port development to residents, the city, and public opinion. It also holds a seat on the Port Authority Board, which helps to ensure that municipal interests are represented in decision-making. From interviews, however, it became clear that although the municipality is willing to take steps forward, it struggles to bring its different visions onto the same page with all stakeholders involved, including the Port Authority. This lack of coordination makes it difficult to move ahead with a clear and consistent agenda for the port. In addition, the municipality owns certain green spaces within the port area, near to the project site, on which the Port Authority depends for development. However, the port currently has no insight into the provincial plans for these plots.

The third ambassador is the private sector, represented by companies such as BSA, Nuevo Puerto, CAM, and Raízen. They play a decisive role because they bring financial capital and investment capacity. These resources are essential for the realization of projects and the development of the port. Although the Port Authority has formal authority, it relies heavily on private investment, which gives these companies strong influence on the port's strategic direction. This dependence often forces the Port Authority to adapt its vision to investors' priorities and development wishes.

In project management theory (Thamma, 2023), stakeholders in a power-interest grid are categorized as 'Manage Closely', 'Keep Satisfied', 'Keep Informed', and 'Monitor'. This helps to decide where to invest its attention, communication, and management efforts, focusing on the most influential actors. In the

case of the Port Authority: the Province, Municipality, and private investors should be managed closely, national agencies and CFI kept satisfied, local residents, workers, and visitors kept informed, and lower-influence actors such as universities and transport companies monitored.

2.7 Stakeholder interview analysis

This chapter presents the results of ten semi-structured interviews with various stakeholders. The purpose of the interviews was to gain insight into the visions, challenges, and expectations of the stakeholders regarding the Port of Santa Fe and the redevelopment of the project area. Furthermore, the goal was to identify the tensions and similarities between the various stakeholders. Stakeholders ranged from CEOs of major companies operating in the port to the port director itself and representatives from the municipality of Santa Fe City.

The findings from each interview are systematically grouped in a pre-prepared document under recurring themes such as: vision, developments, public-private relations and public transport along the river. Similarities and differences between responses were summarized, and conclusions were drawn. The gathered insights complemented the document review and site analysis, providing a well-founded understanding of how various stakeholders envision the port's future.

2.7.1 Overview of interviewed stakeholders

Table 2.1 shows who was interviewed and their respective roles and organizations.

Table 2.1: List of interviewed stakeholders with corresponding role and organization

Interviewed stakeholder	Role and organisation
Maria José Correa	CEO - Torre Puerto S.A.
Daniel Arditti	President - CAM Construcciones
Carlos Fertonani	Director - Santa Fe Producciones
Carlos Luis Paz	President - Raul A. Negro (RN-group)
Leandro González	President - Port Authority (EAPSF)
Miguel and Jorge Ian Weiss Ackerley	Mayor of Santo Tomé, Digital Transformation Advisor for Province of Santa Fe
Lucila Garcia and Virginia Eberhardt	Director of Cooperation, Investment and Foreign Trade at the Municipality of Santa Fe
Ricardo Szupiany	Engineer at Universidad Nacional del Litoral (UNL)
José Reyt	Architect and professor of Urbanism and History, Universidad Nacional del Litoral (UNL)
Technical Department EAPSF [2025]	Technical team of the Port Authority

2.7.2 Interview results

The team interviewed 4 private, 4 public and 2 academic stakeholders. The overall vision is broad but fragmented, each actor has priorities shaped by their role. Below you find each stakeholder and a summary of their visions, the elaborate overview of all insights can be found in Appendix B.

Maria José Correa

Sees the port as a prime waterfront real estate location, with projects such as the Casino, Hotel, and Amarras driving redevelopment. Emphasizes public–private interdependence, where the state provides rules and infrastructure and private actors invest. Promotes the 15-minute city concept, an urban planning model developed by Carlos Moreno (Moreno, 2021), together with strong connections, bike paths, plazas, and green lungs, prioritizing sustainability. Highlights tourism and hospitality as key economic drivers. Considers integration with Alto Verde important, but primarily a government responsibility. Views the Raízen oil storage terminal as incompatible with urban redevelopment. Public and private sectors are mutually dependent: private capital generates jobs and taxes, while the State must provide clear rules and infrastructure. Collaboration between public and private is sometimes simpler and sometimes more complex, but co-existing is constant.

Daniel Arditti:

Sees port as an alternative waterfront real estate location, with housing towers as main driver (e.g. Amarras, Garden Residences, Tower). Emphasizes public–private complementarity (state provides order, planning, and stability; private sector invests). Stresses the need for urban order and enforcement (traffic, waste, coexistence). Supports river access and floating constructions. Green spaces and public parks are essential to distinguish the port and improve quality of life. Integration with Alto Verde is important but a long-term, state-led process.

Carlos Fertonani:

Sees port as a hub for tourism, gastronomy, and leisure, with restaurants and river tours as key drivers. Emphasizes the need for more green spaces, promenades, and public areas that generate empathy with nature. Supports fluvial transport for tourism and regional trips, but rejects a direct boat link to Alto Verde as impractical (prefers promenades on both shores). Advocates for better mobility inside the port (tram, buses, bikes) to reduce car congestion and parking problems. Criticizes current designs for lacking greenery and attractiveness. Believes tourism can help bridge divides and promote Santa Fe's history and natural assets.

Carlos Luis Paz

Sees the port mainly through a logistics and infrastructure lens, emphasizing cargo movement, salvage operations, and industrial functionality. Advocates for greater use of the waterway for regional cargo (barges over trucks) but is realistic that dredging to Santa Fe is not viable. Stresses the importance of functional separation: oil depots and heavy industry should not coexist with residential and commercial development. Sees Alto Verde as a valuable labor pool, already employing locals, and stresses training and education as tools for social recovery. Skeptical about fluvial public transport due to safety and cost concerns. Critical of inadequate slope protection and calls for more ecological, biodiversity-sensitive solutions instead of traditional concrete works.

Leandro González:

Sees the port as a place where productive operations and urban development must coexist. Highlights the port's historical role in Argentina's agro-export and acknowledges its later crises. Advocates for building consensus among municipality, province, private sector, and citizens, stressing the need for clear rules and long-term planning. Emphasizes integration of Alto Verde and reducing symbolic barriers between communities and the port. Supports green public spaces (10% of land reserved) as key for accessibility and coexistence. Recognizes the potential of fluvial transport, but underlines legal and financial challenges. Sees his role as providing strategic direction while balancing productive capacity with the urban Masterplan.

Miguel and Jorge Ian Weiss Ackerley:

Sees Santo Tomé as “three cities in one” (middle-class, lower-income, wealthier north) and wants to

strengthen social integration. Describes Santo Tomé as a “sleeping city” since most cultural and social life happens in Santa Fe, and aims to make it more dynamic and independent. Believes the industrial role of Santa Fe’s port is largely outdated, as competing cities already dominate. Instead, it sees tourism and small-scale fluvial transport as the port’s main opportunities. Supports step-by-step development: first tourism projects, then expanding to river connections with Santa Fe. Advocates for a clear strategic vision from the government to guide investments and tenders. Also developing a nature reserve project with international funding to showcase biodiversity and attract visitors.

Lucila Garcia and Virginia Eberhardt:

Sees Santa Fe as a future commercial and logistics hub for the north of the province, with strong potential in barge transport to Paraguay, Brazil, and Uruguay. Argues that dredging is too costly, so development should focus on making the port commercially attractive and shifting to barge-based trade. Supports fluvial public transport to connect Alto Verde and the port, emphasizing social inclusion, since residents already cross illegally by boat. Introduces a fluvial transport project plan, Transporte Público Fluvial, that has already been developed and is based on the Businú concept of Colombia (Minister of Transport Colombia, 2025). Highlights the lack of a shared vision between municipality, province, and port as a barrier to progress. Draws on international examples (Rotterdam, Montería, Peru) and stresses alignment with sustainability goals (SDGs, EU agreements).

Ricardo Szupiany:

Focuses on the hydrological and ecological dynamics of the Paraná and Salado rivers, providing expertise on slope stability, erosion, and climate risks. Emphasizes that floods, droughts, and low water levels pose major challenges for the port and city. Advocates for nature-based solutions (vegetation, floating gardens, ecological buffers) combined with engineering approaches to stabilize slopes. Highlights the impacts of pollution (agriculture, sewage) on water quality and biodiversity. Sees an opportunity to integrate ecological restoration with urban design, making the waterfront more resilient to climate change.

José Reyt:

Sees Santa Fe shifting from an industrial port identity toward a green/blue city focused on public space, ecology, and design. Believes industrial functions will gradually disappear and should be replaced by residential, commercial, and recreational uses. Advocates for nature-based, low-maintenance solutions instead of heavy concrete. Calls for reclaiming public access to the riverfront (at least 50m should remain public). Sees Alto Verde as an opportunity for inclusive tourism rather than displacement. Supports river transport and pedestrian-first design with fewer cars, more walking routes, and cultural/tourism infrastructure.

Technical Office [2025] - the Ente Administrador Puerto Santa Fe (EAPSF)

Emphasizes the need to balance operational functionality with urban integration, particularly by connecting the people to the water through more greener and more accessible spaces. Envision a waterfront that continues to serve port activities while also becoming a space for public use, tourism, and contribute to coexistence between the city, water and the Port. Underlined the importance of addressing slope protection through safe and ecological solutions, enhancing fluvial transport as part of future mobility, and reusing underutilized areas for other functions. Are also involved in a fluvial transport project plan. Moreover, acknowledged the challenges of fluctuating water levels and the need for more sustainable infrastructure. Collaboration between public institutions and private actors is essential to ensure feasible and coordinated development.

2.7.3 Main insights interview results

This section summarises the main points of agreement and divergence among stakeholders regarding the future of the port of Santa Fe and the redevelopment of the project site.

→ All stakeholders agreed that the project site’s waterfront area holds high potential and strategic value.

→ Private stakeholders in real estate and tourism identified strong opportunities for development, particularly in residential and commercial sectors.

- Academic stakeholders emphasized that the waterfront should primarily serve ecological and public purposes.
 - Public stakeholders envisioned a balanced mix of industrial and commercial functions.
- Mobility and connectivity emerged as key concerns. Stakeholders highlighted congestion, inadequate infrastructure, and poor public transport.
- Connecting Alto Verde is considered crucial yet difficult, requiring multiple steps and strong municipal coordination.
- Tourism versus industry revealed diverging priorities: private investors favor tourism, residential, and commercial development, while Paz and González defend maintaining an industrial and productive role. García suggested introducing barges in order to maintain the industrial activity.
- All stakeholders, except González, foresee Raízen's departure once its contract ends.
- Environmental considerations were widely supported. Most stakeholders value green spaces and sustainable mobility, while academics further underline climate risks and slope stability.
- Public and private sectors must collaborate, as neither can redevelop the port independently. However, this partnership remains complex and often challenging.

3. Technical analysis: river and slope stability

This chapter investigates the hydrodynamic and ecological processes and their influence on the stability of the Port of Santa Fe's waterfront. The analysis provides the foundation for designing resilient slope protection systems and integrating ecological principles into future waterfront redevelopment.

3.1 Ecological situation

This section explores the region's ecosystems and its importance for the river behaviour, the biodiversity they sustain, and the ways in which human activities shape and impact them. Particular focus is given to the Port of Santa Fe, where natural river behaviour and human impact challenge the river's ecosystem.

3.1.1 The Paraná river system

The Paraná River is the most important natural feature of Santa Fe. It runs almost 4,900 kilometers through Brazil, Paraguay, and Argentina, making it one of the largest rivers in the world (Duchesne, 2024). The course of the Paraná River can be seen in Figure 3.1. Around Santa Fe, the river creates a wide floodplain with wetlands, lagoons, small channels, marshes, and river-edge forests.

These areas flood regularly and form a variety of different habitats. They provide many services; wetlands store water during floods and release it slowly, vegetation filters pollutants and stabilizes riverbanks, and forests store carbon and provide space for wildlife. Together, these ecosystems reduce flood risks and support high biodiversity.



Figure 3.1: Map of the Paraná River

3.1.2 River fluctuations

The Paraná River near Santa Fe usually rises and falls between 1 and 2 meters during the year. This may seem small but in Santa Fe it has major consequences because the city lies only slightly above river level. Even modest changes can flood low-lying neighborhoods like Alto Verde, cut off access, or reduce navigability.

Upstream hydrology

Most of the water that passes Santa Fe comes from rainfall in Brazil and Paraguay, where the upper Paraná and its tributaries feed into the system. These flows are then joined locally by the Salado River which can be seen in Figure 3.1, this can cause water levels to rise largely during heavy storms. Upstream hydroelectric dams also play a role by releasing water in dry periods and holding it back during floods, which reduces extremes but disrupts natural seasonal rhythms (Instituto Nacional del Agua, 2025).

Hydrometric monitoring

To follow these changes, the river level is measured daily at the port with a hydrometric ruler. The readings are tied to a fixed point called the “cero hidrométrico”, which is linked to the national height system. This makes it possible to compare data across many decades (Prefectura Naval Argentina, 2025). These measurements, which are shown in Figure 3.2, are also essential for daily decisions. In Santa Fe, an alert level is issued when the river reaches 5.30 m, while evacuation protocols are triggered at 5.70 m.



Figure 3.2: graph of hydrometric measurements Port of Santa Fe

Wave and wind

Wave action and wind are important factors influencing the stability of the Santa Fe waterfront. The wide, open stretches of the Paraná River provide a large range, allowing winds, especially from the south and southwest, to transfer energy over long distances and generate powerful waves. (Memoria Técnica, 2022; Informe Final Acta 2, 2021). Hydraulic calculations show that during strong wind events, waves can reach heights up to 1.3 meters under 50-year recurrence conditions (Memoria Técnica, 2022).

Historical extremes

Santa Fe has faced several destructive floods, notably in 1914, 1998, 2003, and 2007 (Vionnet & García, 2003; Alvarez, 2022). The 2003 event was particularly damaging and occurred because the natural floodplains upstream had been heavily reduced by deforestation and farmland conversion. Normally, vegetation in wetlands slows floodwaters: roots anchor the soil, plants absorb and store water, and rough surfaces reduce the speed of flows. Without this natural buffer, heavy rainfall moved quickly into the river, raising levels faster and overwhelming defenses (APFDigital, 2019). The maximum velocity of 2.13 m/s was measured during the 1998 flood (Informe Final Acta 2, 2021).

On the opposite side, between 2020 and 2022, the Paraná underwent a historically intense low-water period. In July 2021, the hydrometer at Dyke 2 in Santa Fe’s port marked just 24 cm, the lowest level in fifty years (Bordón, 2021).

It is not only the height of the river that matters, but also how long the duration of the different water levels. Long floods saturate soils, weaken riverbanks, and damage infrastructure. During an interview with the Universidad Nacional del Litoral (UNL), a university in Santa Fe, it was mentioned that long droughts reduce water quality, dry wetlands, remove hydrostatic support for slopes, and increase the risk of fires in the floodplain.

Climate change

Climate change is expected to intensify the natural variability of the Paraná River system and exert new pressures on Santa Fe. As mentioned above, a trend toward more frequent and extreme weather events is seen. Heavy rainfall is expected to become more intense, while dry periods will last longer, creating a sharper contrast between floods and droughts (Barros, 2015). Flood events are expected to become stronger and more frequent, while prolonged droughts like the recent bajante may also occur more often.

3.1.3 River dynamics

The river's behavior in Santa Fe is shaped by a mix of upstream water inputs and local geomorphic processes. Three main drivers below explain the fluctuations and constant reshaping of the Paraná.

Meandering and sediment transport

The Paraná is a meandering river. This means that the currents erode the soil on the outside of the bends while depositing sand and silt on the inner bends, causing the course of the river to slowly shift (Smith, 2002). This process can also reshape the surrounding slopes, creating irregularities in their form and contributing to changes in the river's gradient and flow patterns. The continuous shifting of the river creates sandbanks and islands that alter navigation routes and require dredging to keep channels open. These sediment dynamics also influence the local slope of the riverbed: deposition can flatten certain reaches while erosion deepens others, creating uneven gradients and affecting the stability of nearby slopes. At the same time, this constant movement renews soils in the floodplain, making the land fertile and sustaining wetlands.

Thalweg migration

The thalweg, the deepest line of the river channel, does not stay fixed (International Institute for Law of the Sea Studies, 2021). An overview of the thalweg can be seen in Figure 3.3. It gradually shifts, causing the strongest currents to concentrate against different banks over time. When it moves closer to one side, that bank experiences higher energy flows and stronger erosion, while the opposite bank may accumulate sediment. This continuous lateral erosion often undercuts the toe of the slope, steepening it and reducing its stability. As the slope becomes steeper, it becomes more prone to failure and mass wasting, further reshaping the riverbank profile. For example, in Santa Fe, the thalweg has shown a tendency to migrate toward Alto Verde, increasing pressure on its waterfront slopes (Informe Final Acta 2, 2021).

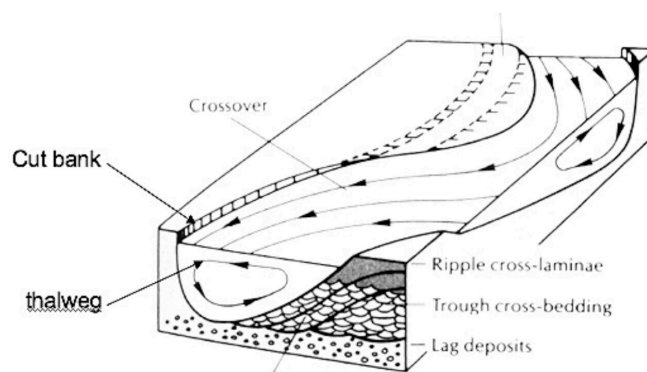


Figure 3.3: Thalweg explanation

3.1.4 Ecosystem and human impact

A healthy river ecosystem is vital for both ecological balance and physical stability. As emphasized by experts from the UNL, vegetation, animals, and microorganisms work together to regulate water flow. Plants and root systems stabilize slopes, trap sediments, and slow runoff, while wetlands and floodplains act as natural buffers that absorb and gradually release water.

According to the UNL experts, these biological systems also influence the river's hydraulic behaviour. Vegetation along the banks increases surface friction, which slows the flow near the edges and reduces erosion. When these natural elements are degraded or removed, the current accelerates and becomes more turbulent, leading to stronger meandering and thalweg migration that further destabilize the slopes.

To strengthen these natural processes, it is also essential to promote the return and presence of native fauna. Fish species like Sábalo and Dorado are important for food chains; they recycle nutrients and maintain aquatic balance, but their life cycles depend on seasonal floods that create spawning grounds (Quirós et al., 2007). Aquatic plants, such as reeds and grasses stabilize the soils, filter sediments, and provide shelter for juvenile fish during high flows (Schipper, 2023). Larger wetland mammals, such as capybaras, also graze on aquatic vegetation, subtly influencing plant cover and maintaining the balance of wetland habitats. By restoring habitats that attract fauna, the ecosystem becomes more resilient, enhancing the stabilizing effects on slopes and the overall hydraulic balance of the river.

In the context of Santa Fe, preserving these ecological functions is very important for managing the dynamic behaviour of the Paraná River. A resilient ecosystem distributes flow energy more evenly, mitigates erosion, and supports both biodiversity and human safety. When these natural processes are disrupted, the entire system, ecological and infrastructural, becomes more vulnerable. However, in the urban and industrial setting of Santa Fe, these natural balances are increasingly influenced by human activities. The following sections examine how these human pressures affect both the river system and the stability of its slopes.

Shipping and dredging

Shipping traffic disturbs aquatic habitats through noise, waves, and pollution from fuel and oil residues. Dredging to keep channels open changes sediment transport, increases turbidity, and can destroy fish spawning grounds. While most large-scale dredging is concentrated further downstream near Rosario, some dredging is still carried out near Santa Fe to maintain navigable depth (Informe Final Acta 2, 2021).

Urban expansion into floodplains

Santa Fe has expanded into flood-prone areas, reducing wetlands and river-edge zones. This has led to a decline in biodiversity and a weakening of the natural buffer role of floodplains. In the neighborhood of Alto Verde these changes are particularly evident. Each time the river rises, parts of the area flood, altering soil conditions, vegetation patterns, and habitat connectivity

Industry effects

As emphasized in the interview with experts from the UNL, industrial activities in the port zone produce wastewater and emissions. At the same time, runoff from surrounding farmland brings fertilizers and pesticides into the river. On top of this, a large portion of the city's sewage flows directly into the Paraná without full treatment, which adds organic waste and pathogens to the water.

Tourism and recreation

The waterfront of the port also supports recreation and tourism, which can have both positive and negative effects. Well-designed green spaces and public parks can help to restore ecological functions and raise awareness of environmental values, but unmanaged use leads to waste, trampling of river-edge zones, and disturbance of wildlife. Observations along the port show that much of the trash on the slopes comes from visitors (Loyarte, 2023).

Shift in approach

In the Santa Fe waterfront area, many interventions still rely heavily on concrete structures to protect against flooding and erosion. While these hard-engineered solutions provide short-term stability, they weaken the ecological balance of the river. To improve resilience, it would be beneficial to integrate more ecosystem-friendly approaches, combining necessary engineered protections with natural elements such as replanting river-edge vegetation, restoring habitats, and developing hybrid flood defenses that support both safety and biodiversity.

3.2 Current slope stability

The slopes and waterfront infrastructure of the Port of Santa Fe are increasingly unstable. Along the North Diversion Channel, erosion and riverbed deepening have triggered frequent landslides, most notably the collapse of a 100-year-old gravity wall at Dyke 1, causing around 15 meters of the structure to fall into the water (Memoria Técnica, 2023). In areas along the site, engineered protection measures do not exist, and improvised measures such as dumping debris have only worsened long term stability leaving the site in an undeveloped state (Informe Final Acta 2, 2021). If left unaddressed, the risks include further collapses of docks and adjacent infrastructure, direct danger to human safety, disruption of port operations with financial losses, environmental hazards from potential spills, collateral damage to surrounding roads, utilities, and transport connections (Convenio Marco Master Plan, 2024).

To fully understand these challenges, the next sections analyze the physical conditions in greater depth, focusing on: site investigation, soil analysis, failure mechanics and insights from comparable projects, to inform more sustainable and effective interventions.

3.2.1 Mapping the project site

To understand the varying ground conditions along the project site, it is divided into three main zones based on soil investigation data, field observations, and previous studies (Informe Final Acta 2, 2021). The three different zones can be seen in Figure 3.4. The Green zone corresponds to the area where soil measurements were taken during the CAM housing project in 2015, providing reliable data on soil stratigraphy and stability (CAM Construcciones, 2015). The Blue zone represents areas where construction debris has been dumped for protection. The Red zone marks a section with greater

steepness and lower elevation. These zones provide a spatial overview of the different ground conditions along the riverbank; their specific stability issues are analyzed in more detail in the following Sections.

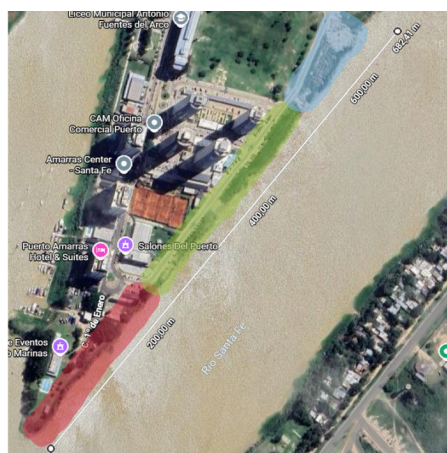


Figure 3.4: Site divided into three zones

The Argentine National Height System is applied to standardize all elevation measurements. This system is defined by the Instituto Geográfico Nacional (IGN) (Instituto Geográfico Nacional, n.d.), Argentina's national geodetic authority, and its reference zero point is established in Mar del Plata, based on mean sea level observations. All height data in this report are therefore expressed in IGN reference units.

3.2.1.1 Predictable soil layer (green zone)

The Green Zone represents the central portion of the slope, extending from 250-500 m from the end of the left bank (Club Marinas). This area is the biggest part of our project and most research is focused on this area. This zone is analyzed as the base case to identify and evaluate the primary failure mechanisms.

Based on the dataset of the slope profiles (Perfiles Transversales Canal de Derivación Norte, 2021) the cross-sectional profile of the slope was analyzed, this can be seen in Figures 3.5 and 3.6. The orange line represents the 2021 measurements, the green line represents 2016 and the black line represents 2006. The results indicate that the ground surface is approximately +16 m IGN, while the lowest point reaches approximately -12 m IGN. The slope gradient is expressed as a ratio between vertical (V) and horizontal (H) displacement, which for the case of the Green zone is a maximum of 1V:1H at T243.

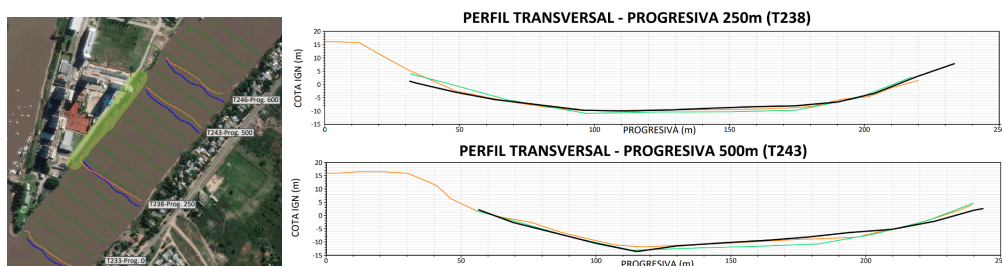


Figure 3.5 and 3.6: Cross-sectional profile of green zone

3.2.1.2 Extra steepness and low ground level (Red zone)

The Red zone, which extends from 0-250 m from the left bank (Club Marinas), includes areas with steep slopes and low ground elevations, making them particularly sensitive to erosion and riverbed deepening (Informe Final Acta 2, 2021).

In this area, the ground level reaches approximately +11 m IGN, while the maximum riverbed depth has deepened to around -10 m IGN. The slope gradient in this section exceeds 1V:1.5H, indicating that the bank has become markedly steeper due to continuous erosion processes.

This trend is clearly visible in the profile comparison which can be seen in Figure 3.7, where the orange line, representing 2021 measurements (Perfiles Transversales Canal de Derivación Norte, 2021), shows a noticeably steeper slope than earlier profiles. The hydrodynamic image further confirms that the main current now shifts toward the end of the left bank, directly facing this steep section.

Given these combined factors, deepened riverbed, steep slopes, and concentrated currents, any future stabilization or protection works in this zone must include alternative solutions capable of resisting higher hydraulic loads and maintaining stability under fluctuating water levels.

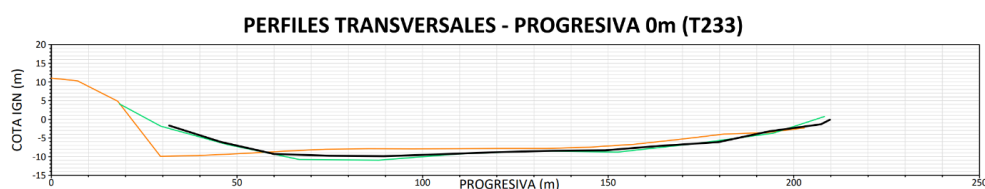


Figure 3.7: Cross-sectional profile red zone

3.2.1.3 Construction debris zone (Blue zone)

The Blue zone, located about 500–650 m from the left bank, near Club Marinas, has been eroding because the deep dock at the Raízen oil storage terminal pulls the main river current toward the dock. This increases the flow speed around the upstream corner. In addition, ship movements create propeller and thruster wash, drawdown, and short waves that temporarily raise water pressure near the bank. Together, these effects erode the base of the slope and cause a gradual retreat of the shoreline. The cross-sectional profile of the Blue zone is shown in Figure 3.8.

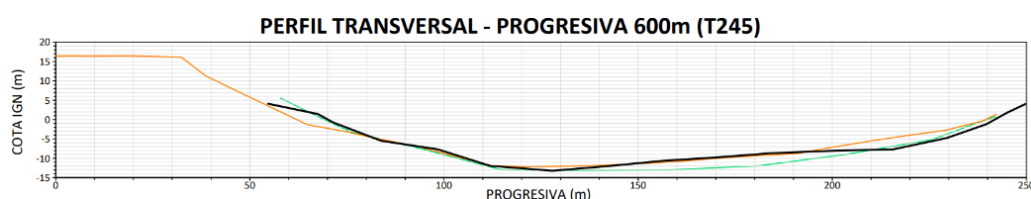


Figure 3.8: cross-sectional profile Blue zone

In response to this retreat, and to reclaim usable waterfront, construction debris, concrete blocks and brickwork, has been dumped along the right margin as an informal protection and land-gain measure. As can be seen on the (satellite) pictures in Figure 3.9. In Figure 3.10 the waterfront in 2015 can be seen, additionally in Figure 3.11 the same waterfront 10 years later can be seen.



Figure 3.9, 3.10 and 3.11: Construction debris and erosion of the bank in Blue zone

However, the debris worsens slope stability. The irregular, permeable fill creates uneven faces, obstructs surface and sub-surface drainage, prevents durable vegetation cover, and offers little continuous toe support. The debris also results in limitations for urban integrations (Informe Final Acta 2, 2021).

3.2.1.4 Drainage pipes

Early infrastructure works in the 20th century, such as water and drainage network construction, involved major excavation and filling. This disrupted the natural soil layers, leaving the ground susceptible to instability (Fabbri & Méndez, 2018).

Effective slope protection along the river must be designed in coordination with the existing stormwater network (Informe Final Acta 2, 2021). The early development of the Port and the introduction of urban drainage systems significantly altered the natural runoff, leading to frequent flooding and the creation of artificial outlets (Fabbri & Méndez, 2018). Currently, four stormwater outlets discharge directly into the river, as shown in Figure 3.12.

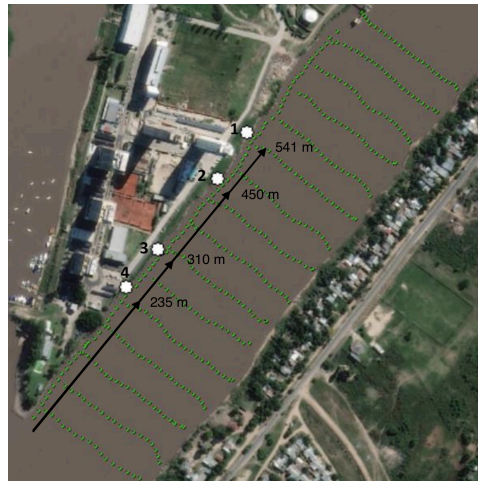


Figure 3.12: Location of the drainage pipes along site

These discharge points must be carefully integrated into the protection design to prevent local scouring, erosion, and hydraulic backflow, which could otherwise compromise the stability of the riverbank.

3.2.1.5 Irregular slope profile

After exploring the site, it was observed that the slope surface is uneven, with several irregular sections and changes in gradient. An impression of the site can be seen in Figures 3.13 and 3.14. In areas where the slope cuts deeper into the land, the erosion impact is stronger and conditions appear

more critical. These zones show visible instability and higher vulnerability, as shown in the photographs.

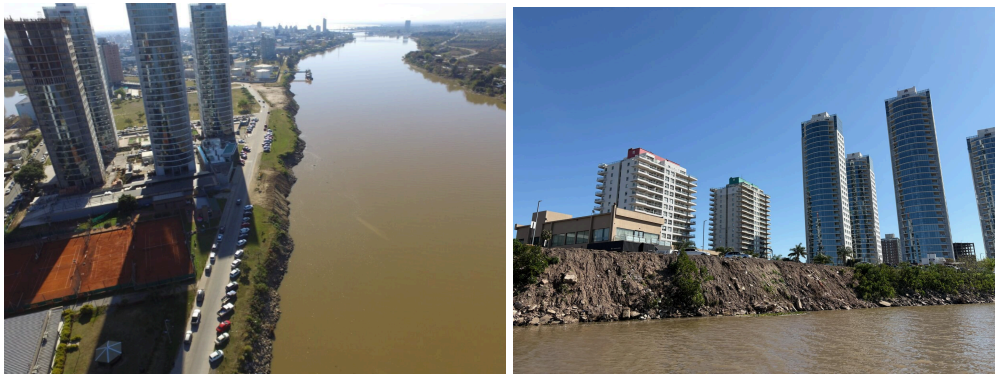


Figure 3.13 and 3.14: Photos taken during site observations

3.2.2 From soil structure to slope failure

To assess current slope behavior and identify potential failure mechanisms, the soil conditions of the study area were analyzed in more detail. The focus is on the Green zone, as it represents the main project site and has therefore been studied most thoroughly. Compared to the debris-covered Blue zone and the steeper Red zone, the Green zone contains the most consistent and intact soil layers, providing a reliable basis for understanding overall slope performance.

By examining its stratigraphy, material properties, and interaction with water levels, this section establishes the baseline conditions needed to interpret the main failure types occurring along the river.

3.2.2.1 Soil analysis

To analyze the soil layers in the Green zone, reference is made to a previous soil investigation carried out during the CAM housing project on Dyke 2. This study includes a geotechnical soil profile log developed from both laboratory and field tests. The investigation provided soil data from multiple points across the CAM project site, as illustrated in Figure 3.15. For this Section, the results from point P3 are used, as it is the closest location to the site (CAM Construcciones, 2015).



Figure 3.15: Location of used soil data from CAM project

The soil assessment combined field investigations, including the Standard Penetration Test (SPT), with laboratory analyses. The most relevant parameters are summarized below:

- *Triaxial Shear Test (c, φ)*: Determines shear strength through cohesion and the angle of internal friction, the key parameters controlling slope stability.
- *Standard Penetration Test (SPT, N-values)*: Provides estimates of soil density and consistency. Low N-values indicate weak layers prone to instability.

- *Atterberg Limits and Consistency Index (Ic)*: Define the plasticity and state of clays; low Ic values correspond to very low strength.
- *Natural Water Content (w)*: High values reduce effective stress and shear strength; in sands, full saturation may induce pore pressure buildup.
- *Unit Weights (γ)*: Influence the driving forces within the slope, directly affecting stability.

The subsurface profile indicates several weak layers that govern slope stability. An overview of the different layers can be found in Figure 3.16, red indicating weak soil layers and grey indicating stable soil layers. The most critical layers are located at approximately 12 m IGN and between 8 and 4 m IGN. These will be elaborated below:

- *SM-SC (silty-clayey sand, very loose, 12 m)*: This layer exhibits low cohesion (0.59 kg/cm^2) and an extremely low friction angle (4.5°). The natural water content (19.8%) and low plasticity index (5.1%) indicate minimal resistance to deformation. Its very loose structure and weak shear strength make it a key zone of potential instability.
- *ML (soft silt, 8 m)*: Characterized by low dry density (1.352 t/m^3) and high water content (30.1%), this layer has a consistency index of 0.82, reflecting a nearly plastic state. It is soft, compressible, and represents a significant weakness within the slope profile.
- *SM (Silty sand, non-plastic, loose, 7 m)*: Located near the surface, this soil consists of a silty sand with no plasticity. It has a dry density of 1.578 t/m^3 and a natural water content of 9.2%. Due to its very low penetration resistance and loose structure, this layer is highly susceptible to erosion and contributes to shallow instability within the slope profile.
- *SP (poorly graded sand, 5 m)*: This layer consists of non-plastic, very loose sand with moderate dry density (1.632 t/m^3) and water content of 20.6%. The lack of cohesion and high deformability suggest low stability under loading and potential for deep-seated failure.

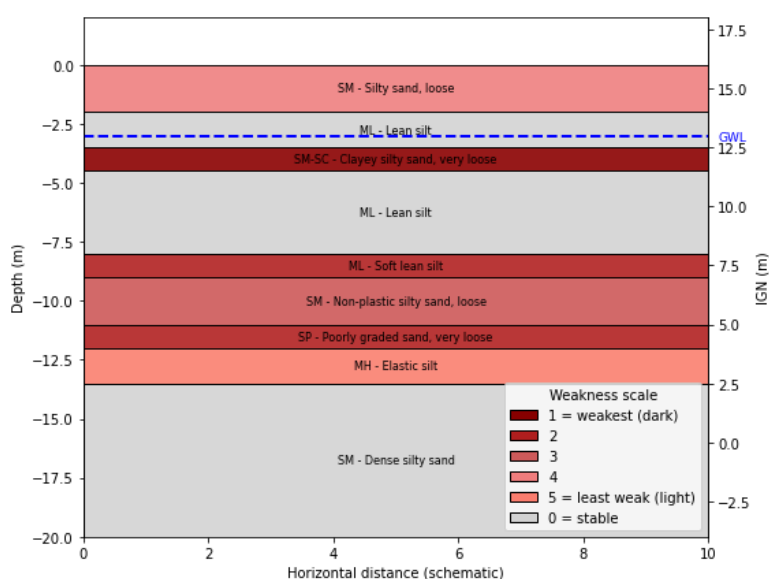


Figure 3.16: Different soil layers at P3.

3.2.2.2 Failure types

In this section, the slope's instability was analyzed by identifying key failure mechanisms based on soil and hydraulic conditions. The initial failure types are rapid drawdown and erosion, seen in Figure 3.17, these two types reinforce a third type, called circular failure.

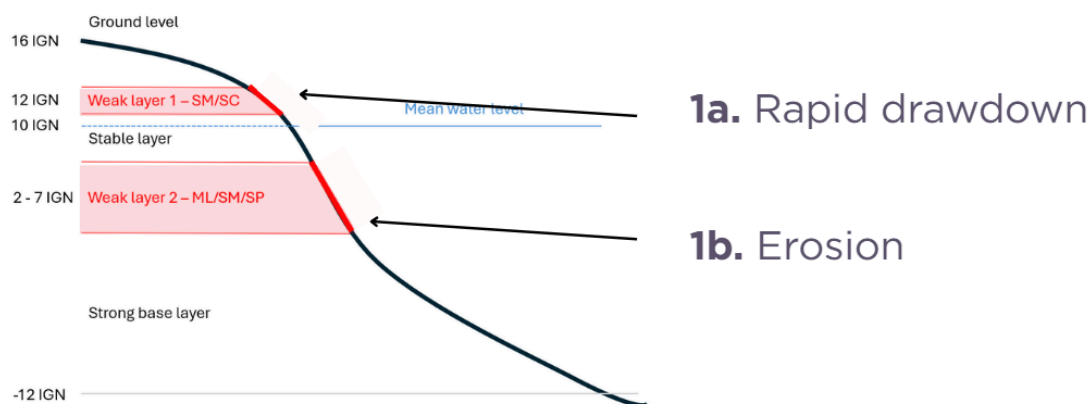


Figure 3.17: Different failure mechanisms and their occurrence

Failure mechanism 1a: Rapid drawdown

The SM-SC (silty-clayey sand) layer at approximately 12 m IGN lies just below the groundwater table, measured at around 3.05 m in the P3 borehole. Under normal conditions, pore pressures within this layer are balanced with the external water pressure of the river. However, when the river level drops rapidly, the external hydrostatic pressure decreases almost instantly, while pore pressures within the fine-grained matrix of the SM-SC layer dissipate slowly. This imbalance causes an increase in excess pore pressure and a corresponding reduction in effective stress, resulting in a sharp loss of shear strength. Given the very low friction angle (4.5°), the layer depends almost entirely on its small cohesive component (0.59 kg/cm^2) to maintain stability. Consequently, the SM-SC layer is highly sensitive to rapid drawdown conditions, when the river level falls below this horizon.

The hydrological records from the Paraná River (Informe Final Acta 2, 2021) show that water levels vary seasonally between approximately 11.7 m and 14.8 m IGN. As the top of the SM-SC layer lies near 12.5 m IGN, this horizon is regularly submerged during high-water periods and exposed as levels fall. These fluctuations cause the soil to cycle between saturated and partially drained states, leading to repeated changes in pore pressure. During rapid drops in river level, the external water pressure decreases faster than internal pressures can dissipate, creating a temporary excess pore pressure within the layer. This process contributes to rapid drawdown conditions, reducing effective stress and making the SM-SC layer particularly prone to instability during and immediately after falling river stages.

Failure mechanism 1b: Erosion

The erosion analysis of the site, supported by the flow pattern shown in Figure 3.18 (Líneas de corriente, 2019), illustrates how surface water currents interact with the slope and affect its stability. The visible flow patterns in the river indicate the direction and velocity (m/s) of the current, highlighting areas where water movement concentrates and where erosion is most likely to occur. On slopes exposed to strong currents and varying water levels, erosion develops both along the surface and near the toe of the slope, where flow energy is highest.

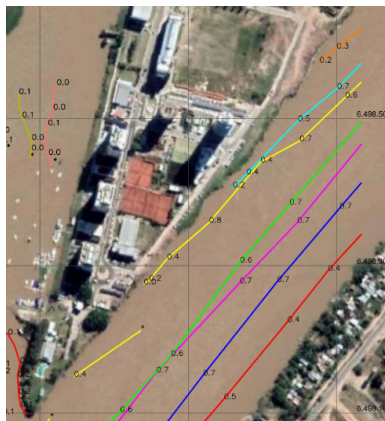


Figure 3.18: Current profiles from Líneas Corrientes

From the flow pattern shown in Figure 3.18 (Líneas de corriente, 2019), it can be seen that the yellow, light blue, and orange flow lines move toward the slope, indicating areas where the hydraulic current directly impacts the riverbank and increases erosion potential. In contrast, the green, pink, blue, and red lines follow a smoother path parallel to the river, suggesting more stable flow conditions. The yellow, light blue, and orange lines also appear to slow down as they reach the slope, likely due to hydraulic resistance, before deflecting and curving back toward the bank. This repeating pattern of approach and return suggests zones of localized flow concentration and recirculation, which can result in more erosion near the slope toe.

In this context, the layers most vulnerable to erosion are the SM–SC and SP layers, both displaying low resistance and high sensitivity to hydraulic action.

In addition to surface water erosion, other dynamics caused by wave and wind action further accelerate the erosion of the slope. Winds from the south and southwest generate the highest waves along this section of the waterfront, transferring energy to the slope face and loosening surface materials (Memoria Técnica, 2023).

Failure mechanism 2: Circular slope failure

Circular slope failure, also referred to as rotational failure, is illustrated in Figure 3.19, which shows the main forces and moments acting on a potential curved failure surface. In this mechanism, the soil mass tends to rotate downward and outward along a concave, circular path defined by a weak soil layer within the slope profile.

To understand why this happens, it helps to recall how gravity acts on sloped ground. Gravity always pulls straight down on the soil. On a flat surface, this force simply pushes into the ground, keeping the soil stable. But on a slope, that downward pull splits into two parts: one part presses the soil into the slope, while the other part pulls it downhill, this is what makes the soil want to slide.

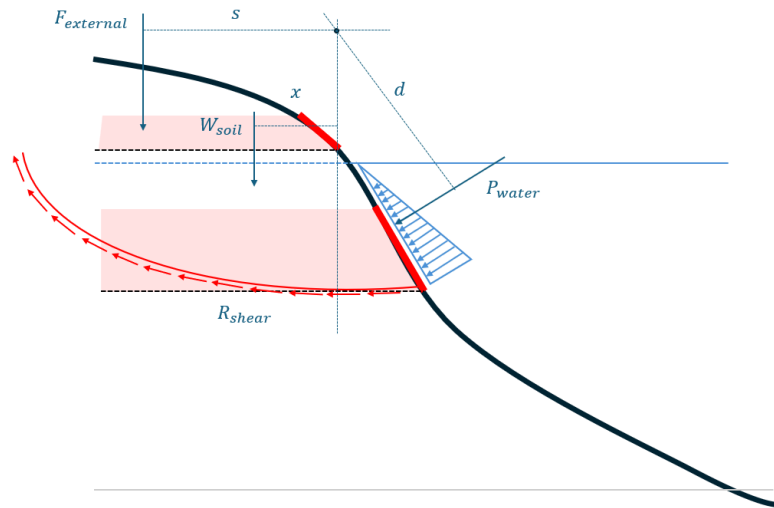


Figure 3.19: Moments acting on the sliding surface during circular failure

In circular failure, several forces act on the slope:

- Soil weight (W_{soil}): the weight of the soil pulling it downhill.
- External loads ($F_{external}$): extra forces on top of the slope, such as from buildings or vehicles.

Together, these create the disturbing moment (M_d), the force that tries to make the soil rotate and slide along a curved surface.

Opposing this is the resisting moment (M_r), made up of:

- Water pressure (P_{water}): the hydrostatic pressure from the river, which helps support the slope.
- Shear resistance: the soil's own strength along the curved slip surface, which depends on the shear resistance coefficient (R_{shear}), the length of the circular path (L), and the radius (r).

$$M_d = F_{ext} * s + W_{soil} * x$$

$$M_r = P_{water} * d + R_{shear} * L * r$$

When the disturbing moment exceeds the resisting moment ($M_d > M_r$), the balance of forces is lost, and rotational movement occurs.

The circular failure is expected at the discussed weak layers, namely SM-SC (silty-clayey sand, 12 meters, IGN) and SP (poorly graded sand 5 meter IGN). Although circular slope failure can occur independently, it is often reinforced by the combined influence of erosion and rapid drawdown.

Fluctuating river levels, especially during rapid drawdown, can activate circular failure, as the external water pressure (P_{water}) suddenly decreases while internal pore pressures remain high. This loss of hydrostatic support reduces stability and increases the likelihood of rotational sliding along the weak SM-SC layer.

As a result of erosion, the geometry of the slope changes, the length (L) of the potential circular failure path, and thus the area over which shear resistance (R_{shear}) acts are reduced. This can be seen in Figure 3.20. The reduction in the available shear surface directly lowers the total resisting moment.

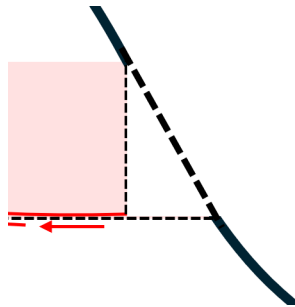


Figure 3.20: Lower area of resistance due to erosion at toe

3.2.2.3 Factor of safety current slope

Given the identified failure mechanisms, it is necessary to quantify the current stability of the slope. This is achieved through the calculation of the Safety Factor (SF), which expresses the balance between resisting and driving forces acting on the potential failure surface.

$$SF = \frac{\text{Resisting force}}{\text{Disturbing force}} = \frac{F_R}{F_D}$$

The Safety Factor for a potential planar failure surface was calculated using the conventional limit-equilibrium expression (U.S. Army Corps of Engineers, 2003):

$$SF = \frac{c'L + (W \cos(\theta) - U) * \tan(\varphi)}{W \sin(\theta)}$$

Where:

W = weight of the sliding block, which is determined using the total unit weight of the CAM data.

U = pore pressure at depth of the failure, which is determined using the ground water level of the CAM data.

θ = slope angle at sliding block, which is the maximum measured value of 45° (1V:1H) will be used, which was found in 2.2.1.1. Predictable soil layer (Green zone).

φ = friction angle of the soil, which is found in (Memoria Técnica, 2023) for a comparable site: 35°

c' = effective cohesion of the soil, which is assumed to be 10 kPa for slightly over-consolidated silty clay.

L = trial plane length of the sliding block.

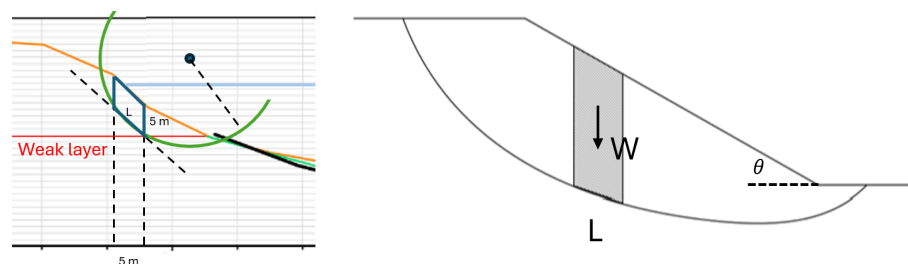


Figure 3.21 and 3.22: Sliding block used for SF

Figures 3.21 and 3.22 show how the slice is defined from the most critical point of the slope at T243 (Perfiles Transversales Canal de Derivación Norte, 2021). The SF of this part results in:

$$SF = 0.67$$

The calculated SF indicates that the current slope condition is critically unstable. In geotechnical engineering, a stable slope typically requires an SF greater than 1.3–1.5 under static conditions to ensure an adequate margin of safety against failure (U.S. Army Corps of Engineers, 2003).

An SF below 1.0 signifies that the driving forces exceed the resisting forces, meaning the slope is already in a state of incipient or ongoing failure. This low value confirms that the slope, particularly along the weak SP (poorly graded sand) layers, cannot maintain equilibrium under current hydraulic and mechanical conditions.

3.2.3 Similar projects and applied solutions

Waterfront stabilization projects in Argentina and internationally, demonstrate a broad spectrum of interventions to counter slope instability. These can be organized into five main families: retaining wall systems, rock and block armoring, armored slope blankets, engineered soil reinforcement and drainage, and nature-based stabilization.

Each family contributes to slope stability through a specific physical mechanism:

1. **Retaining wall systems** are engineered structures designed to resist lateral earth and hydrostatic pressures. These systems are typically composed of strong, durable materials, which provide the structural resistance needed to hold back soil and water. They are particularly effective in areas with weak or unstable soil layers, as they prevent circular slope failure by stabilizing the slope and ensuring the soil remains intact. The walls are designed to transfer the earth pressure and water load onto a foundation, preventing the slope from sliding or collapsing under the weight.
2. **Rock and block armoring** is an effective method of protecting slopes from erosion caused by water movement. This system uses loose or modular elements. These elements act as an energy-dissipating barrier, breaking up the force of incoming water currents. By absorbing and redirecting the energy of the water, the system reduces the impact on the slope, preventing erosion and surface scouring at the waterline.
3. **Armored slope blankets** provide a flexible, adaptable protection layer that helps prevent erosion on slopes, particularly in areas where water levels fluctuate or where rapid drawdown occurs. The flexibility of these materials allows them to conform to changes in slope geometry and water levels, providing continuous protection even as conditions shift. They also mitigate erosion by protecting the soil surface from the direct impact of water.

4. **Engineered soil reinforcement and drainage** systems improve the internal strength and stability of weak soils by enhancing soil cohesion and controlling pore water pressures. These systems typically involve the integration of reinforcement materials and drainage elements that work together to prevent instability. By strengthening the soil structure and managing water flow, they reduce the risk of slope failure, especially during events like rapid drawdown or heavy rainfall.
5. **Nature-based stabilization** uses vegetation and natural ecological processes to enhance slope stability. By integrating plants and natural elements, this approach helps bind the soil, absorb wave energy, and restore the natural hydraulic balance of the slope. The roots of plants provide cohesion, reducing erosion and improving soil strength. This method works in harmony with the environment, offering a sustainable solution that promotes biodiversity and long-term resilience. By restoring natural processes, nature-based stabilization reduces reliance on engineered solutions and ensures that the slope remains stable through ecological restoration.

Together, these five solution families address the multiple causes of instability at Santa Fe's waterfront. The following section describes examples for each family that are later used for a final concept decision in Phase 2.

1. Retaining wall systems

- Gravity walls: Large, reinforced concrete structures used in docks to resist lateral pressures from soil and water, providing stability by relying on their mass (see Figure 3.23).
- Sheet piles and pile-supported quays: Vertical barriers made from steel or concrete piles, commonly used in limited spaces to retain soil and support quay decks (see Figure 3.24).
- Filled sandbags: Large bags filled with sand or other materials are used as a single, robust barrier to prevent erosion and stabilize slopes (see Figure 3.25).

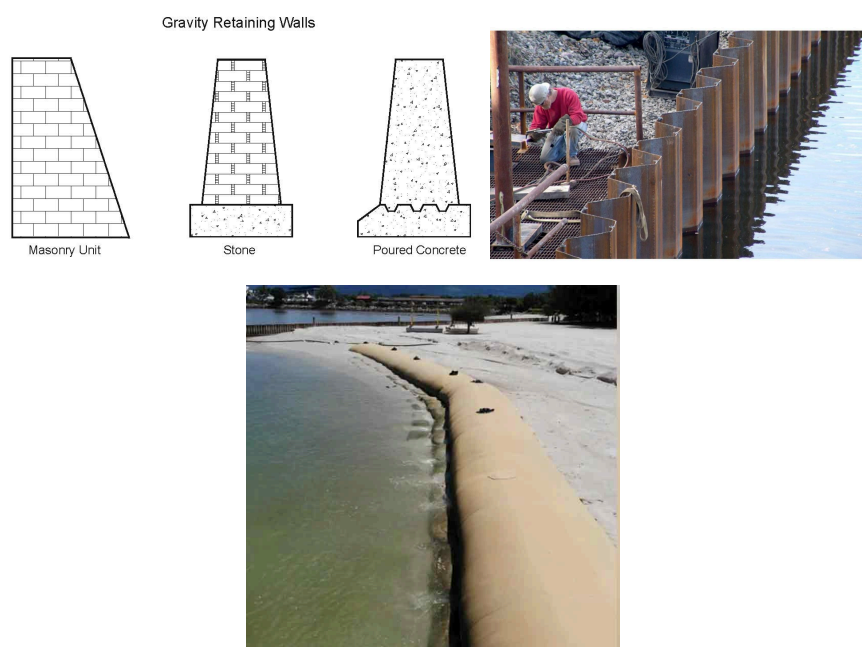


Figure 3.23, Figure 3.24 and Figure 3.25: Examples of retaining wall systems

2. Rock and block Armoring

- Riprap revetments: Large stones placed on slopes (see Figure 3.26).
- Gabions: Wire mesh cages filled with stones or other solid materials (see Figure 3.27).
- Concrete armor units: Interlocking precast concrete units (see Figure 3.28).



Figure 3.26, Figure 3.27 and Figure 3.28: Examples of rock and block armoring

3. Armored slope blankets

- Geocontainers and geocells: Flexible, soil-filled structures. Geocontainers add mass to prevent erosion, while Geocells form a grid that distributes loads and prevents soil movement (see Figure 3.29).
- Grouted riprap: Stones bound with grout (see Figure 3.30).
- Block mattresses: Linked precast units forming adaptable slope armor (see Figure 3.31).



Figure 3.29, Figure 3.30, Figure 3.31 : Examples of armored slope blanket

4. Engineered soil reinforcement and drainage

- Hydraulic fill: Cohesive soils used to rebuild embankments and restore slope geometry (see Figure 3.32).
- Vegetated riprap: Combination of rocks and vegetation to stabilize the soil (see Figure 3.33).
- Drainage systems: Systems like relief wells and horizontal drains to manage groundwater flow (see Figure 3.34).



Figure 3.32, Figure 3.33 and Figure 3.34: Examples of soil reinforcement and drainage

5. Nature-based stabilization

- Vegetation blanket: Protective layer made of grass mats and topsoil placed on slopes (see Figure 3.35).
- Afforestation: Planting native trees and vegetation binds the soil with deep-rooted plants (see Figure 3.36)
- Brush mattress: Layer of natural materials such as brush and shrubs (see Figure 3.37).



Figure 3.35, Figure 3.36 and Figure 3.37: Examples of nature-based solutions

3.2.4. Navigation channel

An important boundary condition for designing a slope protection is the location of the navigation channel. This channel functions, among others, as the access to the Raízen oil storage terminal for its vessels. These vessels have a beam of 18.2 meters (Wotol, 2014) which can be seen in Figure 3.38.

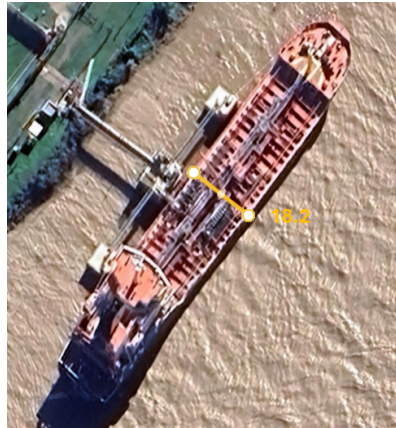


Figure 3.38: Satellite photo of Raízen vessel

The required width of the navigation channel is determined using PIANC guidelines (PIANC, 2014). The overall bottom width (W) of an access channel with straight sections is given for a one-way channel by:

$$W = W_{BM} + \Sigma W_i + W_{BR} + W_{BG}$$

Where:

W_{BM} = width of basic maneuvering lane as a multiple of the design ship's beam B .

ΣW_i = additional widths to allow for the effects of wind, current et cetera.

W_{BR} = bank clearance on the right side of the channel.

W_{BG} = bank clearance on the left side of the channel.

In which all values are indicated in multiples of the vessel's beam (e.g., 0.5 B) which are derived from PIANC guidelines (PIANC, 2014). For all parameters, a moderate vessel speed in protected water (inner channel) is assumed, which results in:

$$W = 1.5 B + 0.6 B + 0.5 B + 0.5 B$$

$$W = 56.42 \text{ meter}$$

Also, the draft of the vessel should be taken into account, which is 20 feet (6.1 meter) (El Cronista, 2024). From PIANC, the concept design channel depth is defined as:

$$h_{CD} = F_s + B$$

Where:

F_s = the ship related factor.

B = bottom related factor.

Both determined by PIANC assuming a moderate speed in a sand or clay bottom gives:

$$h_{CD} = 1.12T + 0.4 = 7.23 \text{ meter}$$

This is the minimal required depth that is required for the vessel to pass.

4. SWOT and problem definition

This chapter identifies the main challenges and opportunities shaping the redevelopment of the Port of Santa Fe. Through two SWOT analysis and three problem statements, it establishes the foundation for defining strategic, spatial, and technical directions that guide the project's vision.

4.1 SWOT analysis

A SWOT analysis is a strategic method to evaluate the strengths, weaknesses, opportunities and threats of an organization or project. In this project, two complementary SWOTs were developed based on findings from desk research, site observations and stakeholder interviews.

Two complementary SWOTs were developed at different levels of analysis:

- A strategic SWOT, addressing the broad city and port context.
- A project site SWOT, focusing on the specific conditions of the project site area.

4.1.1 Strategic SWOT: city and port context

The strategic SWOT examines the Port of Santa Fe as a whole and its relationship to the surrounding city and region; it can be seen in Figure 4.1.

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
<ul style="list-style-type: none"> • The port has a strategic location between cities next to the Paraná river: good trade location. • Its waterfront location makes it a popular and valuable location for renting and investing. • The port is surrounded by natural landscape and a waterfront. • The port has a strong historical identity: story, old buildings, cranes. • The port owns operational assets, e.g. recent investments in new equipment for operational activities. • The city port has a number of commercial facilities (mall, casino, hotel) attracting visitors. • The residential area of the port has a classy image. • The port is situated in Santa Fe, the Capital of Province and thus an important city. • There are green areas to make the port more livable, including 1) the border of the coast, 2) four designated areas for greenery within the port city. • There are fixed term contracts, keeping the power with the Port Authority, including Shell's 2030 term. • Many urban design plans are available, which is a strong asset: Masterplan concepts. • Operating terminals for revenue: public terminals • The port is a desired area for private investors • The port is situated close to the city center (walking distance). 	<ul style="list-style-type: none"> • Co-existence between functions: operational and industrial vs. residential & commercial activities <ul style="list-style-type: none"> ◦ No alignment between different functions • The infrastructure is overloaded: connections between the port and surrounding areas are insufficient, resulting in significant traffic and road congestion. • Access routes to the port are inefficient: <ul style="list-style-type: none"> ◦ Vessels arrive through a tunnel. The port authority is responsible for maintaining the channel leading to the tunnel. This dredging is very expensive. ◦ Access roads for cars are inefficiently located. • There is limited time for investors to make a margin on their rented plot: fixed term contract. • Investors are not willing to invest in public spaces because it does not generate income. • There are less operational activities than desired/before, leading to less port revenue. • Renovations are needed: outdated terminal, machines and infrastructure. • Trash in the river • There is no clear vision for the development between the many stakeholders involved. <ul style="list-style-type: none"> ◦ This lack of external alignment makes it difficult to move ahead with a clear and consistent agenda for the port. 	<ul style="list-style-type: none"> • Potential strategic trading location for inland vessels between Cordoba and Paraguay. • Scaling up water sports activities: canoeing, kayaking, and stand-up paddleboarding. Along with water events and competitive swimming and rowing. • Building on existing ideas about fluvial public transport, in collaboration with: the municipality and surrounding cities. <ul style="list-style-type: none"> ◦ Connection to surrounding areas: Alto Verde, Santo Tomé, Paraná - tourism strategy. ◦ Connection to the beach. • Building on water (houses, restaurants) to improve connection to the water. • Nature reserve: create ecological reserves/protected areas to increase biodiversity. • Use the strength of the surrounding nature for tourism activities: e.g. tours, nature parks. • City Port transportation: sustainable mobility (less cars, more cycling/walking, public transport, 15-minute city) • Integration of culture: skate, sports, art, history • Receive funding from the government or nation through: program for public port • Renewable energy usage through solar panels • Partnerships with UNL for new projects • Quarterly meetings with strategic partners / involved stakeholders to align visions and ambitions. 	<ul style="list-style-type: none"> • Operational and tourism competition from other ports: Rosario and Paraná. • Uncertain legislation within the province and country. • Economical crisis in the country. • Climate change scenario: water level fluctuations → floods - affected urban and natural systems. • Further extension of slope damage due to meandering and sediment transport. • Risk of water quality decrease and pollution due to feces, industrial wastewater, construction runoff. <ul style="list-style-type: none"> ◦ Water pollution threatens local aquatic life and the overall ecosystem health. • Public and private parties have conflicting interests. • Different communities: social polarization - port residents vs. city residents. • Revenue from operational/terminal activities is insufficient to sustain the port in the long term. • Unhappy port residents due to new construction developments. • Industrial activities conflict with natural habitat restoration. • No interest in high investments from the Province.

Figure 4.1: Strategic SWOT - city and port context

4.1.2 Project site SWOT: project site context

The project site SWOT focuses on the project site area, this can be seen Figure 4.2.

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
<ul style="list-style-type: none"> There is room for development of the area, with greenery. High-end living in this residential area - the residential towers have a stylish appearance. There is a feeling of safety and tranquility: especially compared to the city centre, there is more safety and style. The project site is surrounded by a natural landscape: the waterfront and nature. There are beautiful views from this area. Fixed term contracts, the land returns to the Port Authority: <ul style="list-style-type: none"> Shell contract ends in 2030. There might be another use for this area. There is a (small) area for the commercial activity, making it interesting for investors to invest. Location of the project site: <ul style="list-style-type: none"> Direct river access There are sport clubs with connection to the water: a public club (Azopardo) and a private club (Club Marinas). 	<ul style="list-style-type: none"> The slope next to the project site is in poor condition and ecologically fragile, which makes it unsafe for residents and visitors. When developing the slope, current structures must be taken into account: sewerage and rainwater drains in the slope. The project site is adjacent to the Raízen (Shell) area. For safety reasons, construction is prohibited within 143 meters of the center of this area. Looking at the project site, there is approximately 30 meters of no-building area. Various functions live close together: industrial vs. residential and commercial activities (Shell next to residential area). There is poor urban connectivity on dyke 2: few clear cycling and walking paths. There is no clear vision for this area. There is trash in the river and area. The area next to the project site is owned by the municipality: there is no information about the development plans of this area. Contractual requirements for investors, including those regarding the construction of infrastructure and specific building styles, do exist, but they are not binding enough, meaning they are not implemented in practice. There is no 'physical connection' to the river (e.g. docks), partly because of the very steep and unsafe slope. People are not allowed to swim in the river. 	<ul style="list-style-type: none"> There are potential investors for the development of the project site. Strategic use of the water: <ul style="list-style-type: none"> Water events: swimming, rowing, etc. Connection to water sports facilities: regatta, canoeing, kayaking, sup. Connection to surrounding areas: e.g. Alto Verde and Santo Tomé. Sustainable port transportation: improved cycling and walking routes for cyclists and pedestrians - less cars. There is room to build on the water: e.g. houses, restaurants, terraces. Fertile soil: nature-based solutions are possible. Cultural engagement: skate, sports, art, museums, etc. Implementing flood-resilient designs and slope stabilization. Contractual fact: at least 5% of the private investments should be allocated to public infrastructure outside the plot, which helps to develop the area. 	<ul style="list-style-type: none"> Seasonal water level fluctuations of the Paraná River. Climate change increases flood risks. Weak soils and erosion in the slope accelerate deterioration and increase the risk of landslides/structural collapse of the wall. The river width is decreasing (has been decreasing the last 50 years). Strong current of the river. Polarization (port residents vs. city residents). Unhappy port residents due to new construction developments: they want to maintain the exclusivity and peace in the neighborhood. Potential conflicts between tourism development and ecological preservation. Investors are not willing to pay more for public space access areas. Uncertain legislation: ROU Urban determines the land's intended use. This is a municipal decision and can change suddenly. Economical crisis and instability in the country.

Figure 4.2: Project site SWOT - Dyke 2 context

Together, these SWOTs form the basis for the problem statements and inform the development of the port vision and urban design concepts for the project site.

4.2. Problem Statements

The above analysis is used to consolidate the findings and define the main challenges and potentials for the redevelopment of the Port of Santa Fe. This section formulates three problem statements: one at the strategic level, which emphasizes the vision for the port as a whole, one at the project site level, which focuses on the challenges of redeveloping the project site and its slope into an urban concept, and one at the technical level, which addresses the geotechnical instability of the slope and the need for sustainable stabilization measures. All problem statements are again based on the stakeholder interviews, site observations and desk research.

4.2.1 Strategic level - Port and surrounding area

The redevelopment of the entire Port of Santa Fe is constrained by the lack of a shared long-term vision between different stakeholders on the layout and function of the Port. These stakeholders include the Port Authority, municipality, private investors, residents, and nearby communities.

While the Port Authority seeks to recover operational capacity, the municipality emphasizes sustainable connectivity and reduced dredging through increased use of river transport. Private investors prioritize real-estate and tourism development, whereas port residents and the Port Authority, call for accessible green public spaces. Meanwhile, Alto Verde remains socially and economically isolated, with conflicting views on how integration should occur.

This division of opinions is also reflected in the port's function. Operational, commercial, residential and recreational uses in the port currently coexist. Stakeholders have different views on how to balance operational activities with commercial and residential development, and there are no

long-term agreements on how to manage this transition. Additionally, social differences remain existent between affluent port residents, daily visitors, and low-income neighborhoods. This leads to a division between the communities and makes inclusive redevelopment of the port more difficult. Lastly, from an ecological perspective, current designs often take too little account of the river and its ecosystems. The area offers great potential for co-existence with flora and fauna in the floodplain of Parana river and its surroundings.

An aspect most stakeholders agree on is the Port currently lacks well-developed and accessible green spaces. Although people live along the waterfront and enjoy the view of the river, there are too few inviting places to spend time in a green and comfortable environment. The unsafe ramp of the waterfront, undeveloped grass plots, and lack of basic amenities are evidence of this neglect. As a result, the waterfront is not fully realizing its potential to serve as a vibrant urban environment.

Several challenges remain in linking the port to the rest of the city. Access to the port remains dominated by car traffic, leading to congestion, insufficient parking, and limited mobility alternatives. This is because infrastructure for walking, cycling, and river-based transport is still underdeveloped. Both the Municipality and the Port Authority envision a future in which sustainable fluvial transport will play a key role in the Port's development.

Economically, operational activities are declining, the port terminals are underutilized, and revenue from logistics is insufficient to sustain the port in the long term. Vessels reach the port through a dredged access canal that requires continuous maintenance by the Port Authority, which is very costly.

Additionally, public and private investors have greater interest in investing in the commercial and residential side of the port than public green spaces, as these do not generate direct revenue. However, the Port Authority wants to attract more tourists and the citizens of the city of Santa Fe by providing them these public access spaces. The port must therefore diversify its economy and attract investments that balance profitability with public wishes.

4.2.2 Project site level - To be developed area and slope

The Port Authority envisions the site as a public green space meant to serve both residents and tourists while strengthening the connection to the river. At present, however, the surrounding area on Dyke 2 is dominated by new residential towers and provides only fragmented and underdeveloped green spaces. Additionally, the project site's waterfront remains physically disconnected from surrounding neighborhoods and the river itself, functioning primarily as an exclusive residential zone rather than an accessible urban space.

Creating this accessible waterfront necessitates significant investment, yet public funding is currently unavailable. The realization of the plans therefore depends on private investors, generating (as mentioned) tension between the public objectives and private interests. Currently, the only mechanism that contractually guarantees public benefit is the requirement that 5% of private investments be allocated to public infrastructure outside the private plots. There is more need for a plan that secures both financial feasibility and meaningful public value.

4.2.3 Technical level - slope stabilization

The slope along the Port of Santa Fe faces critical technical challenges due to multiple weak soil layers and gradual degradation caused by the dynamic forces of the Paraná River. The most significant contributors to the risk of erosion and landslides are fluctuating water levels that cause rapid drawdown, and the erosive effects of currents and waves. Cross-sectional profiles showing significant

land loss and images revealing deep gaps and missing sections, confirms this severe risk. The calculated Safety Factor (SF) of 0.67 further confirms the slope's critical instability.

Existing stabilization measures, such as retaining walls, have proven insufficient for long-term protection as they often fail to account for the natural dynamics of the river and its surrounding ecosystem. Furthermore, the improvised use of construction debris creates uneven, permeable fills that obstruct drainage, hinder vegetation growth, and worsen slope instability.

A conventional approach, relying on traditional cement-based solutions, contributes to biodiversity loss by preventing the growth of natural vegetation, which is vital for stabilizing the soil. Given these increasing environmental pressures, there is a need for a sustainable and effective approach to slope stabilization that balances engineering with ecological restoration.

4.2.4 Creating a shared direction

The three identified problem levels serve as a structured foundation for the following approach in Phase 2. The strategic level forms the basis for the overall vision, which is translated into four guiding pillars that steer the long-term redevelopment of the Port of Santa Fe. The project site level provides inspiration for conceptual ideas that can be implemented on the project site. Finally, the technical level addresses the engineering solutions required for slope stabilization.



PHASE 2

Design & solutions

PROFUNDIDADES EN

RIO PARANA
HOJA 12
(Hacia el centro)

H-140

Roovers, trees (for shade)

Solar Tree

Floating systems

Different kinds of gates along

promenade

walking along the water, like long-term water

walking between water bridge over road

vertical parks

floating bridge

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Introduction of Phase 2

Phase 2 builds on the findings and problem statements derived from Phase 1 and moves from analysis to the formulation of design concepts and solutions. This phase focuses on developing the following key outcomes:

- A strategic vision for the Port of Santa Fe,
- Urban design concepts for the Dyke 2 project site, and
- A technical solution for the slope instability at the project site

Because these elements operate at different levels, the phase is divided into two parts.

Chapter 5 addresses the strategic and spatial development: it presents the long-term vision for the port, based on four pillars, and uses this to create design concepts for the project site.

Chapter 6 focuses on the technical slope stabilization component, where alternative stabilization strategies are assessed through a Multi-Criteria Decision Analysis (MCDA) to identify the most suitable solution for the site.

5. Urban design development: vision and project site

5.1 Vision for the Port of Santa Fe

The vision for the Port of Santa Fe is directly based on the strategic problem statement and its key challenges defined in Phase 1. This statement revealed several underlying challenges, including the absence of a shared long-term vision among stakeholders, fragmented spatial development, limited accessibility, and weak integration between the port, the city, and surrounding communities.

From this analysis, four main trends and needs were identified. These were translated into four guiding pillars, each addressing one of the core challenges. Together they form a strategic vision for the port's future development. The 4 pillars are explained in the following sub-sections.

5.1.1 Pillars and objectives

1) *Connectivity & sustainable mobility*

→ The port will be reconnected to the city and the river through public fluvial transport between surrounding cities, making better use of the water. Car traffic in the port will be reduced, while pedestrians, cyclists, and river public transport will be given priority. The physical connection between the port, the water, and surrounding areas will be strengthened.

← This responds to current congestion, poor infrastructure, and the limited (river) accessibility that isolates the port from its surroundings.

2) *Attractive & livable environment*

→ The port will evolve into a green and accessible waterfront that improves the daily life of its residents and visitors. It strengthens the relationship between people and the river, as is desired by the Port Authority.

← This addresses the current lack of comfortable, well-designed public spaces and the absence of incentives to invest in a more inviting environment.

3) *Co-existence*

→ The port will become a place where industrial, commercial, residential, and recreational functions coexist, where social barriers between surrounding communities and the port are reduced, and where people and nature live in balance through ecological integration.

← This responds to the conflicting interests among stakeholders and the existing separation between the port, nearby communities like Alto Verde, and the surrounding natural environment.

4) *Economic & cultural vitality*

→ The port will strengthen its role as a driver of economic growth and cultural identity for Santa Fe by diversifying into (river) tourism and cultural initiatives. The historic value of the port will be preserved and this can be used to help with tourism development. This will transform the waterfront into a vibrant and attractive destination, while ensuring compatibility with the port's ongoing plans and operations.

← This addresses the decline in operational activities and the need to align private investments with long-term public wishes.

Application of pillars on the project site

Together, these four principles form the strategic vision for the port's future redevelopment. The project site serves as the first concrete application of this vision, translating the four guiding principles into spatial design concepts. As an area with high potential for transformation, it offers the opportunity to demonstrate how the vision can be realized in practice.

5.2 Concept development

This part focuses on translating the overall vision into tangible design concepts for the project site. To illustrate this process, Figure 5.1 presents the complete ideation flow, showing how the vision at the strategic level is gradually transformed into concept directions at the project-site level.

5.2.1 Ideation phase

As shown in Figure 5.1, the ideation begins with the four guiding pillars that were introduced in the previous section. These will serve as the foundation for our design thinking process, an iterative approach to creative problem-solving.

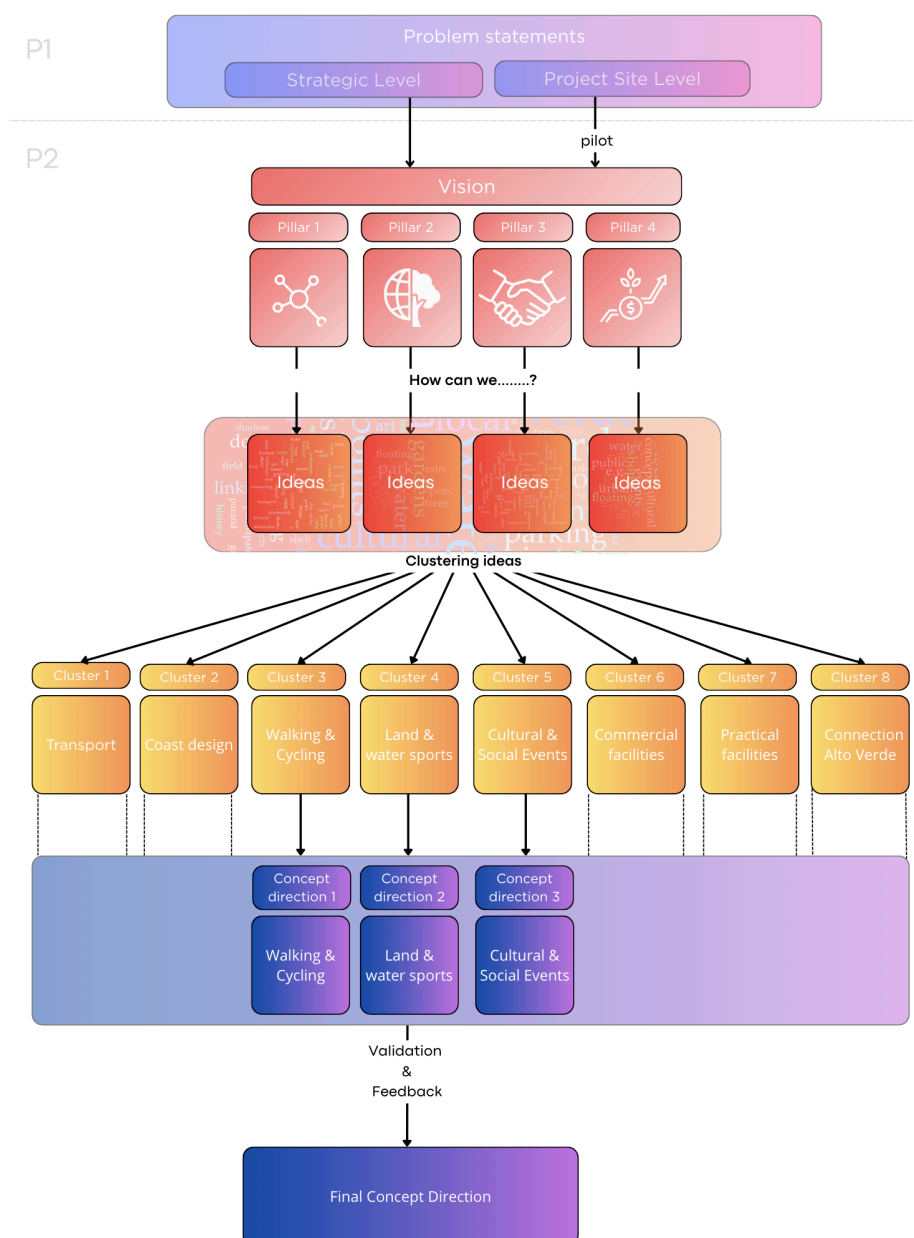


Figure 5.1: Overview of the concept development process

To structure the brainstorming, the “How can we...?” method was applied to each pillar. This is a creative method that reframes challenges into opportunities for design exploration. For each pillar, the team asked themselves the following questions:

- How can we (physically) connect the port to the city and the river?
- How can we make the port a more attractive and livable environment?
- How can different functions, communities, and the surrounding flora and fauna coexist sustainably?
- How can the port strengthen its cultural identity and economic vitality?

By answering these questions, a wide range of ideas were generated. A complete overview of all ideas and the results of the brainstorming session can be found in Appendix C.

5.2.2 Clustering

Following the ideation phase, all ideas were firstly printed and then clustered according to thematic similarity, this can be seen in Figure 5.2. As visualized in Figure 5.1, this clustering step shows the transition from individual ideas per pillar toward more structured design opportunities. The clustering process resulted in eight main clusters:

1. Transport
2. Coast Design
3. Walking & Cycling
4. Land & Water Sports
5. Cultural & Social Events
6. Commercial Facilities
7. Practical Facilities
8. Connection with Alto Verde



Figure 5.2: Photo of the brainstorm session

5.2.3 Main clusters

After mapping all clusters, a critical reflection was performed on which ones were essential to realizing the vision and which ones could be combined or refined. Through this synthesis, three main clusters were identified that could independently embody the vision while remaining mutually complementary.

The final main clusters include:

- Main Cluster 1: Land & Water Sports
- Main Cluster 2: Walking & Cycling
- Main Cluster 3: Cultural & Social Events

Consequently, all remaining clustered ideas were redistributed among these main clusters to ensure that the entire vision and its pillars were fully addressed. Based on this, three *concept directions* were defined.

5.2.4 Concept directions

This section introduces the three concept directions. Each concept translates one of the main clusters: sport, recreation, and culture, into a functional vision for the project site. All elements within each concept were categorized according to the four guiding pillars, to verify that every part of the vision was represented. In Figure 5.3, the symbols that represent each of these pillars can be seen.



Figure 5.3: The four guiding pillars

5.2.4.1 Concept 1: The Active Riverside

The Active Riverside was created to link the river and urban area through sports and water activities. It is envisioned as an active social zone where people come together through sports and movement, which should also create a direct connection between the land and the river; an impression can be seen in Figures 5.4 and 5.5.

Elements

The *Active Riverside* concept integrates elements that invite users to interact with the river in various ways, with sports as the primary activity. The specific elements can be seen in Figure 5.6, they include (water)sports and other outdoor activities. Paths along green areas are designated for pedestrians and cyclists to connect the area to the rest of the city, and stepped terraces and docks provide direct access to the water for kayaking and similar sports. Supporting elements include shaded rest areas and picnic tables.

In addition, informal and low-threshold activities such as jeu de boules offer opportunities for social interaction and inclusion, giving people a reason to stay, connect, and build a sense of community around the site. A sports club with a canteen supports this social dynamic while also enabling private investors to make profit.



Figure 5.4: The Active Riverside



Figure 5.5: The Active Riverside by night



Figure 5.6: Elements of the Active Riverside concept

5.2.4.2 Concept 2: The Urban Waterfront Park

The key idea of this concept was creating a relaxing and inspiring environment. Concept 2, is envisioned as a calmer, green, and aesthetic park landscape along the water that focuses on relaxation, walking, and inspiration; an impression can be seen in Figures 5.7 and 5.8.

Elements

The specific elements of this concept can be seen in Figure 5.9, the elements are focused on giving pedestrians and cyclists the best experience. The visitor can walk calmly to its next destination in the port, or hide themselves in secluded areas for relaxing and taking a break, while enjoying the view of the river. A walking bridge over the water reinforces the connection between city and water. A view tower provides a panoramic outlook over the port and river. Benches and picnic tables are strategically placed to offer views and create comfortable resting and eating points, while dynamic walking routes guide pedestrians through open and shaded green areas. Small-scale elements, such as kiosks and

cafés coffee, add social interaction and chance of profitability without disturbing the calm atmosphere. Trees, cozy corners, and art ensure that the waterfront feels both green and modern.



Figure 5.7: The Urban Waterfront Park

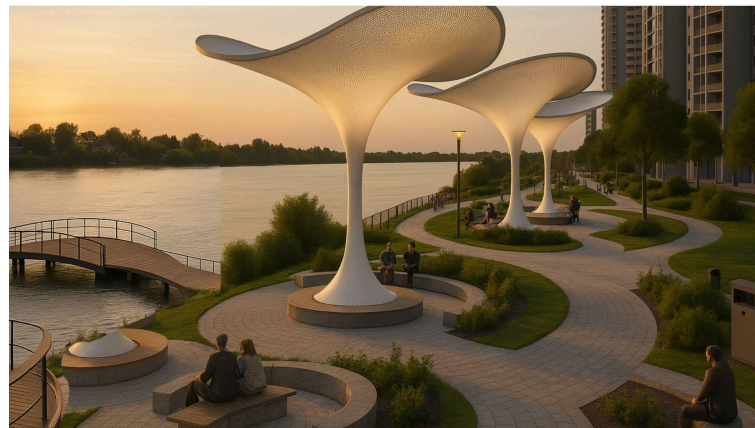


Figure 5.8: The Urban Waterfront Park



Figure 5.9: Elements of the Urban Waterfront Park concept

5.2.4.3 Concept 3: The Cultural Port

The Cultural Port was developed as a meeting place for everyone, day and night. The concept aims to position the port as the socio-cultural heart of Santa Fe through public spaces and cultural activities; an impression can be seen in Figures 5.10 and 5.11.

Elements

The specific elements of *The Cultural Port* can be seen in Figure 5.12, the design integrates spaces for events, mural art, stalls, and hospitality, encouraging both cultural exchange and connection. Cafés, asado areas, and green spaces foster social interaction. Docks where boats can moor and visitors can access the water, together with viewpoints and fluvial transport links, strengthen the connection between the port, the city, and the river. There is a local café at the site that brings people from all over the city together. Both the events and the café create a profitability element. Supporting facilities such as pathways, fences, water points, and (paid) public toilets ensure comfort and accessibility.



Figure 5.10: The Cultural Port

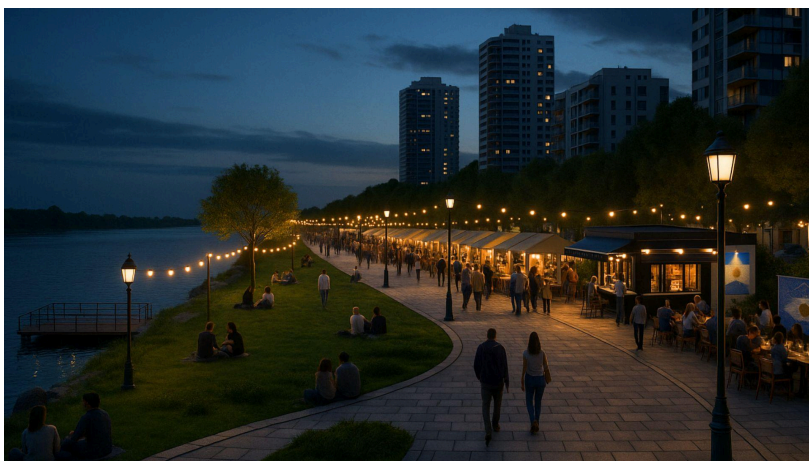


Figure 5.11: The Cultural Port by night

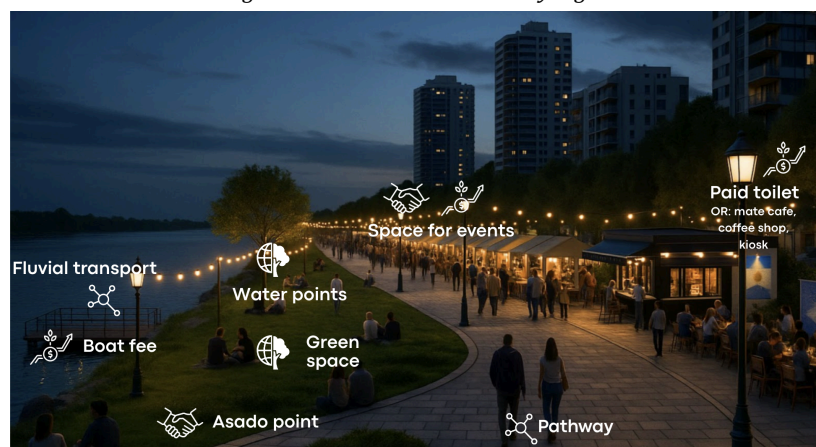


Figure 5.12: Elements of The Cultural Port concept

5.2.5 Validation of the concepts

To determine which concept best aligns with the long-term vision for the Port of Santa Fe and was most desired for further development, a feedback and validation process was conducted. The evaluation followed a multi-step qualitative methodology, integrating several feedback loops in order to capture different perspectives on the three concepts. The following steps were taken:

1. Interactive midterm presentation

The first step of validation and feedback was collected during an extensive Q&A after the midterm presentation, in which the three concepts were presented to colleagues of the Port Authority (different teams and departments). This conversation validated that the Port Authority agreed with the different concept directions. However, they did have valuable feedback (discussed in Section 5.3). This feedback was collected and later discussed with our supervisor.

2. Survey

To systematically compare the three concepts, a (Spanish) Google Forms survey was conducted, which can be found in Appendix D. The survey was distributed among colleagues and stakeholders of the Port Authority after they attended the midterm presentation.

The survey contained both quantitative and qualitative questions, structured around the following components:

- Perceived likelihood of use of each concept by Santa Fe residents and visitors.
- Preference rankings of key facilities and features per pillar (e.g., terraces, docks, kiosks, or event spaces).
- Alignment with expectations for the port's future.
- Stakeholder preference mapping, asking respondents to indicate which concept they believed would be favored by residents, investors, the municipality, and the government.
- Comparative ranking of the three concepts based on feasibility, overall preference, and potential to attract investment.
- Additional open questions about missing elements, undesirable features, and suggested improvements.

3. Supervisor feedback

The third validation step involved a targeted feedback session with the project supervisor, who also represents the Port Authority technical team. The supervisor's expert perspective was used to contextualize the (subjective) survey results.

To enable comparison and support the selection of a final direction, all collected feedback was summarized in the following sections, outlining the main strengths, weaknesses, and suggested improvements of each concept. This approach also allowed the final concept to integrate strong and well-received elements from the other concepts, ensuring a balanced design outcome.

5.3 Concept evaluation

This section evaluates the three proposed concepts based on all collected feedback. The assessment considers their strengths, weaknesses, potential risks, missing elements and suggestions.

5.3.1 Evaluation concept 1: The Active Riverside

Overall, colleagues of the Port Authority were enthusiastic about *The Active Riverside*. They thought people from Santa Fe would make use of the facilities in this concept. However, they did not think the four stakeholders they were questioned about in the survey, the municipality, residents, investors, and the government, would prefer this concept over the others.

Strengths

- This concept stimulates river tourism and encourages interaction with the water.
- The stepped terraces and docking facilities particularly strengthen the connection between the land and the river.
- Large green areas and comfortable public spaces make the area more livable.
- By encouraging sports and physical activity, the concept promotes social cohesion.
- The design of the concept makes the area more dynamic and lively, attracting visitors throughout the day and into the evening.

Weaknesses and risks

- Kayaks and jeu de boules were not found to be desired activities in this area.
- Both investors and nearby residents value exclusivity in the area. This concept may potentially cause nuisance and conflict with the investors' vision for the site.
- Several aspects of this concept are already offered in nearby areas of the port (kayak and cafés).
- The maintenance requirements of this concept are relatively high due to the presence of outdoor sports facilities and water-related infrastructure.
- The inclusion of water sports introduces potential safety risks for users.

Missing elements and suggestions

- Designated areas where people can sit and drink maté (Argentinian drink).
- More trees to provide shaded areas and improve comfort during hot weather.
- A solar-powered station to supply electricity and include a water point with heated water for public use.
- A tire inflation point for cyclists.

5.3.2 Evaluation concept 2: The Urban Waterfront Park

Overall, colleagues of the Port Authority were positive about concept 2. The survey showed that the colleagues of the Port Authority were of the opinion that every stakeholder group would, to some extent, prefer concept 2.

Strengths

- This concept creates tranquility and continuity along the project site, by using dynamic walking routes with viewpoints.
- The concept is easy to implement, since it has low technical complexity.
- The goal of the concept, the relaxing and inspiring experience, is met by a green and aesthetic park landscape along the water and with this connecting the area with nature and the rest of the area.
- Information points are interesting to inform visitors about facts of the area.

- A walking bridge contributes to the connectivity with the water.
- Residents of the port and investors that live there would be interested in this concept, because the area will stay more calm in comparison to the other concepts.

Weaknesses and risks

- There is little economic activity or tourist attraction.
- This concept has less inclusive and social functions, this could result in little interaction and connectivity.
- This concept may be too modern now in terms of style, it may not fit well with the existing architectural style of the port area.

Missing elements and suggestions

- More open spaces.
- Spots for bike maintenance.
- Solar-powered spots where visitors can get heated water for maté and charge their phones.
- Information points describing the species of flora and fauna and the history of the port.
- A public dock where people can enjoy the river and dock their boat.

5.3.3 Evaluation concept 3: The Cultural Port

Overall, feedback from colleagues of the Port Authority indicated that concept 3 was appreciated for its cultural ambition and potential to strengthen the port's identity. However, concerns were raised about its feasibility and potential conflicts with local residents and investor interests.

Strengths

- The concept can support both day and night activities, which increases the area's attractiveness.
- Elements such as docks, information viewpoints and event spaces.
- Temporary events in the area, the organizers remain responsible for cleaning the area.
- Events create the opportunity of attracting citizens and tourists all year round.
- The concept promotes public-private synergies and encourages collaboration between investors and the Port Authority.

Weaknesses and risks

- Nuisance and potential conflicts with local residents and investors, as these groups prioritize peace and privacy over public use.
- Asado places, because that could cause litter, excessive smoke and odor in the residential area.
- Small temporary commercial places like market stands or food trucks because of their association with litter and odor.
- Cultural events (like local markets) are already represented in the city center of Santa Fe, which limits the uniqueness and appeal of a new cultural area within the port.
- The concept does not yet offer a strong connection between the port, the river, and river tourism.

Missing elements and suggestions

- Open spaces and rest or maté areas.
- Integrate elements about local flora and fauna.
- Minigolf as a potential recreational facility

5.3.4 Overarching feedback all concepts

The survey, followed by the Q&A and a validating conversation with our supervisor also generated some general feedback that applied to all concepts and the overall vision of the port area.

- The area should be attractive and usable during the evening and nighttime.
 - A connection with Alto Verde is important but also complex. Stakeholders suggested focusing on developing a vision for this connection rather than an immediate physical link.
 - Historical and cultural identity should play an important part in the design of the project.
 - Keep in mind the connection with the river. For example, fences are not wanted, as they block views and access to the river.
 - The project should help bridge the fragmented visions between the Municipality, the Port Authority, the Government, investors and residents. None of the current concepts fully achieve this yet.
 - Better connections to bus stops and public transport to make the area more accessible.
 - The project should attract investment. By maybe giving investors some freedom to decide what can be built along the promenade, supported by examples or design guidelines to spark interest.
 - The best outcome could come from combining elements of all three concepts, bringing together different aspects for activity, relaxation, and culture into one design.
- #### 5.4 Final concept selection
- The smaller-scale facilities are less appealing to both the investors and the board of the Port Authority: they are primarily interested in multipurpose buildings with higher long term investment potential.

5.3.5 Concept selection

Feedback from the Port Authority colleagues during the midterm presentation indicated a clear preference for Concept 2, *The Urban Waterfront Park*. Out of the three concepts, they believed this one would be most preferred by the four stakeholder groups considered in the survey: the municipality, residents, investors, and the government.

The area has a need for accessible green space, and Concept 2 effectively addresses this through a calm, continuous park landscape that strengthens the connection between the city, the port, and the river. Additional sports facilities were not seen as necessary, as these are already available nearby. Large events, central to Concept 3, were viewed as undesirable due to the noise, litter, and inconvenience they could cause for local residents. Concept 2's simplicity, low technical complexity, and livable atmosphere align well with the preferences for peace and exclusivity in the area.

However, the feedback also showed that Concept 2 lacks some of the social and cultural activity found in the other concepts. Therefore, the decision was made to further develop Concept 2 as the foundation for the final design, while integrating selected elements from Concepts 1 and 3.

5.4 Concept composition

The final concept is based on the evaluation of Concept 2: *The Urban Waterfront Park* and guided by a list of design requirements from Appendix E.1. A selection of these requirements was used to assess how well Concept 2 performed. When Concept 2 did not sufficiently meet certain "must" or "should" requirements, relevant elements from Concept 1 and Concept 3 were integrated.

The applied requirements and results are shown in Appendix E.2. In the Excel file, each concept is evaluated as meeting (yes), partially meeting (medium), or not meeting (no) the criteria. All “must” requirements were included, as they define the essential design conditions, and most “should” requirements were considered, except those marked in red, which are too detailed or technical for this phase (e.g., tree species and utility connections). These will be addressed in Phase 3, together with the “could” requirements.

Incorporating elements of Concept 1 and Concept 3, results in a coherent final design that meets the requirements and aligns with the overall vision and four pillars.

5.5 Final concept direction

The Urban Waterfront Park concept is the leading concept. Therefore, we take most of the elements from this concept as the starting point for the final design. These include:

- Sufficient spaces for relaxing areas; this will be in the form of green spaces and parks.
- Dynamic walking routes; pedestrian paths that are not in a straight line, but have curvature.
- Viewing tower; this will add to the connection with the port and the river.
- Walking bridge; this will add to the connection with the river.
- Picnic tables where people can sit down and eat in order to make the area more attractive to stay for a longer period of time.
- Benches with a view of the water, serving the same function as the picnic tables and ensuring connection to the river.
- Street lights and lanterns to make the area attractive during the night.

From *The Active Riverside*, we take aspects that make the final concept more connected to the river, using:

- Stepped terraces; these adapt to the fluctuating water levels and can be used to connect the area to the river.
- Docking places where boats can moor and to enhance connectivity with the river.

From *The Cultural Port*, we take aspects that generate more income for investors and that integrate more tourism facilities, using:

- Informational viewpoint to educate visitors about the surroundings, flora and fauna.
- Space for temporary events to make the concept more feasible while strengthening the social connection between the city and the port area. Potential nuisance can be better managed since events would take place only occasionally and under the responsibility of the organizers.
- Integrating historic value ideas in the form of art or architecture.

Additionally, there were a few missing elements of the concept which were also not included in the other two concepts:

- Spots for bike maintenance, as the city of Santa Fe offers free public bikes.
- Solar-powered spots where visitors can get heated water for maté.
- A multipurpose building that is a bigger investment for investors.

The following opportunities are classified under the long-term vision for the port, which will be discussed in long-term roadmap in Chapter 11:

- Connection with Alto Verde
- Fluvial transport, in line with current plans
- Floating plastic collectors

In Chapter 8, these elements will all be brought together and the final concept will be introduced.

6. Technical development: slope protection

This chapter builds on the results of Phase 1, chapter 3, which provided insight into the soil conditions, failure mechanisms, and possible solution types. It focuses on selecting a concept for stabilizing and redeveloping the slope along the waterfront.

To develop suitable stabilization strategies, the slope was divided vertically into two main parts which can be seen in Figure 6.1:

- Middle zone: the central part of the slope that is partially submerged and is directly affected by river fluctuations. This part is exposed to wind and wave action, as well as current erosion and rapid drawdown effects.
- Toe zone: the lower section that is always submerged and therefore always in direct contact with the river, is mostly affected by current erosion.

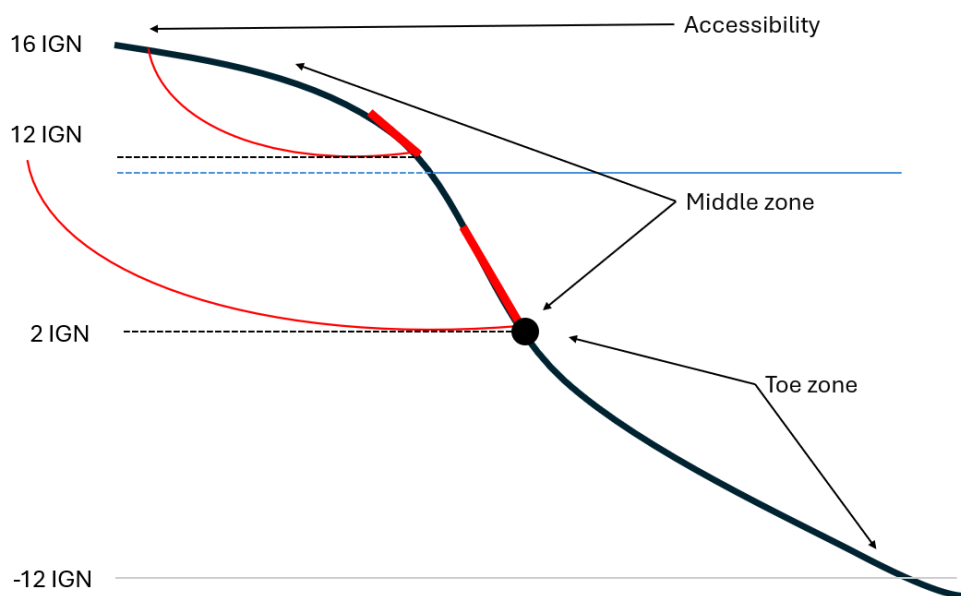


Figure 6.1: Division of the slope into middle and toe zone.

For both zones, multiple design options were proposed, based on the five families of solutions introduced in Phase 1: retaining systems, rock and block armoring, armored slope blankets, engineered soil reinforcement and drainage, and nature-based stabilization. Thus, a set of possible solutions was defined for the toe zone and another for the middle zone, taking into account the different hydraulic and geotechnical conditions in each zone.

6.1 MCDA criteria and evaluation framework

To determine the most suitable slope stabilization configuration, a Multi-Criteria Decision Analysis (MCDA) was applied. This approach was used to evaluate the proposed solutions for both zones separately to identify the most effective and context-appropriate methods. The selected methods for the toe and middle zone can then be integrated into one final, coherent slope design.

The MCDA systematically assesses the performance of all potential design alternatives based on a list of requirements derived from the analysis in Phase 1, which can be seen in Appendix E.1. These requirements were grouped into five main categories for evaluation: protection, ecosystem, constructability, costs and usability.

- The protection cluster assesses the technical effectiveness of each intervention to prevent slope failure. Criteria included the solution's ability to counter rapid drawdown effects, wave and wind erosion, current erosion, and to maintain stability under varying river levels or external loading. For the toe zone, only the latter two mechanisms were considered relevant.
- The ecosystem cluster assesses the ecological performance of each solution, including its potential to support flora and fauna, increase habitat and enhance biodiversity. These aspects are important for evaluating the ecological integration of the slope.
- The constructability cluster assesses the practical feasibility of the solution's implementation. This included the local availability of materials, the need for hydraulic fill, the required toe extension, and compatibility with drainage water outlets.
- The cost cluster assesses the financial implications of each alternative, weighing material and construction costs, expected maintenance efforts, and estimated lifespan. This evaluation provides insight into the financial feasibility of each option.
- The usability cluster assesses the human-centered aspects of the design alternatives, particularly pedestrian attractiveness and accessibility. These parameters were only included for the middle zone, as this section of the ramp connects directly to public spaces and paths.

After defining the criteria clusters, their relative importance was determined through a pairwise comparison which can be seen in Table 6.1. This method compared each cluster with all others (e.g., protection versus ecosystem), and a "+" was assigned to the cluster deemed most important to the project objectives. The number of positive outcomes per cluster determined the relative importance, which was then used to determine the criteria weights for the MCDA.

Table 6.1: Pairwise comparison of MCDA criteria clusters

	Protection	Ecosystem	Constructability	Cost	Usability	Score
Protection	x	+	+	+	+	4
Ecosystem	-	x	-	+	+	2
Constructability	-	+	x	+	+	3
Cost	-	-	-	x	+	1
Usability	-	-	-	-	x	0

6.2 MCDA Analysis

The MCDA, which can be found in Appendix F, provides a clear comparative overview of how each stabilization option performs across the evaluated criteria. The analysis was conducted separately for the middle zone and the toe zone.

6.2.1 Middle zone

In the middle zone, where water levels fluctuate, the concrete block mattress stands out as the most reliable and practical solution for slope stabilization, achieving the highest score. Made of interconnected concrete blocks, this system forms an erosion-resistant layer that remains stable under fluctuating water conditions. Its open structure allows water to flow through, reducing uplift pressure and preventing soil erosion underneath. When placed over a geotextile filter layer, the block mattress further protects the slope from erosion. Concrete is widely available and commonly used in local infrastructure, making the block mattress both cost-effective and easy to install. It can be installed quickly, up to several hundred square meters per day, and even underwater, which significantly reduces labor costs and construction time (Lim et al., 2012).

However, while the concrete block mattress performs excellently in terms of structural stability, cost-effectiveness, and ease of installation, it does not contribute well to the ecosystem. The rigid, non-vegetative surface provides less support to plant growth or ecological habitats compared to nature-based solutions. It lacks the ability to create microhabitats for flora and fauna, which is an important aspect of maintaining a healthy ecosystem along the riverbank.

In contrast, geocells and vegetated riprap performed well across most MCDA categories, particularly in the ecosystem cluster. Geocells, with their three-dimensional structure, provide effective soil stabilization and prevent erosion. However, their effectiveness diminishes in the lower sections of the slope, where strong currents and water flow lead to erosion, making it difficult for the geocells to remain stable and integrated with the slope. The challenges of establishing vegetation, especially in submerged areas, further limit the long-term effectiveness of geocells in supporting an ecosystem. Similarly, vegetated riprap performs well by dissipating wave energy and creating spaces for vegetation to stabilize the soil. While it overall performs well in the MCDA, its application is limited in Santa Fe due to the scarcity of suitable rocks, making it costly to import.

Other tested measures, such as gabions, concrete armor units, grouted riprap, hydraulic fill, drainage systems, vegetation blankets, brush mattresses, and afforestation, performed less effectively overall. Most provide insufficient resistance against erosion and fluctuating water levels, or are unsuited to the dynamic hydraulic conditions of the site.

In conclusion, while both geocells and vegetated riprap provide ecological benefits and perform well in protecting the slope, their practicality is limited due to material availability, the challenges posed by erosion, and difficulties in establishing stable vegetation, particularly in submerged areas. The concrete block mattress, while not contributing significantly to the ecosystem, remains the most reliable option in terms of structural stability, cost-effectiveness, and practicality for long-term slope stabilization in the middle zone.

6.2.2 Toe zone

In the underwater toe zone, where hydraulic forces and flow velocities are the strongest, the concrete armor units and concrete block mattresses achieved the highest performance scores, with armor units performing slightly better in terms of hydraulic protection. The interlocking geometry of armor units provides strong resistance against erosion by dissipating flow energy and preventing displacement under heavy currents. However, placing these massive concrete units below water requires specialized equipment to ensure proper positioning and interlock. This process makes installation both more complex and more expensive. Given the moderate hydraulic conditions observed at the Port of Santa Fe (average flow velocity of approximately 0.7 m/s) and considering the costs, armor units could be considered overdesigned for the site.

Considering cost, constructability, and long-term performance, extending the concrete block mattress, already identified as the most suitable solution for the middle zone, down to the toe zone presents the most logical and efficient approach. This continuous protective layer not only is cheaper to produce, it also minimizes the number of critical transition points between systems, reducing potential weak zones where erosion or structural failure could begin. The flexible structure adapts to minor deformations of the riverbed while maintaining stability. In addition, its open configuration allows limited water flow, relieving uplift pressure and preventing soil washout beneath.

Other tested measures, including grouted riprap, filled sandbags, gravity walls, and sheet piles, proved less effective overall. Most provide insufficient resistance to the strong hydraulic loads at the toe or lack the long-term durability required for permanent underwater exposure.

In summary, while concrete armor units deliver the highest hydraulic protection, the concrete block mattress offers the most feasible solution for the toe zone. Extending it from the middle zone downward ensures structural continuity, reduces critical pressure points, simplifies construction, and provides consistent, cost-effective protection under local hydraulic conditions.

6.2.3 Final Selection and Ecological Adaptation

Based on the analysis presented in Section 6.2.2, concrete block mattresses were chosen as the most suitable solution for the slope. For this decision, a trade-off was made: prioritizing usability, low maintenance, cost efficiency, and technical reliability over more eco-friendly or nature-based design approaches.

To enhance the ecological value within this technically-oriented choice, further research was conducted into potential improvements of the selected system. This led to the proposal to use articulated concrete block (ACB) mattresses. These systems can incorporate openings that enable vegetation growth while maintaining hydraulic stability, this can be seen in Figure 6.2 (Masonry & Hardscapes, 2014).



Figure 6.2: Articulated concrete block mattress (ACB)

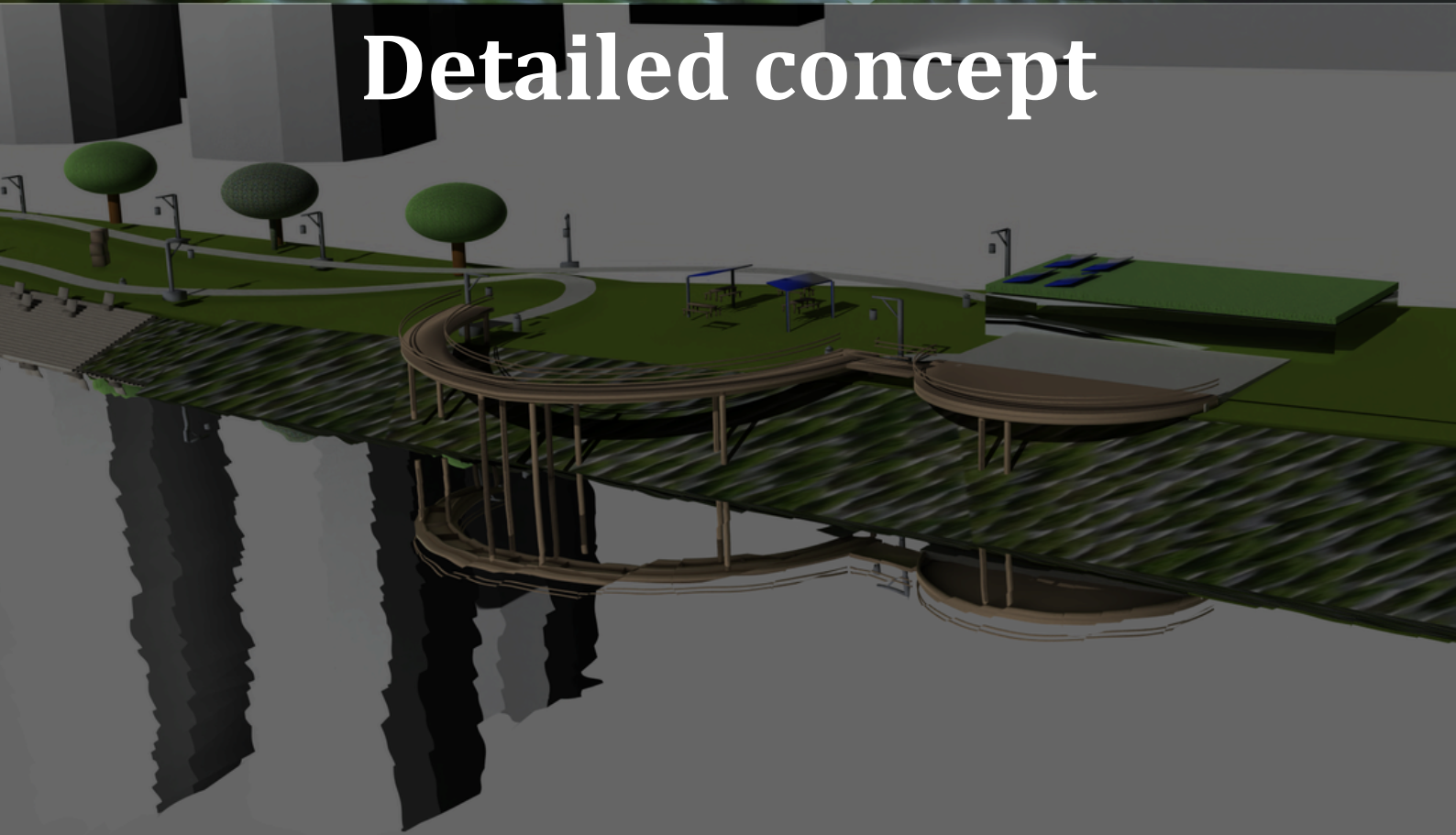
Integrating vegetation into the block mattress system provides both structural and ecological benefits. On the exposed parts of the slope, plant roots help bind the upper soil layers, increasing strength and stability. They also improve water infiltration and reduce surface runoff, which helps protection during heavy rain or high water levels. Underwater, the holes in the block mattress create small spaces where fine sand and mud can settle, and where small aquatic organisms can live. These spaces also slow down the water close to the riverbed, which helps prevent the soil from being washed away. In addition to these functional benefits, adding greenery improves the visual quality of the riverbank and helps the port present a more natural image (Masonry & Hardscapes, 2014).

This approach has a balance between technical reliability and ecological awareness. While the final design prioritizes stability and cost efficiency, the integration of articulated block mattresses introduces opportunities to restore ecological function within a robust, low-maintenance structure. This will be further developed in Phase 3.



PHASE 3

Detailed concept



PHASE 3: DETAILED CONCEPT

Introduction of Phase 3

Phase 3 builds the urban design and stabilization method chosen in Phase 2 and moves from conceptual development to detailed design. This phase focuses on translating the selected strategies into an integrated and feasible project proposal for the Port of Santa Fe.

The main objectives of this phase are to refine the technical slope stabilization design, elaborate the urban design for the Dyke 2 project site, and merge both components into a coherent and realistic final concept.

To achieve this, the phase is divided into four chapters:

- Chapter 7 first presents the technical slope stabilization method.
- Chapter 8 develops the urban design, detailing the functional layout of the project site.
- Chapter 9 integrates both components in a 3D model that visualizes the final concept, combining the technical slope stabilization solution and urban elements into one comprehensive design.
- Chapter 10 concludes the phase with a PESTEL analysis, evaluating the political, economic, social, technological, environmental, and legal factors influencing the project's implementation.

7. Technical design: slope stabilization solution

This chapter translates the selected protection concept from Phase 2, the Articulating Concrete Block (ACB) mattress system, into a detailed technical design. While Phase 2 focused on comparing and selecting alternatives, this phase will develop the chosen solution into a design suited to the conditions at the Port of Santa Fe.

The design process follows a bottom-up approach, starting with the definition of the slope geometry and hydraulic fill requirements. Establishing these parameters first provides the geometric and hydraulic framework for all following calculations, helping to determine the required strength, stability, and dimensions of the protective layers. Once these foundations are set, the chapter continues with the configuration of the protection system, including anchoring, drainage, and a cost estimation.

Chapter 11 includes a series of recommendations, summarizing key design considerations, practical implementation aspects, and opportunities for improving the ecological and technical performance of the system in future stages.

7.1 Slope dimensions

Based on the existing slope profiles and the defined boundary conditions for the slope design, the geometric dimensions of the slope are established. To accommodate the application of the ACB mattress system, the slope is configured with a triangular cross-section, where the base aligns with the riverbed and the height extends upward along the riverbank. The rough outlines of the slopes are presented in Figure 7.1.

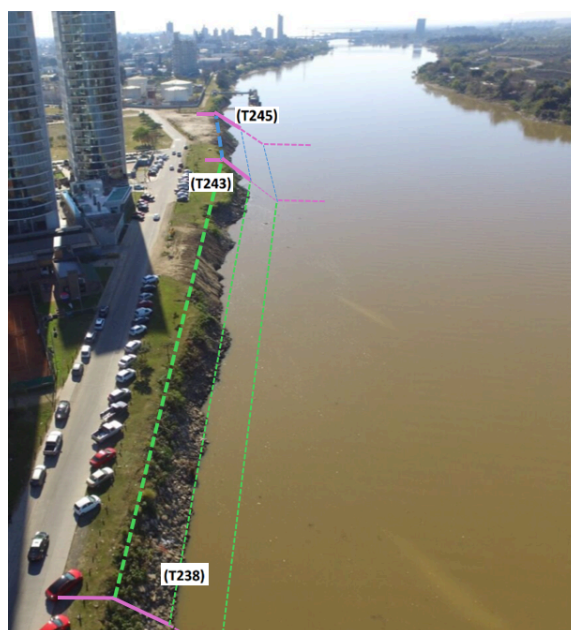


Figure 7.1: Outlines of slope design

7.1.1 Slope geometry and design criteria

Figure 7.2 illustrates the cross-sectional profile at T243, along with the required dimensions of the navigation channel. For determining the angle of the slope, T243 is used as a base case because this is in the middle of our section of the slope. Based on the calculated channel width (56.42 m) and channel depth (7.23 m) from Section 3.2.4., a reference slope line was drawn to ensure that the channel geometry remains within the established navigation boundary. From this geometric assessment, the maximum extension of the toe that satisfies the boundary conditions, corresponds to a slope gradient

of 1V:2.9H. This gradient prevents the slope from extending into the navigation channel while maintaining constructability and hydraulic safety.

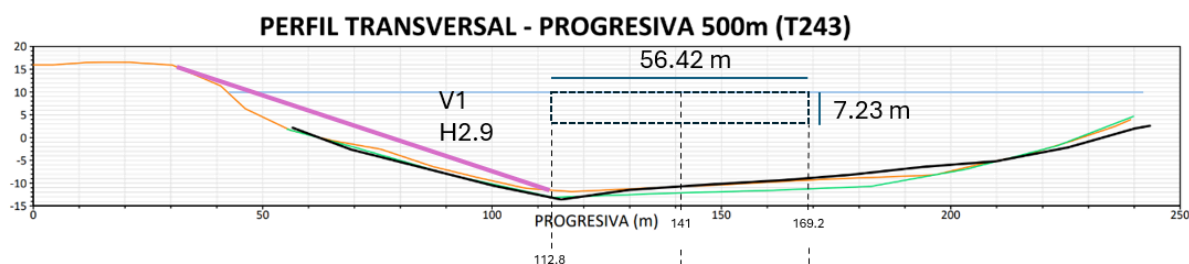
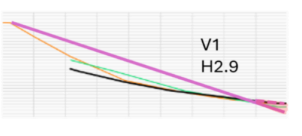
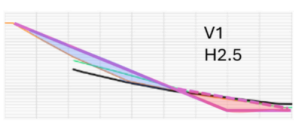
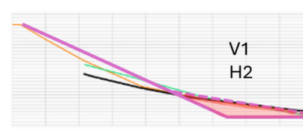
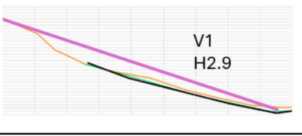
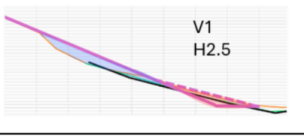
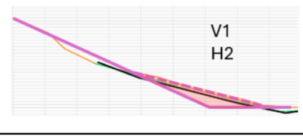
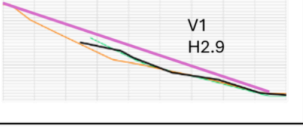
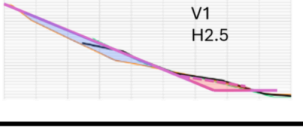
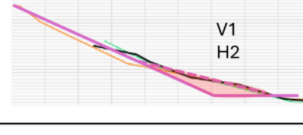


Figure 7.2: Required dimensions of the navigation channel

In addition to the navigation channel constraint, a second boundary condition for determining the slope angle is the extent of dredging required to construct the slope. As the slope becomes steeper, the toe of the bank advances further into the riverbed, requiring greater excavation at the bottom to achieve the designed geometry. This additional dredging not only increases construction cost and complexity, but may also disturb the existing riverbed morphology and sediment balance. Consequently, the slope angle cannot be made arbitrarily steep, as excessive dredging would extend below the natural riverbed level.

To further evaluate the influence of slope inclination, several configurations were analyzed, as summarized in Table 7.1. The corresponding factors of safety were calculated using the same methodology applied in Phase 1, ensuring consistency with the earlier stability assessment. Dredging intervention required can be seen in Table 7.1 in red for the different locations. The results show a clear relationship between slope steepness, dredging volume, and overall stability. As the slope becomes steeper, the toe extends deeper into the riverbed, increasing dredging requirements while reducing the SF.

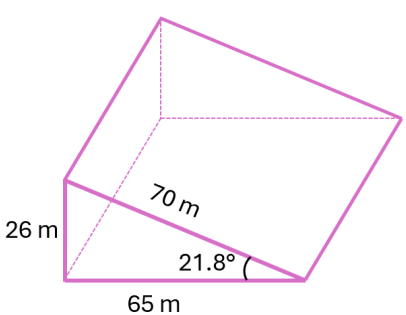
Table 7.1: Different configurations for the slope profile

Slope gradient	1V : 2.9H	1V : 2.5H	1V : 2H
FS	2.23	1.9	1.5
Slope profile: T238			
Slope profile: T243			
Slope profile: T245			

The intermediate configuration of 1V:2.5H offers the most balanced outcome, maintaining an adequate SF of 1.9 with limited dredging. This makes it the most efficient design, combining hydraulic compatibility with geotechnical stability without excessive excavation. The final design therefore adopts a 1V:2.5H gradient, corresponding to an inclination of 21.8°.

Table 7.2 summarizes the main dimensions of the slope.

Table 7.2 Main dimensions of the slope

Slope angle	21.8°	
Horizontal extension	65 m	
Vertical height	26 m	
Length of the sloped surface	70 m	
Length of shore Blue zone	150 m	
Length of shore Green zone	250 m	

7.1.2. Hydraulic fill

With the given slope geometry, the hydraulic fill can be determined. Hydraulic fill refers to the controlled placement of dredged or borrowed soil material, to reconstruct or level the unprotected slope prior to the installation of the concrete mattress. The fill material is pumped or discharged to the target area, allowing it to settle and form the desired slope geometry of 1V:2.5H. This section makes a rough estimation of the required volume of the fill.

The fill volume is determined by estimating the average required fill across all available cross sections, indicated in blue in Table 7.1. This average value is then multiplied by the total length of the slope to obtain the total fill volume in cubic meters. The results can be seen in Table 7.3.

Table 7.3: Average required fill volume

Green zone	T238 plane fill	38 m ²
	T243 plane fill	34 m ²
	Average plane fill	36 m ²
	Cubic fill	9200 m ³
Blue zone	T243 plane fill	34 m ²
	T245 plane fill	55 m ²
	Average plane fill	44.5 m ²
	Cubic fill needed	6675 m ³

To account for variations in the existing terrain, the deviation between the current ground alignment and the intended design profile was analyzed using satellite imagery and the scale reference obtained from Google Earth. The deviation was measured by calculating the perpendicular distance between the two profiles at multiple points along the slope using coordinates. The average deviation is implemented like a parallelogram which is visualized in Figures 7.3 and 7.4. The parallelogram has an area that is defined as:

$$A = L * \sigma_{mean} * \sin(\theta)$$

Where:

L = length of the slope.

σ = mean deviation.

θ = slope angle which is defined as 21.8°.

The deviation area is multiplied by the shore length of the zone to determine the extra cubic fill needed, the results can be found in Table 7.4.

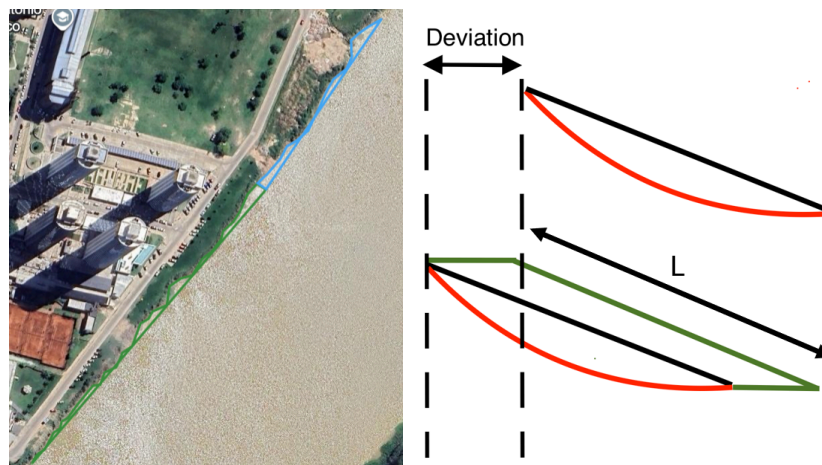


Figure 7.3 and 7.4: Deviation of the existing slope

Table 7.4: The extra cubic fill required

	Mean deviation (m)	Deviation area (m^2)	Cubic fill (m^3)
Green zone	2.14	55.64	13910
Blue zone	2.29	59.54	8931

Summing the cubic fill needed per zone and the correction margin for the varying slope results in a total fill of $38716 m^3$. To account for vertical settlement, 5% of the fill volume is added to the total volume (Departments of the Army and the Air Force, USA, 1983). Which results into:

$$V_{hydraulic\ fill} = 40651 m^3$$

7.2 Protection

The slope protection system consists of two complementary layers: an open-cell ACB mattress and a geotextile layer, which can be seen in Figure 7.5.

The top layer is the ACB mattress, composed of interlocking concrete blocks with open cells. These blocks can flex slightly to follow the contour of the slope, providing resistance against hydraulic forces while accommodating minor ground movements. The dimensions of the blocks are determined by calculating the required erosion SF of this solution. The openings will have suitable fillings which combine strong hydraulic protection with opportunities for natural vegetation.

The bottom layer is a non-woven geotextile. It functions as a filter between the soil and the upper structure. It allows water to pass through while preventing fine soil particles from being washed out, ensuring a stable foundation even under varying water levels and flow conditions.

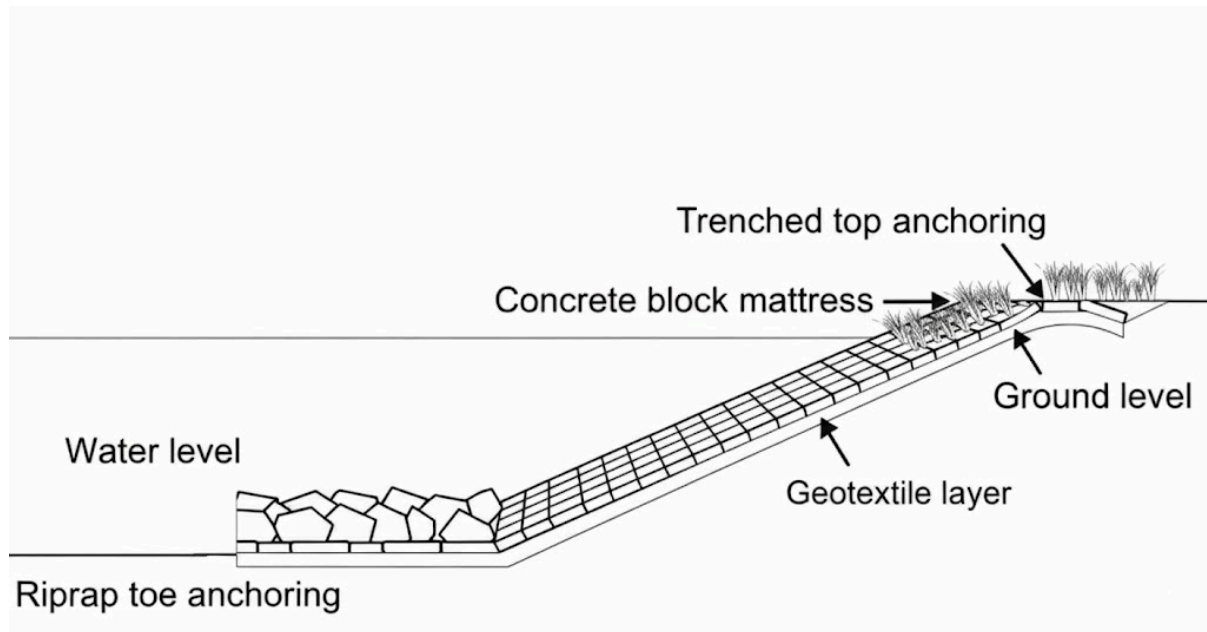


Figure 7.5: Conceptual design and its different layers

7.2.1 Erosion safety factor

While the Safety Factor presented in Section 3.2.2.2 evaluates the sliding stability of the slope based on its current geometry, soil strength, and pore-water conditions, it does not directly capture the progressive erosion that can occur at the slope toe. Toe erosion gradually reduces the resisting forces at the base and alters the geometry, lowering protection over time. To account for this process, a complementary erosion safety margin is needed which indicates the strongness of the protection of a concrete block mattress.

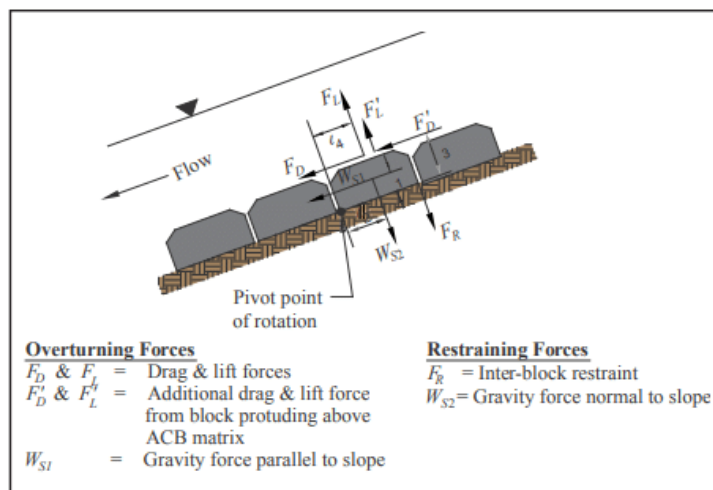


Figure 7.6: Force interactions on an ACB mattress

To prevent this erosion and protect the slope surface, the Hydraulic Stability Method was applied. This method, described in Design Manuals for ACB Revetment Systems (NCMA, 2020; United States Department of Agriculture, Natural Resources Conservation Service, 2007), evaluates the resistance of articulated concrete blocks against hydraulic forces. The force interactions on the ACB mattress can be seen in Figure 7.6.

The method is suitable for flow velocities below 2.43 m/s, which fits the conditions at the Port of Santa Fe, where the design flow velocity is approximately 0.7 m/s, and the peak velocity of 2.13 m/s was recorded during the 1998 flood (Informe Final Acta 2, 2021).

The Safety Factor in this method represents the ratio between the restraining moments, caused by block weight and friction, and the overturning moments, caused by drag and lift forces from water flow. It can be expressed as follows:

$$SF = \frac{\ell_2 W_s a_\theta}{\ell_1 W_s \sqrt{1 - a_\theta^2} \cos \beta + \ell_3 F_D \cos \delta + \ell_4 F_L + \ell_3 F'_D \cos \delta + \ell_4 F'_L}$$

Where:

- W_s : submerged weight of the block.
- F_D, F_L : drag and lift forces on the block.
- $\ell_{1,2,3,4}$: geometric moment arms.
- a_θ : geometry-related reduction factor.
- β, δ : slope and flow angles.

Given the relatively low design flow velocity at the site, the Hydraulic Stability Method was used to evaluate the stability of the concrete block system. Using the Excel design tool provided in the ACB Design Manual (NCMA, 2020), the SF was calculated.

Although typical projects accept an SF between 1.3 and 1.5, a higher value of 2.0 was adopted to reflect the more complex hydraulic conditions at the Port of Santa Fe, which is a bended channel with complex wave action, turbulence, and vessel-induced flow. This choice aligns with design recommendations for channel bends and other hydraulically demanding locations (NCMA, 2020).

The dimensions of ACBs typically range between 4 and 9 inches (100–230 mm) in thickness, with common footprints from 12 × 12 inches to 18 × 15 inches (NCMA, 2020). Thicker units or larger footprints are generally applied in high-velocity zones or steep slopes, while thinner, lighter blocks are used where flow energy is lower and constructability or ecological integration are priorities.

The selected ACB parameters for the slope-specific configuration are presented in Table 7.5.

Table 7.5: The selected ABC parameters

Parameters	Specification	Reasoning
Thickness	4.5 inches (114 mm)	Provides adequate submerged weight for expected velocities below 1.5 m/s while minimizing material use and transport costs.
Footprint	12 × 12 inches (305 × 305 mm)	Standard modular size ensures predictable interlocking behavior, uniform hydraulic resistance, and efficient on-site installation.
Open area	30%	Promotes vegetation growth within and above the cells, enhancing ecological value and reducing visual impact above the waterline.

To verify the performance of this configuration, shear stress parameters were adopted from the ACB Design Manual (NCMA, 2020), which provides results from full-scale hydraulic testing on comparable open-cell systems. However, these tests were carried out under more demanding conditions than those

expected in Santa Fe, namely on a 1V:2H slope and with higher flow velocities. The reported performance parameters from these tests are:

- Critical shear stress (τ_{c}): 11 lb/ft²
- Maximum tested velocity (V_{c}): 10 ft/s (3.0 m/s)

The resulting SF value is: 2.10

This value exceeds the target SF = 2.0 and confirms that the selected configuration provides a stable and robust design under both design and peak flow conditions.

7.2.2 Block geometry and cable connection

For slope protection, a rectangular, two-slot open-cell concrete block was selected, which can be seen in Figure 7.7. This design provides enough open space while maintaining its strength. The block dimensions are determined to be 114 mm thick with a 305 × 305 mm footprint for enough submerged weight to resist local flow velocities with an open area of about 30% for vegetation growth.

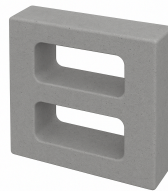


Figure 7.7: Design of single ACB

Compared with hexagonal or H-shaped alternatives, the rectangular block is much simpler to produce and install. It can be made using a single-part steel mold compatible with standard paving-block equipment, which shortens production time and ensures consistent dimensional accuracy. The two rectangular slots maintain structural strength while promoting drainage and plant establishment, reducing uplift pressure and turbulence during flood or drawdown conditions.

As shown in Figure 7.8, the blocks are cast in modular molds, with ropes pre-threaded through the cavities before concrete is poured. The ropes are arranged in a longitudinal and transverse grid, as shown in Figure 7.9, ensuring every block is connected in both directions.



Figure 7.8: Example of a modular mold

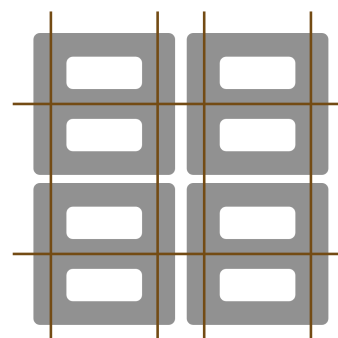


Figure 7.9: ACB connection using ropes

Once cured, these ropes become integrated within the block system, forming flexible, cable-connected mats that can be placed directly on the geotextile layer.

For the cable connections, UV-stabilized polyester (PET) rope was selected. This material provides the optimal balance between durability, strength, and cost for the site's freshwater and moderate flow conditions. Polyester ropes are highly resistant to moisture, UV radiation, and alkaline environments such as concrete, ensuring long-term performance without the risk of corrosion that affects galvanized or stainless-steel cables (NCMA, 2020).

With a diameter of 16 mm, the polyester ropes offer a minimum breaking load of approximately 50–70 kN, providing ample capacity to maintain mat integrity even under partial load transfer or localized damage. (BuyRope, n.d.)

Polyester ropes are also easy to handle and integrate during production. Their flexibility enables quick threading through the mold, while their light weight simplifies transport and field placement compared to metal cables. These practical advantages support local, low-cost fabrication and efficient installation.

7.2.3 Filling of the blocks

The ACB block cells are filled with different materials depending on their position along the waterline. (NCMA, 2020).

Above the waterline, the openings are filled with a sandy soil mix that drains well but still retains enough moisture and nutrients for plant growth. This allows vegetation to take root, improving the appearance of the slope and supporting limited ecological value. (U.S. Army Corps of Engineers, 2011)

Below the waterline, the cells are filled with rounded gravel. This material adds weight, prevents erosion, and allows water to pass freely through the structure without damaging the underlying layers.

7.2.4 Geotextile layer

A geotextile layer is placed beneath the concrete blocks to prevent erosion of the fine sandy soil. It acts as a filter and separator, allowing water to pass through while holding the soil in place. This prevents the loss of material under the blocks and ensures the long-term stability of the slope protection. When the open cells of the concrete blocks are filled with soil, vegetation can grow on top of the geotextile.

Its porous structure lets water and air reach the roots while keeping the soil in place, enabling plants to establish and contribute to the natural appearance and ecological value of the slope.

A non-woven geotextile is chosen because of its flexibility, high permeability, and durability. It is made from synthetic fibers, usually polypropylene, that are randomly arranged, needle-punched, and heat-bonded to form a dense but porous mat.

Non-woven geotextiles adapt easily to irregular surfaces and resist puncturing during installation. They also perform well under fluctuating hydraulic pressures, which is essential for the Santa Fe site, where water levels and ship-induced currents vary throughout the year.

Together, the ACB layer and the non-woven geotextile layer form a durable and low-maintenance protection system that prevents erosion, strengthens the land-water interface, and enhances the ecological value of the shoreline.

7.3 Anchoring of protection

This section presents the design considerations for the anchoring elements of the revetment system, including both the toe and crest anchoring. These components play a critical role in ensuring the overall stability and durability of the concrete block mattress. The toe anchoring prevents sliding and local erosion at the lower boundary of the slope, while the crest anchoring secures the upper termination of the revetment and prevents uplift or displacement of the blocks.

Figure 7.11 illustrates the general configuration of the solutions described in this chapter. It should be noted that this figure is provided solely for visualization purposes and does not represent the detailed design.

7.3.1. Toe anchoring

The block mattress will extend down to the riverbed elevation (≈ -10 IGN), where the slope transitions into a milder inclination, functioning as an extension of the cover layer along the bed. The profile can be seen in Figure 7.10. Field observations in the red-zone cross section confirm that erosion has progressed to this elevation, reinforcing the need for protection extending at least to the natural bed.

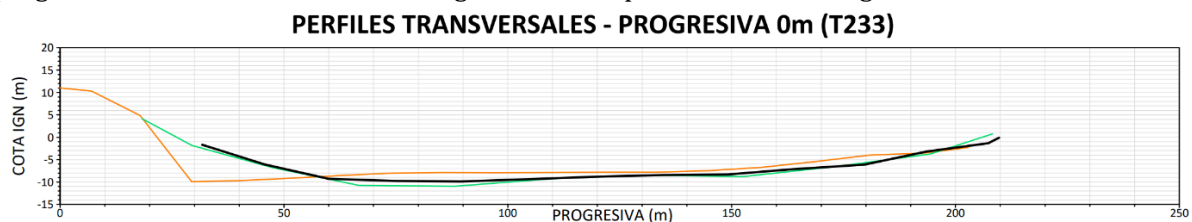


Figure 7.10: High erosion around -10 IGN at T233

The toe section will be anchored with a riprap layer, following the recommendations of (Pilarczyk, 1999). If the water depth is more than twice the wave height, much of the wave force will be dissipated on the structure face and a smaller extension width may be adequate, but it must be at least equal to the wave height (H). According to different examples of this paper, the width of the toe protection should be between $3H$ and $4.5H$. The height of the extension should be between $1H$ and $1.25H$. The wave height is 1.3 meters, which is explained in Phase 1. For maximum safety, the highest values are used. This gives a width of 5.85 meters and a height of 1.63 meters.

7.3.2 Crest anchoring

The upper termination of an ACB revetment should be embedded in a termination trench with a two-block embedment and backfilled flush with the surface.

The concrete blocks used in this project measure 305 × 305 × 115 mm. Based on guidelines, the anchoring trench is designed with a depth of 250–350 mm and a width of 450–550 mm. The geotextile filter will be extended beneath the mattress and folded into the trench to ensure continuity and prevent piping. The trench will be backfilled with compacted granular material such as sand or gravel, with an optional thin top layer of soil for surface integration (NCMA, 2020), (Contech Engineered Solutions, n.d.).

This configuration provides sufficient restraint to the concrete block mattress and ensures continuity of protection along the upper boundary of the slope.

7.4 Drainage pipes

The existing drainage outlets, which locations are listed in Phase 1, currently discharge stormwater directly onto the slope. To ensure that the new block mattress system remains stable and protected, a dedicated outlet structure is introduced around the drainage pipes that have a diameter of 0.4 meters (Technical Team, 2025).

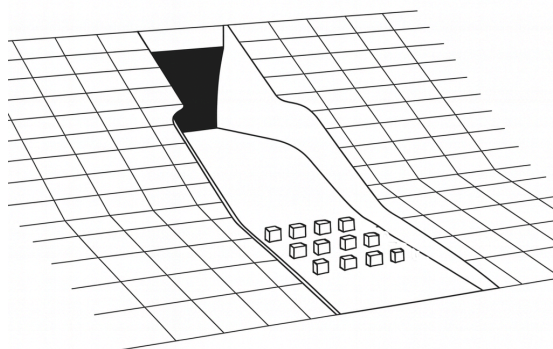


Figure 7.11: Conceptual design of drainage discharge

This design channels the outflow through a concrete chute with energy-dissipating blocks at the base, reducing flow velocity before it reaches the block mattresses. This design can be seen in Figure 7.11 By controlling the discharge energy and spreading the flow evenly, it prevents local erosion, undercutting, and uplift of the mattress elements. Similar solutions have been successfully applied along the Costanera in Santa Fe, where they have proven durable and efficient under varying hydraulic conditions.

7.5 Cost estimation

The cost estimation for the concept design is primarily derived from material costs. The materials considered can be seen in Table 7.6.

Table 7.6: Cost estimation of the slope

Part of slope	Material	Cost per unit (ARS \$)	Reference
Hydraulic fill	Sand (m^3)	8.931	(van 't Hoff & t Nooy van der Kolff, 2013)
Geotextile layer	Mat (m^2)	4.500	(Costos - Cifras On Line, n.d.)
Block mattress	Concrete (m^3)	157.000	(Costos - Cifras On Line, n.d.)
Block mattress	16 mm PP rope (m)	899	(Mercado Libre, n.d.)
Block mattress	Vegetation soil (m^3)	280.000	(Sustrato Para Huertas Terrafertil X 50 Dm3, n.d.)
Block mattress	Rounded gravel (m^3)	73.000	(Piedra Partida X M3, n.d.)
Toe anchor	Riprap fill (m^3)	58.660	(Granite Rock Rip Rap 36", n.d.)
Crest anchor	Backfill sand (m^3)	280.000	(Sustrato Para Huertas Terrafertil X 50 Dm3, n.d.)

The quantities of these materials are determined based on the design dimensions established in the preceding section. For the cost estimation, suppliers located near Santa Fe capable of providing the required materials were identified. The total cost for each material was calculated by multiplying the unit price, based on supplier volume pricing, by the corresponding quantity required.

The estimation of hydraulic fill quantities and material properties was guided by (van 't Hoff & t Nooy van der Kolff, 2013), developed in the Netherlands and intended to serve as standard guidelines for dredging and reclamation works. However, while these guidelines offer a useful reference, the actual price for hydraulic fill may differ in the Santa Fe context: on one hand, abundant local dredged sand may reduce material cost; on the other hand, logistical factors, such as transport over long distances, limited local processing, or supply constraints, could drive the price higher than the benchmark used.

Transportation costs were generally excluded from the estimation, with the exception of riprap material. Since riprap is not locally available near Santa Fe, a rough estimation of the transport costs were incorporated for this material only.

Material costs for the amount of concrete for the drainage discharge was estimated by a rough design that represents the demarcation of the pipes.

Based on the material quantities and unit prices considered, the total estimated material cost amounts to approximately 1.35 million USD. Appendix G provides a detailed breakdown of the estimated costs per material.

In addition to the material costs, overall construction costs were estimated by applying a total multiplier of 3 to account for labour, general expenses, company profit, and taxes. This factor was proposed by the project's technical team in Santa Fe, based on their experience with similar local works and typical cost structures in the region. It reflects that, in practice, total project costs tend to be approximately three times the material cost once labour and contractor margins are included.

According to the team, this rule of thumb is suitable for the conditions in Santa Fe and provides a sufficiently accurate basis for the current stage of the port concept design, where the estimate serves primarily as an indicative cost assessment (Technical Team, 2025).

Based on this approach, the total estimated cost of the project is approximately 4.05 million USD.

8. Urban design: The Santa Fe Riverside Park

Building on the analysis of the three initial concepts, the final proposal combines the strongest elements of each concept. Concept 2, *Urban Waterfront Park*, serves as the foundation and is enriched with selected aspects from Concepts 1 and 3 to create a comprehensive design. This section presents the result: *The Santa Fe Riverside Park*, a place “where the city meets the river”. It transforms the waterfront into a calm yet vibrant urban park, where residents and visitors can slow down, gather, and rediscover the value of living by the water.

The design elements of Santa Fe Riverside Park will be examined in detail. Collectively, these ideas present a cohesive visionary concept for the port, based on the project's four overarching pillars. As mentioned, the proposed concept serves as a pilot project within the vision that bridges the gap between the current design ideas and the port's long-term development strategy.

8.1 Main elements

The main site elements within this concept each have a detailed design that will be further elaborated in the sections below. Each element is illustrated through an imaginative visualization. Some proportions may differ from the technical details, as the visuals aim to present the spatial intent only. Therefore, the written descriptions and suggestions of the different elements guide the definitive (technical) results, which are later formalized in the final concept 3D model (Chapter 9). For an overview of all elements and how these are positioned within the urban concept, see Figure 8.1.

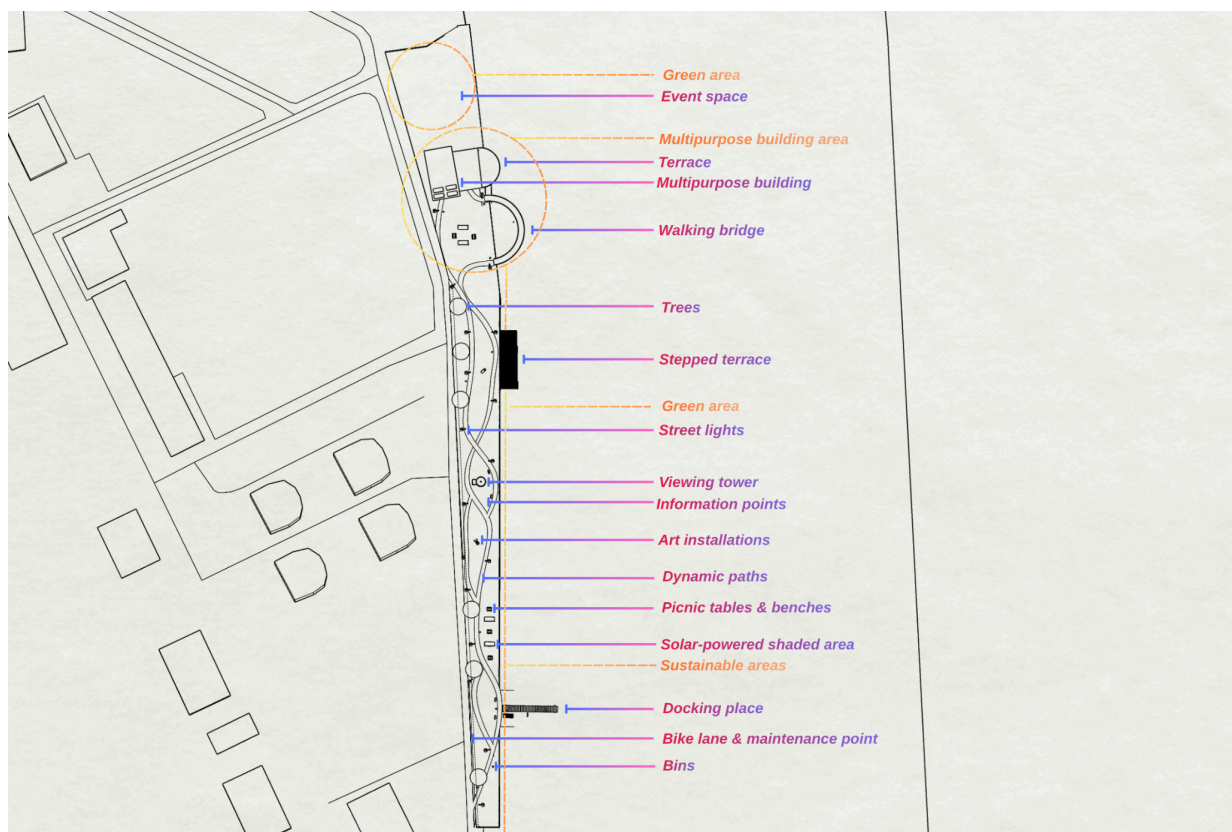


Figure 8.1: Overview of all the project site and all the elements

8.1.1 Docking place

The design of the docking area consists of two main components: the dock itself and a connection to the land by using a staircase. The primary design considerations were the steepness of the slope and the fluctuating water levels of the Paraná River. Hydrological records from the river have shown that water levels vary significantly. Therefore, the dock has been designed to adjust to these fluctuations, ensuring year-round accessibility.

The dock's surface remains approximately 0.5 meters above the water level, allowing users to easily embark and disembark from smaller boats. Additionally, non-slip surfaces and handrails ensure safety. The durability of the docking area has been addressed through the use of low maintenance and recyclable materials.

In the previous chapter, a slope of 1:2.5 was proposed based on site research. Using this slope, the ramp connecting to the dock is too steep for safe implementation, making a ramp connection unfeasible. Instead, stairs have been used to connect the dock to the land. To create a feasible and safe design, the slope adjacent to the dock will be locally adapted. A few meters of the existing embankment can be cut vertically, forming a 90-degree retaining edge. Along this vertical section, a floating dock is positioned. The floating dock, 30 meters in length and 3 meters wide, is adjacent to a staircase for visitor access. The staircase includes handrails on one side for safety. Visitors can always dock their boats on one side of the 30-meter dock, with the other side partially blocked by the stairs, depending on the water level.

To account for the fluctuating water levels, the dock is supported by concrete pontoons mounted beneath a rigid frame, allowing it to rise and fall with the river. The pontoons are hollow and filled with either air or closed-cell foam, providing buoyancy to counteract the dock's weight. To prevent horizontal movement, the dock is anchored by four vertical steel guide piles, two near the stairs and two at the far outer edge of the structure. These piles are driven into the riverbed and allow the dock to move vertically with the water level while remaining horizontally stable.

The staircase next to the dock was designed based on the height difference. The top of the steps is at 16 m IGN, while the bottom of the steps is at 12.2 meters, which is equal to the lowest water level (Chapter 3.2.2), 11.7 meters IGN plus the height of the floatable dock, 0.5 meters. The model with accurate dimensions and slope configuration can be seen in Figure 8.2. In Figure 8.3, architectural vision for the design of the docking place can be seen.

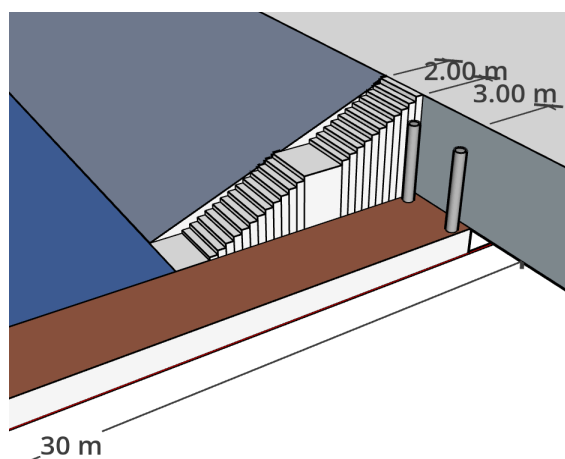


Figure 8.2: Technical model of the docking place



Figure 8.3: Design for the docking place

In terms of materials, the dock structure consists of a galvanized steel frame for strength and corrosion resistance, with concrete pontoons providing flotation and anti-slip timber planks forming the walking surface. Adequate ventilation beneath the deck ensures protection against timber rot. The guide piles are also made of steel, offering the required rigidity and resistance to continuous water exposure. The stairs are constructed from open galvanized steel grating, as the lower part is likely to be submerged during high-water periods. This is the preferred solution for longevity and maintenance. Finally, handrails will be installed on one side of the staircase, also in galvanized steel, and integrated lighting will ensure visibility and safety during evening use.

8.1.2 Stepped terrace

The design of the stepped terrace consists of multiple steps, providing seating areas for visitors. These steps are designed to be floodable without significantly deteriorating their quality. The steps are constructed from concrete, chosen for its durability and low maintenance requirements.

Additionally, another material has been applied to the steps to create seating which enhances both comfort and aesthetics, providing a more inviting space. The seating is primarily placed on the upper steps, as these are least likely to be submerged under water. The seats are made of UV-stabilized HDPE and are anchored to the concrete steps using stainless steel fasteners. These materials are resistant to water, algae and corrosion ensuring long-term durability and very low maintenance.

The stepped terrace spans 30 meters across the width of the slope, with a slope ratio of 1:2.5, consistent with the stabilized slope described in the previous chapter, the design can be seen in Figure 8.4. The steps begin at a height of 16 meters IGN, which corresponds to the top of the slope, reaching a bottom height of 11.7 meters IGN. This ensures that, even when water levels are low, the seating areas remain accessible and dry.

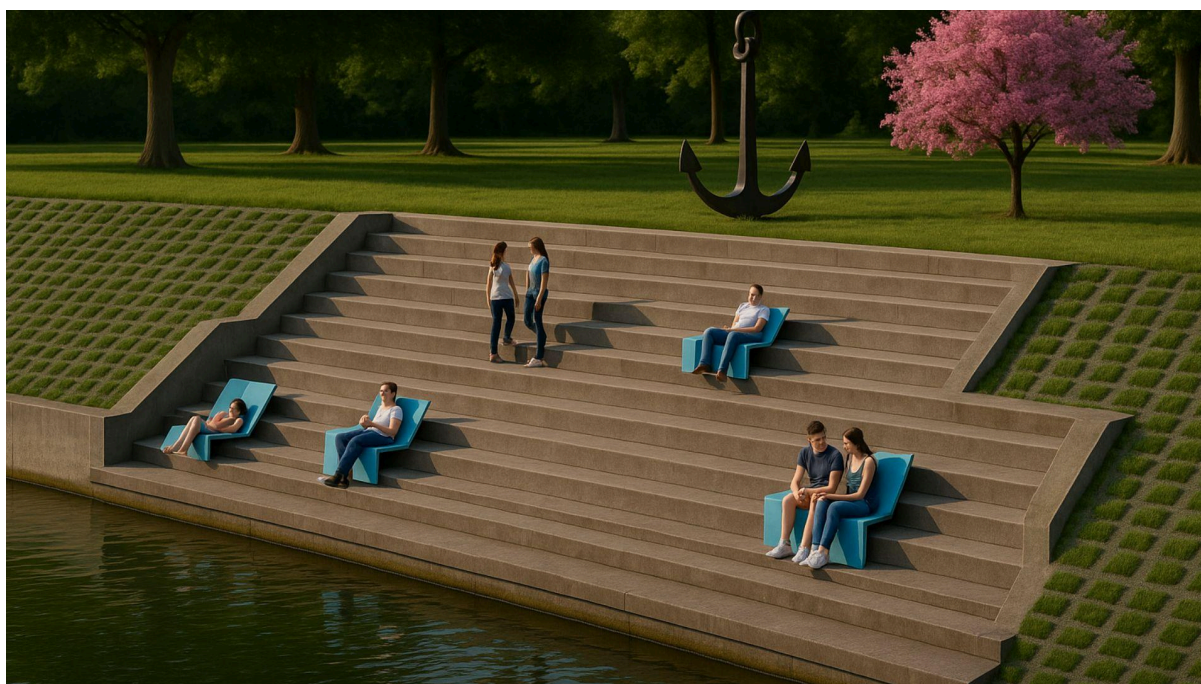


Figure 8.4: Design of the stepped terrace

8.1.3 Multipurpose building area

In Figure 8.5 a visualization of the multipurpose building area together with the terrace and walking bridge is shown. The following sections elaborate on each element in detail, referring back to this image where relevant for clarity and imagination.



Figure 8.5: Design of the multipurpose building area

8.1.3.1 Multipurpose building

The multipurpose building, which can be seen on the right part of Figure 8.5 functions as a social meeting point and has different functions throughout the day and throughout the year. The building is located 13 meters from the waterfront and it includes a large over-water terrace. The building is 25 meters in length and 10 meters in width, resulting in a total indoor area of 250 m², the height of the building is 3.5 meters. The building functions as a flexible space that can be used for various purposes: renting equipment for a relaxing or sporty day, purchasing snacks, as an eventspace, for small exhibitions, workshops, or as a café with indoor and outdoor seating. This café can be a place to drink coffee during the day and function as a bar or small restaurant during the evening. This way people can enjoy the water and the park sites every moment of the day. The building's final purpose will be determined in consultation with the (private) investors, but it will have a commercial use that is appealing to visitors and residents.

The structure of the building is built on steel piles anchored in the riverbank to ensure stability on the soft soil. The remaining material choices, and exterior and interior detailing will be determined during the development phase, in consultation with investors, once the final functions and operational requirements have been decided. One crucial element is that the roof is equipped with solar panels for energy generation, a rainwater reuse system, combined into a green roof that improves insulation. Lastly, a strongly recommended proposal is to create large window openings to provide natural light and direct visual connection to the water.

8.1.3.2 Terrace

This terrace, seen in the lower half of Figure 8.5, forms the outside part of the multipurpose building and extends over the water as a semi-public platform. It connects land and river, offering space for both private use and public passage. The design follows the same material and structural logic as the walking bridge (explained beneath), ensuring visual coherence across the site.

The terrace has a semicircular shape with a radius of 10 meters and a total width of 20 meters, resulting in a total surface area of approximately 314 m². This area provides more than enough space to fit at least 100 persons, since per person 1.5 m² is recommended for comfortable use (Roos Everink, 2025). The terrace is entirely flat, with no slope, and its elevation is set at 16.0 m IGN. There are dual handrails at 0.7 meters and 1 meters to ensure safety for both children and adults.

In terms of stability, multiple poles are used to anchor the structure, with the furthest one positioned 10 meters away from the coast, corresponding to the radius of the semicircle. The structural system consists of galvanized steel girder truss, chosen for its strength, durability and corrosion resistance.

8.1.3.3 Walking bridge

The walking bridge, as shown in the middle part of Figure 8.5, functions as a pathway that extends over the water. It must ensure structural stability, align visually with the port's aesthetic and terrace design, and meet requirements for safety, accessibility, and ease of construction and maintenance.

The total length of the bridge is around 50 meters, forming a semicircular walkway. The radius of this half-circle is 16 meters, this way the pedestrians are able to walk "over the water" and return in a smooth curve. There is also a 5 meters straight section to connect the bridge to the terrace. The length of the bridge over the width of the slope is 20 meters. The bridge has a total width of 3 meters, this way two people can walk beside each other and the bridge is accessible for wheelchairs.

The bridge is designed to reach as close to the water as possible while complying with Decreto 914/97 and the Código de Habitabilidad (Ord. 12.783). It therefore follows a maximum of a 5% gradient, descending from 16.0 m IGN and ascending symmetrically to create a smooth semicircular profile. Dual handrails at 0.7 meters and 1.0 meters accommodate all users, with 2 meters pole spacing ensuring structural stability and safety.

For stability and fixation, multiple poles are used, with the furthest one being 16 meters away from the coast, the radius of the circle. The 5% decline has been taken into consideration. The distance to the bottom at the furthest point is 6 meters.

In terms of materials, the bridge is constructed from galvanized steel using a girder truss system, chosen for its strength, low maintenance and durability. The deck has a non-slip surface to ensure safe use during wet conditions. All materials had to be ecologically friendly, low-cost, and locally available in Santa Fe, aligning with the project's sustainable design approach. The bridge visually and functionally connects to the terrace of the multipurpose building, becoming both a circulation route and an attractive feature that enhances the public experience along the waterfront.

8.1.4 Viewing tower

The viewing tower, as shown in Figure 8.6, is a cylindrical panoramic tower, inspired by the grain silos and storage tanks that characterize the Port of Santa Fe. This design complements the circular form of the walking bridge and terrace. The tower has multiple windows along the staircase and offers panoramic views over the river, Alto Verde and the port area. It is built using the same materials as the walking bridge and the terrace to maintain visual consistency across the site.



Figure 8.6: Design of the viewing tower

Because of the height of the tower, it requires a stable foundation to ensure safety. The tower consists of three levels, located at 12 m above the ground, 16 m and 22 m. The level at 16 m includes an open circular ring between 15 and 17 meters, allowing visitors to walk around the cylinder and look outward. At the highest level, the tower is open at the top and is bordered by closely spaced vertical balusters spaced approximately 0.25 meter apart with a height of 1.30 meters, allowing views of the river and the port while ensuring safety and enhancing the silo-like lookout character. On every level there are information signs about the river, Alto Verde and the Port. There is a viewing binocular in the middle of the third level that is placed on a platform.

The stairs are an internal spiral staircase connecting all levels. The staircase has a minimum clear width of 1.2 meters and the steps have a riser of 160 mm, resulting in approximately 25 steps between ground level and the second level and 38 steps between the second and the third level. For inclusivity, an accessible lookout balcony is provided at the first level (12 m above the ground), allowing elderly or people in wheelchairs the views as well. The tower has a diameter of 5 meters and a total height of 10 meters, starting at 12 meters and reaching 22 meters at the top level. Each level is flat, with handrails at 1.3 meters height and cable mesh infill below the railing to ensure safety. Structurally, the cylindrical form provides excellent wind resistance, while perforated cladding reduces the pressure on the surface. In terms of materials, the tower is made of wood, this makes the tower fit into the Santa Fe Riverside Park design. This does mean the viewing tower needs more maintenance, but this is a consideration that has been made.

8.1.5 Dynamics paths

Throughout the site, there are several dynamic paths for pedestrians, see Figure 8.7. To create a playful effect, the path features many curves. These paths connect the different elements on the site and highlight them by guiding the way to each specific element. The path runs across the entire site, covering over 600 meters in length and 2.5 meters in width. The paths are made of permeable pavement, allowing rainwater to infiltrate into the ground rather than run off, reducing the impact of stormwater.



Figure 8.7: Design of the dynamic path

8.1.6 Green areas

Throughout the entire area, grass is planted to create an inviting space while supporting the local ecosystem, flora, and fauna. Up north to the multipurpose building, there is a large green area, 35 by 45 meters, this can be seen in Figures 8.8 and 8.9. This space can be used for events such as music festivals, sport competitions, or food truck festivals. There is also a park on the other side of the multipurpose building, this park provides space for walking your dog, playing games, sports, or other activities.



Figure 8.8 and 8.9: Potential event space

8.1.7 Street lights

The goal was for the site to be used both day and night. To ensure the area remains attractive and safe during the evening and the night, lighting is essential. Street lights are placed approximately every 20 meters, along the walking path and near the larger elements. To reflect the port's heritage, the design of the street lights are inspired by cranes, which you can see in Figures 8.10 and 8.11.



Figure 8.10 and 8.11: Design of the street lights

8.1.7 Bins

To minimize the environmental impact, effective waste management is essential. Not only is the goal to reduce harm to the environment, but keeping the site clean also makes it a more attractive and livable place. The bins feature two separate compartments for waste segregation, promoting sustainable waste disposal and recycling practices. To ensure the bins fit well within the port's industrial character, their design was inspired by grain silos, as shown in Figure 8.12. The bins are placed next to approximately every fourth lantern.



Figure 8.12: Design of the bins

8.1.8 Picnic tables and benches

Incorporating picnic tables and benches into the site encourages people to stay longer and enjoy the space. Additionally, these features provide areas for relaxation, social interaction and enhance the overall visitor experience, the design can be seen in Figures 8.13 and 8.14.

The picnic tables are designed for people to gather, eat, or drink and the benches are strategically placed near the water, offering a great view, which strengthens the connection between the port and

the river. Both the picnic tables and benches will be made of recycled-plastic boards, called plastic wood, on galvanized steel frame. In the entire area, 5 benches and 9 picnic tables will be placed.



Figure 8.13 Design of the picnic tables



Figure 8.14: Design of the benches

8.1.9 Sustainable areas

In terms of sustainability, a multifunctional solar power-station is designed to provide shaded comfort during the hot summer months while simultaneously generating renewable energy. The integrated solar panels on the roof are used to heat water which can then be accessed by visitors to fill their maté cups, creating an interaction between sustainable technology and local cultural habits, this can be seen in Figure 8.15 and 8.16.



Figure 8.15 and 8.16: Design of the solar powered spots

To promote sustainable mobility within the port area, a dedicated bike lane is introduced between the existing car road and the adjacent green zone. This new lane ensures a safe and comfortable route for cyclists, encouraging visitors and residents to choose bicycles over motorized transport. In addition, a small bike maintenance point is placed in the park, also near a solar power-station, allowing users to inflate their tires or make minor repairs.

8.1.10 Trees

Another way to create shaded areas is through the planting of new trees, this also enhances the green character and ecological value of the site. According to research conducted by the Port of Santa Fe (Especies arboreas a incorporar, 2016), several native tree species were identified as suitable for this

area. Being indigenous to the region, these species are well adapted to the local environmental conditions and can therefore develop optimally. For the site area, a combination of two native species, *Tipuana tipu* and *Tabebuia impetiginosa*, have been chosen. The *Tipuana tipu*, which can be seen in Figure 8.17 is commonly known as Tipa. It is a fast growing tree with a broad and dense canopy, which is ideal for providing shade in pedestrian zones. Its high resilience to heat and urban conditions makes it suitable for open public spaces. The *Tabebuia impetiginosa*, which can be seen in Figure 8.18, is also known as the Pink Trumpet tree. It provides dense shade in summer. The pink flowers which appear in spring introduce a strong color contrast to the area.



Figure 8.17 *Tipuana tipu*



Figure 8.18: *Tabebuia impetiginosa*

8.1.11 Information points

Across the site, several information points are strategically placed to engage visitors and strengthen the connection between people, nature, and the history of the port. The design of the information point can be seen in Figure 8.19. Each point focuses on a different aspect of the area's identity, explaining elements about its immediate surroundings. On the walking bridge and near the stepped terrace, information panels explain the aquatic species in the river, encouraging visitors to appreciate the biodiversity of the Paraná's waterfront. In the viewing tower, information is provided about the other side of the Paraná River, offering insights into Alto Verde and the surrounding natural landscape. Lastly, along the dynamic path, there are also two information points which focus on the historical development of the port, as well as the bird species and terrestrial ecosystems found throughout the area.



Figure 8.19: Design of the information points

8.1.12 Art installations

Art plays an important role in strengthening the identity of the port and reconnecting visitors with its industrial past. Therefore, two art pieces, which can be seen in Figure 8.20 and 8.21, are placed on the site that represent the historical value of the Port of Santa Fe. The first one is an old anchor, transformed into a durable statue that recalls former shipping activities of the Port. The second installation consists of stacked shipping containers that reflects the Ports legacy of trade and logistics. Both artworks serve as visual landmarks, merging the port's robust material heritage with its renewed public function.



Figure 8.20 and 8.21: Design of art

9. 3D model of the final concept

In this chapter, a synthesis of the urban concept together with the design of the slope is shown. The slope was introduced in Chapter 7 as a technical intervention and will be presented here together with the urban design, discussed in Chapter 8.

Although the slope was introduced in a separate chapter, it has always been interconnected with the urban concept. For example, the MCDA (Chapter 6.1) also included urban criteria such as usability. On the other hand, the slope dimensions were used to develop and adjust the urban concept elements. Together, this indicates how the technical and urban designs informed each other, ensuring that the final spatial concept is cohesive and strong.

The spatial site layout and design of Santa Fe Riverside Park was developed in a Computer-Aided Design (CAD) software to transform the concept into a scaled, three-dimensional representation of this waterfront area. The 1:2.5 slope and its design specifications (ACB mattresses with incorporated soil) are included into the model too. The model covers a total surface area of 5,380 m², accurately representing the terrain, elevation changes, and materials.

As shown in Figure 9.1, all components are positioned according to their real-world locations and dimensions, as described in Section 8.1. To create a final and clear overview, it visually distinguishes between main purposes (black) and supporting elements (green), clarifying their spatial hierarchy and relationships across the site.

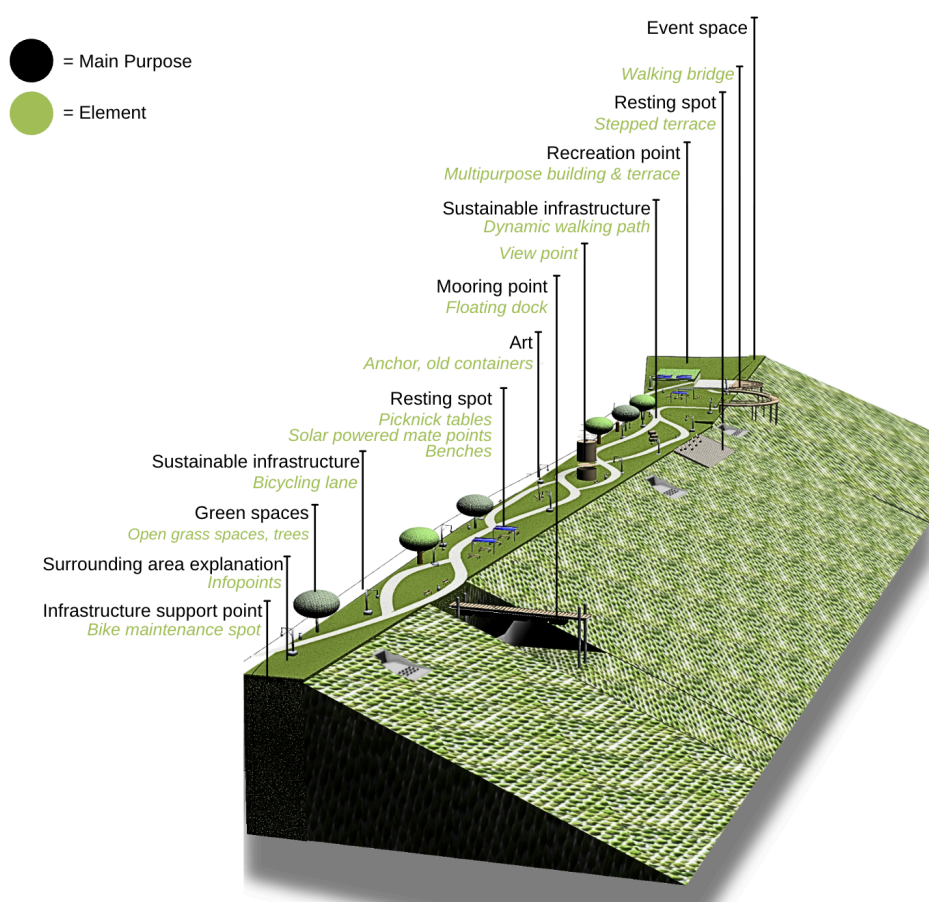


Figure 9.1: concept overview site layout with drainage pipes

In the Figures 9.2, 9.3, 9.4, 9.5 and 9.6, different views and render styles of the model are presented. Although the CAD-file itself cannot be embedded in this report, the link to the file is shown in Appendix H.

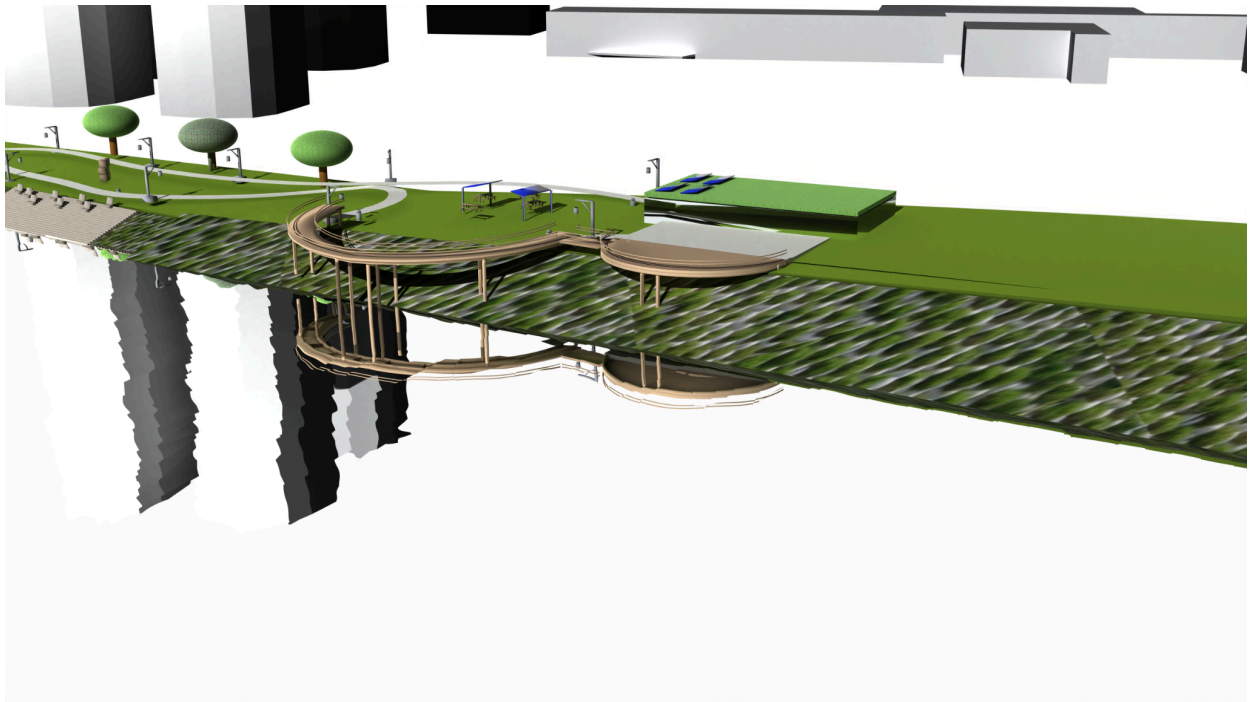


Figure 9.2: CAD model, view from the north of the site area

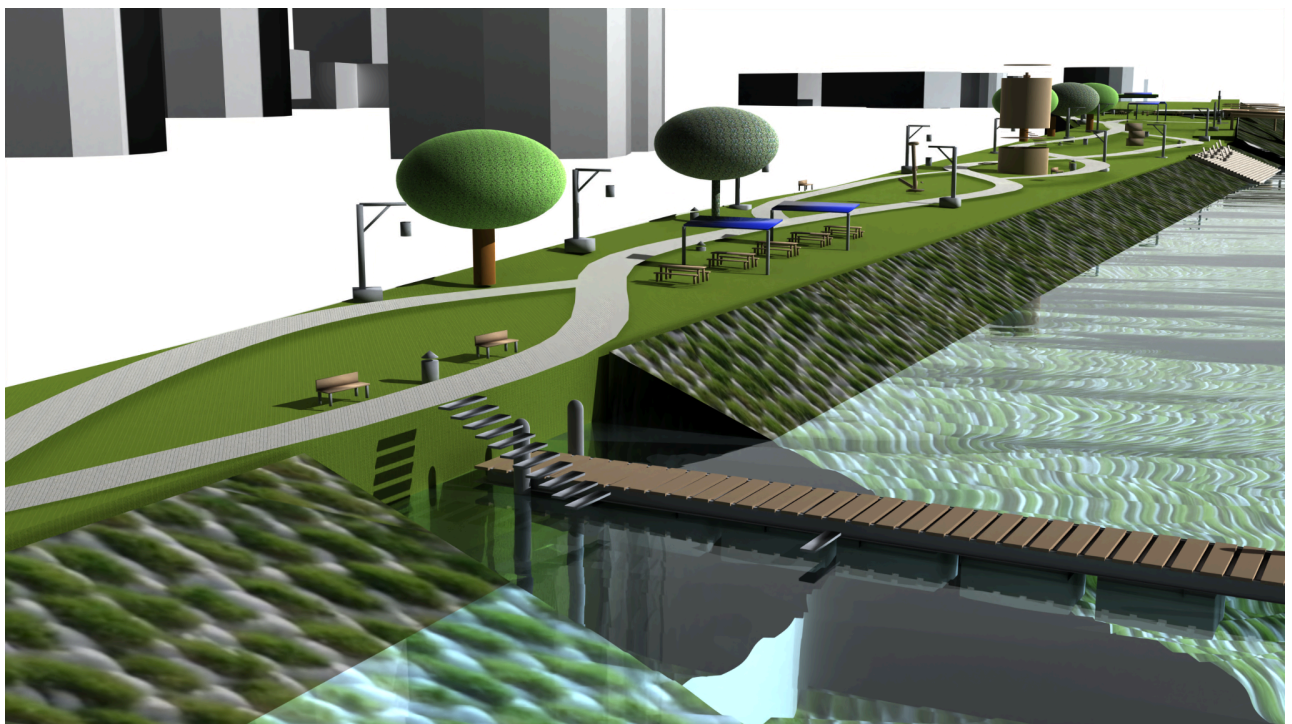


Figure 9.3: CAD model, view from the south of the site area

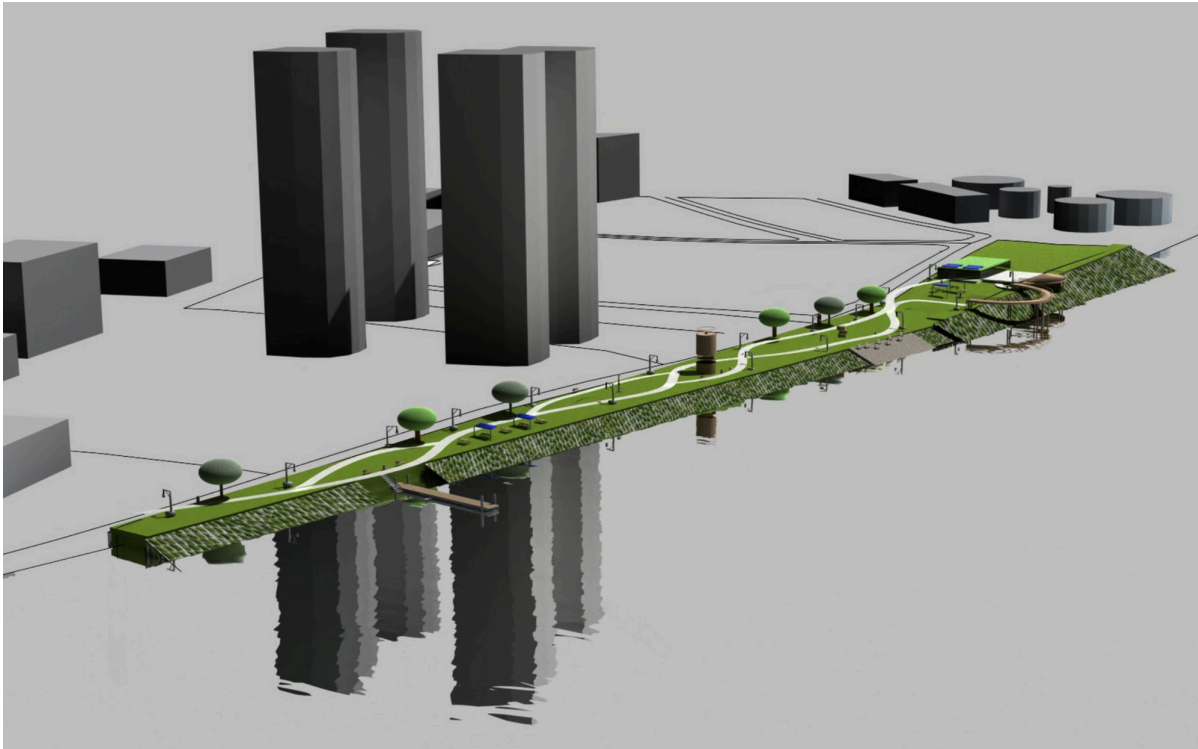


Figure 9.4: CAD model, zoomed out view

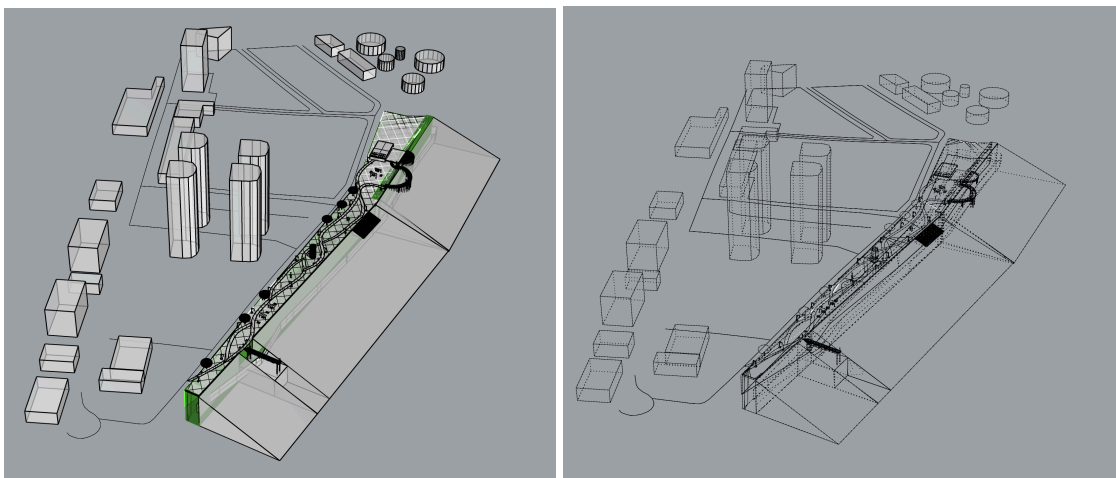


Figure 9.5 and 9.6: CAD model, technical overview from above

10. PESTEL analysis

This PESTEL analysis examines the key external factors shaping the redevelopment of the Port of Santa Fe. It assesses how the proposed vision and total concept, presented in Chapter 9, interact with political, economic, social, technological, environmental, and legal contexts, providing an integrated view of their potential impacts and opportunities.

Political

The proposed vision for the Port of Santa Fe could have a positive influence on the political environment by offering a clear and shared direction for future development. It provides a framework that can strengthen governance and improve coordination and cooperation among the different stakeholders involved in the port's management.

The vision gives the Port Authority a long-term and research-based plan to guide political and administrative decisions. This helps create greater stability and consistency, even when political leadership or priorities change. In this way, the vision can reduce uncertainty and make decision-making more transparent. Moreover, it could serve as a reference for the provincial and municipal governments in their own decision-making processes, for instance, when appointing representatives to the Board of Directors or defining policy priorities related to the port's development. By using the same guiding framework, these stakeholders can ensure stronger alignment and continuity across governance levels.

The pillars *Connectivity & Sustainable Mobility* and *Attractive & Livable Environment* further reinforce cooperation by linking port redevelopment to broader public policy goals such as sustainable transport, accessibility, and urban livability. These themes encourage collaboration between the Port Authority, the Municipality, and the provincial government on shared investments and infrastructure programs. They also enhance the political visibility of the port as part of the city's identity, making its development a joint priority among stakeholders rather than a sectoral issue limited to port operations.

The vision's emphasis on *Coexistence* and *Economic & Cultural Vitality* provides a narrative in which economic development and public benefit can advance together. By presenting redevelopment as a shared opportunity, the vision helps align private investment goals with public interests. This shared focus can ease political tensions and encourage stronger cooperation between stakeholders.

Finally, the vision was developed through field research and stakeholder interviews, which gives it credibility and legitimacy. This evidence-based and participatory process strengthens trust between the Port Authority, government, and local community. It also enhances transparency and accountability in decision-making. Because the vision reflects a wide range of interests, it has the potential to attract broader political and public support for future actions.

Economic

The proposed concept introduces both costs and opportunities for the Port of Santa Fe. Key interventions, such as slope stabilization, a walking bridge, a viewing tower, and a multipurpose building, require significant initial investment. The project therefore depends on a combination of public funding and private investment. Considering Argentina's economic volatility, including inflation and currency fluctuations, a phased implementation strategy is proposed. This approach distributes high-cost elements over time, reducing financial pressure while allowing early, visible progress that can attract additional investors. Furthermore, prioritizing locally available materials and the opportunity of prefabricated construction methods helps mitigate economic risks by limiting dependence on imports and providing greater cost stability.

As discussed in the economic context Section, the Port of Santa Fe operates within a challenging national and regional economy, characterized by currency instability and competition from larger ports such as Rosario. Within this setting, the project's focus on tourism, recreation, and cultural activities offers a realistic alternative path for economic diversification. By creating an attractive waterfront destination, the project aligns with emerging local trends where leisure and cultural investment play a growing role in urban and regional development.

At the same time, the concept creates new economic opportunities for both the port and the surrounding urban area. The multipurpose building and event space can generate steady income to support the long-term maintenance of public spaces and infrastructure. These facilities also encourage local entrepreneurship by providing venues for leisure, cultural, and commercial activities. By integrating tourism and recreation, the project can attract residents and visitors alike, stimulating local spending in nearby businesses such as restaurants, cafés, kiosks, shops, and transport operators.

The project also contributes to job creation at different stages. During construction, local workers and small contractors can be directly involved, strengthening local supply chains and technical capacity. In the operational phase, the new public spaces and facilities will require staff for maintenance, event coordination, and visitor services, creating sustained employment opportunities in the region.

Finally, the economic framework aligns with the vision's pillars of *Economic & Cultural Vitality* and *Attractive & Livable Environment*. Together, these principles link financial viability to social and cultural value, positioning the port as a driver of inclusive and sustainable growth rather than a purely commercial enterprise.

Social

From a social perspective, the concept aims to create an inclusive public space that reconnects people with the river and with one another. It promotes social interaction, accessibility, and comfort by offering spaces for rest, leisure, and community events. The promenade and green areas encourage visitors to spend more time in the port, transforming it from an industrial zone into a shared public environment that fosters everyday encounters and social cohesion. The design of the slope also contributes to these goals by creating safe, accessible, and comfortable connections between the city and the river. Its terraces and resting spots invite people to gather, rest, and enjoy the view, reinforcing the sense of community along the promenade.

Safety and accessibility are central elements of the design. Features such as street lighting, wheelchair-friendly paths, and clear wayfinding ensure that the area can be safely used by people of all ages and abilities. The design complies with national accessibility standards, ensuring that ramps, handrails, and pathways are inclusive and comfortable for everyone.

The concept also builds upon the port's rich cultural and historical identity, as discussed in the cultural analysis Section. By reusing materials such as cranes and containers and referencing the silos and river landscape, the design celebrates Santa Fe's industrial heritage and acknowledges its layered cultural history shaped by immigration and local traditions. This connection between past and present helps residents recognize their collective identity while presenting it to visitors in an engaging and educational way.

Elements such as information points, the viewing tower, and small platforms near the water encourage people to explore and learn about the river environment. This educational aspect enhances environmental and cultural awareness among visitors. Additionally, the multipurpose building and surrounding spaces provide flexible areas for work, small businesses, and informal gatherings, supporting local collaboration and creativity.

Technological

The project integrates a range of practical and innovative technologies that support both construction efficiency and long-term sustainability. Within the slope design, a new adaptation of the traditional concrete block mattress was developed, combining rope-connection technology with openings that allow vegetation to grow between the blocks. This approach strengthens the slope while promoting ecological integration, offering an innovative and cost-effective alternative that the port's own technical team can construct and maintain. The simplicity and adaptability of this system enhance the port's self-sufficiency and reduce the need for specialized external contractors.

In the promenade area, technological innovation focuses on renewable energy and sustainable infrastructure. The multipurpose building includes a solar roof for energy generation, and several solar-powered water and energy points are distributed along the path to provide sustainable amenities for visitors. Together, these features contribute to the project's low operational energy footprint and demonstrate the potential of small-scale renewable solutions in urban waterfront contexts.

Prefabricated construction methods are also applied to ensure faster assembly, cost efficiency, and minimal disruption to port operations. Combined with local material use, this approach reflects a technically feasible and sustainable construction strategy that can adapt to Argentina's economic conditions. Additionally, small-scale interventions such as the bicycle maintenance point promote everyday technological functionality and support the vision's *Connectivity & Sustainable Mobility* pillar.

Environmental

From an environmental perspective, the concept aims to create a sustainable and resilient waterfront. The design integrates environmentally responsible strategies in both the slope and promenade areas to balance ecological performance with human use.

The slope design plays a key environmental role by stabilizing the riverbank and reducing erosion. Its structure allows vegetation growth, improving soil retention and supporting habitat creation along the river edge. This approach enhances biodiversity, contributes to water filtration, and helps maintain the ecological integrity of the riverfront. By enabling parts of the slope to be constructed by the port itself, the design also reduces the carbon footprint associated with material transport and external machinery use.

In the promenade, sustainability is addressed through material selection and energy efficiency. Durable, low-maintenance materials such as galvanized steel and recycled plastic boards ("plastic wood") extend the life cycle of public infrastructure and reduce replacement needs. Renewable energy is promoted through solar-powered shade points and solar panels installed on the multipurpose building. The green roof on this building improves insulation, reduces heat gain, and retains rainwater, while permeable paths decrease runoff and support natural groundwater recharge.

Circular design principles are evident in the reuse of historical port elements in lighting and public art, linking the site's industrial identity to sustainable reuse. Waste separation bins encourage recycling, and the use of native tree species improves the site's microclimate, provides shade, and supports local biodiversity.

Together, these interventions reflect the vision's *Coexistence* pillar, promoting harmony between human activity and the natural environment. The project demonstrates how infrastructure and ecology can be integrated to create a resilient, low-impact, and educational public waterfront for Santa Fe.

Legal

From a legal perspective, the project must navigate a regulatory environment that defines construction, environmental, and operational responsibilities within the Port of Santa Fe. The design has been developed with full consideration of these frameworks to ensure compliance and facilitate a smooth approval process.

The project anticipates the necessary authorizations from the Prefectura Naval Argentina and the Port Authority, particularly for elements located near or over the water, such as the walking bridge, docking areas, and slope protection works. The dimensions and extent of the slope will be designed in accordance with navigational safety regulations to secure Prefectura approval.

In alignment with the Port Authority's technical and environmental requirements, the design incorporates sustainable materials, green infrastructure, and renewable energy systems to meet expected standards for environmental management and circulation. The inclusion of permeable paths, native vegetation, and waste separation systems directly supports the preparation of a *Plan de Gestión Ambiental* and demonstrates proactive adherence to port-wide sustainability obligations.

To meet mobility and circulation regulations, pedestrian and vehicle routes are clearly defined, accessible, and connected to existing public spaces without restricting access. The promenade and green areas have been designed to integrate seamlessly with surrounding infrastructure, fulfilling the requirement that new developments adapt to and enhance shared public areas.

By addressing these legal frameworks during the design phase, the project minimizes approval risks and ensures that implementation proceeds transparently and responsibly. This anticipatory approach supports effective coordination between the Port Authority, Prefectura, and municipal agencies, reinforcing the vision's broader goals of coexistence, accountability, and sustainable urban integration.

11. Recommendations and implementation

This chapter outlines the main steps needed to move the Port of Santa Fe project from concept to realization. Section 11.1 begins with the technical foundation, since the stability of the river slope determines whether the urban design can be safely developed. The chapter therefore identifies next steps that include exploring alternative, more sustainable construction methods, as well as refining site data and validating structural performance to confirm the design's technical feasibility.

Section 11.2 continues with recommendations concerning the urban design of the *Santa Fe Riverside Park*. These recommendations focus on ensuring that the site develops into an attractive, functional, and inviting public space for visitors, both during implementation and in long-term use.

Finally, the chapter looks ahead to the port's wider transformation. A 15-year roadmap outlines how the principles tested in the project site can be expanded across the entire port area, balancing economic, ecological, and cultural ambitions. Together, these recommendations form a bridge between technical feasibility and strategic vision.

11.1 Future research/next steps slope

Feasibility of eco-friendly concrete

To further enhance the ecological performance of the slope protection design and integrate more nature-based principles, it is recommended to investigate the feasibility of eco-friendly concrete solutions for the concrete block mattress system proposed at the Port of Santa Fe. Eco-engineered or porous concrete technologies are designed to increase biodiversity by incorporating ecological functionality into conventional hydraulic infrastructure. By introducing surface irregularities, controlled porosity, and mix compositions, these concretes can promote the growth of flora and fauna while maintaining structural integrity and hydraulic stability, an example of this can be seen in Figure 11.1.



Figure 11.1: Eco-friendly concrete

As part of this study, contact has been established with ECoConcrete (*ECoConcrete - We Bring Concrete To Life*, n.d.), an international provider of eco-engineered concrete technologies. Their feedback confirmed the general suitability of eco-friendly concrete systems for freshwater and slope-stabilization applications similar to the Santa Fe site. Building upon this insight, it is recommended that the port also explore locally produced alternatives, such as porous or bio-receptive concrete developed with regional materials and expertise. This approach could reduce costs, support local industry, and allow for material customization suited to local environmental conditions.

Further research should test these eco-friendly concrete alternatives for strength, durability, and erosion resistance under local conditions. Small-scale or lab tests are advised to compare mix designs and porosity to assess if locally produced porous concrete can meet structural demands.

Practical considerations for implementation

To ensure the feasibility and long-term success of the proposed slope protection system, it is recommended to further investigate several practical aspects related to material production, construction logistics, and maintenance. These topics are mostly relevant in the local context of Santa Fe, where material availability and on-site production capacity may strongly influence the project's viability.

A first point of investigation concerns the production of molds for the concrete block mattress system. As discussed earlier, the mold geometry is relatively simple and could potentially be produced locally. Further research is recommended to determine how the Port of Santa Fe can manufacture the molds and cast the blocks in-house, or whether collaboration with regional precast concrete companies would be more efficient.

A second issue relates to the sourcing of riprap required for toe protection. Riprap availability in the Santa Fe region is known to be limited, which could lead to high transportation costs or delays. It is therefore recommended to carry out a material sourcing study to identify feasible locations, transport routes, or potential substitute materials such as recycled concrete rubble or engineered rock alternatives. Such an assessment would ensure reliable and sustainable material supply during construction.

Finally, although preliminary analysis within this study indicates that the maintenance demand for the concrete block mattress system is relatively low, it is recommended to validate this expectation through a more detailed maintenance study. This should include estimation of inspection frequency, repair needs, and associated costs over the system's design life. Confirming the minimal maintenance requirement would provide stronger justification for implementation, especially given the regional preference for low-maintenance infrastructure solutions in Santa Fe.

Area considerations

As previously described in this report, the Red zone identified during the initial site mapping represents the most vulnerable and unstable section of the project area suffering from a lot of toe erosion, characterized by a steeper slope and lower ground elevation. Given these conditions, this area should be investigated in more detail to determine whether the proposed concrete block mattress system provides sufficient protection or whether a more robust solution is required. Ensuring adequate stability in this zone is essential for the overall effectiveness and durability of the slope protection design.

Furthermore, the potential hydrodynamic effects on the opposite riverbank at Alto Verde should be considered. Implementation of the proposed protection may alter local flow patterns and sediment transport, potentially increasing erosion risks at Alto Verde. Considering the scale of the navigation channel and the proposed intervention, it is recommended to assess how a complementary protection system could be developed for the Alto Verde side.

Site characterization and modeling

To strengthen the reliability of the slope protection design and ensure that the proposed solution performs effectively under real site conditions, further investigation through detailed site analysis and modeling is recommended. The existing data provide a general understanding of the slope geometry and soil conditions; however, more precise measurements and analyses are required to optimize the

design and validate its performance.

First, it is recommended to conduct 3D measurements of the current slope using drone-based photogrammetry or LiDAR scanning. This would allow for a more accurate digital terrain model, capturing small-scale variations in slope geometry and surface roughness that are not reflected in the current dataset. Such detailed mapping would improve the precision of the design layout and hydraulic modeling inputs.

Second, hydraulic modeling should be carried out to simulate the site's behavior under different flow conditions. By integrating the 3D geometry with flow and sediment dynamics, it becomes possible to assess the real hydraulic effects of the proposed protection measures on both the protected slope and adjacent areas.

Third, a comprehensive soil analysis is recommended along and close to the slope to obtain more reliable geotechnical parameters. Current data are limited and spatially coarse; additional sampling and laboratory testing would improve understanding of soil layers and its properties. This information is crucial for verifying slope stability and ensuring adequate design safety factors.

Finally, shear stress and hydraulic stability testing should be performed to determine the maximum shear stress and flow velocity acting on the slope. These parameters are essential for defining the optimal block dimensions and stability thresholds of the concrete block mattress.

Together, these investigations would provide the quantitative foundation necessary to validate and optimize the proposed protection system, reduce uncertainties in design assumptions, and ensure the long-term stability and resilience of the implemented solution.

11.2 Urban design

For the urban design of *The Santa Fe Riverside Park*, presented in Chapter 8, several recommendations can be made to support its implementation and long-term success.

As mentioned in Chapter 8, next to the multipurpose building there is an open green space that can be used for events by the future investor. An important recommendation for the Port Authority is to establish clear regulations, in coordination with the investor, regarding how this area can be used. This should include agreements on how often events can take place each year, what hours they may start and end, and who is responsible for cleaning up the area afterwards.

Concerning the multipurpose building, it is important to ensure that the building remains attractive and functional both during the day and at night, and throughout the entire year. When preparing the tender documents, it is recommended to clearly illustrate the different possible uses and atmospheres of the site. This will make the project more appealing for investors and help ensure a lively, inviting environment that attracts visitors year-round.

Another recommendation is to develop a marketing and communication strategy to promote the redevelopment of the site and attract new visitors, making it an active and recognizable destination in the city.

11.3 Long-term roadmap entire port

Using the final concept of the project site, the next question that arises is how the design of this project site fits into the broader picture of the whole port. To address this question, a long-term roadmap is developed, it outlines the potential implementations for the next 15 years divided into four different horizons. The roadmap is categorized according to the four pillars introduced earlier. The timeline is indicative rather than exact, showing that some implementations can be carried out immediately,

while others are planned for the longer term. The timelines depend on available funding, coordination between the Port Authority and the Municipality, and environmental conditions. The roadmap assumes that Raízen’s contract will end in 2030. The roadmap is shown in Figure 11.2, on the horizontal axis the four different horizons can be seen. While on the vertical axis, the four guiding pillars are shown. The roadmap can also be seen in Appendix I. The components of this roadmap will be discussed in more detail below.

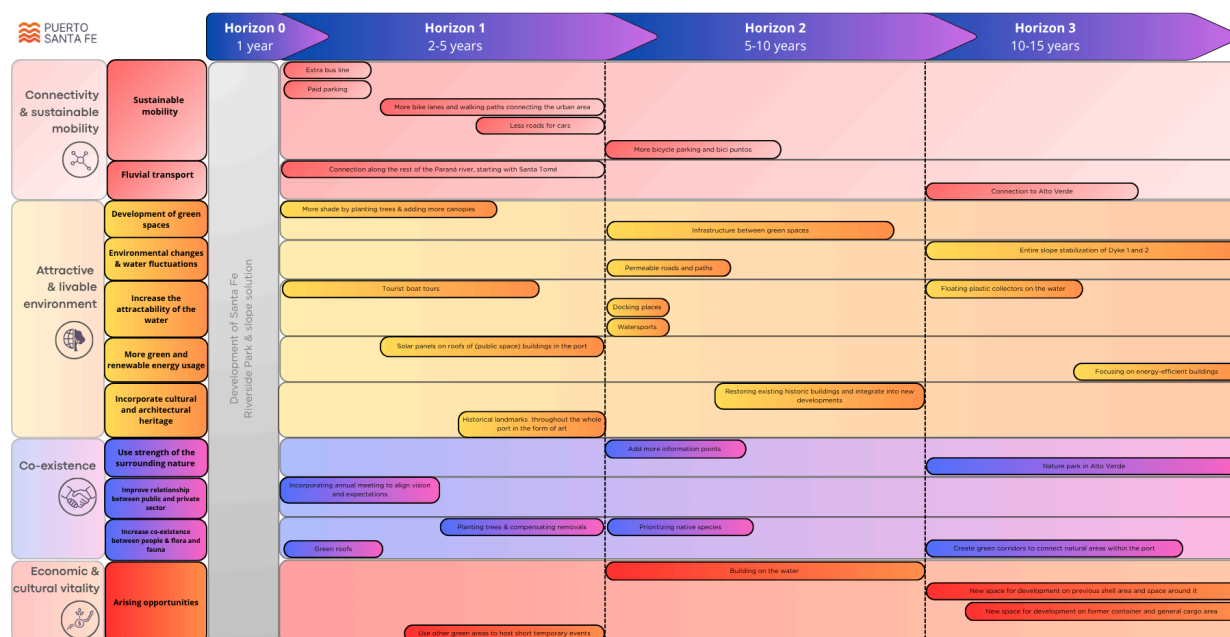


Figure 11.2: Long-term roadmap

Connectivity & sustainable mobility

The first pillar, *Connectivity & Sustainable Mobility*, focuses on improving sustainable mobility and accessibility on the land and on water for residents, visitors, and workers. Relatively low-cost interventions such as an extra bus line and paid car parking can be implemented directly. This would help with the current issue of people using the port area as a parking place for the city. After this construction of protected bike lanes and uninterrupted walking paths would be a good way to safely connect the Port of Santa Fe with the city center. A next step, when the infrastructure for bikes is further developed, would be to include more “bicipuntos” (Chapter 2.2.1) and new bicycle parking spots. It is advised to implement this during horizon 2, as can be seen in Figure 11.3.

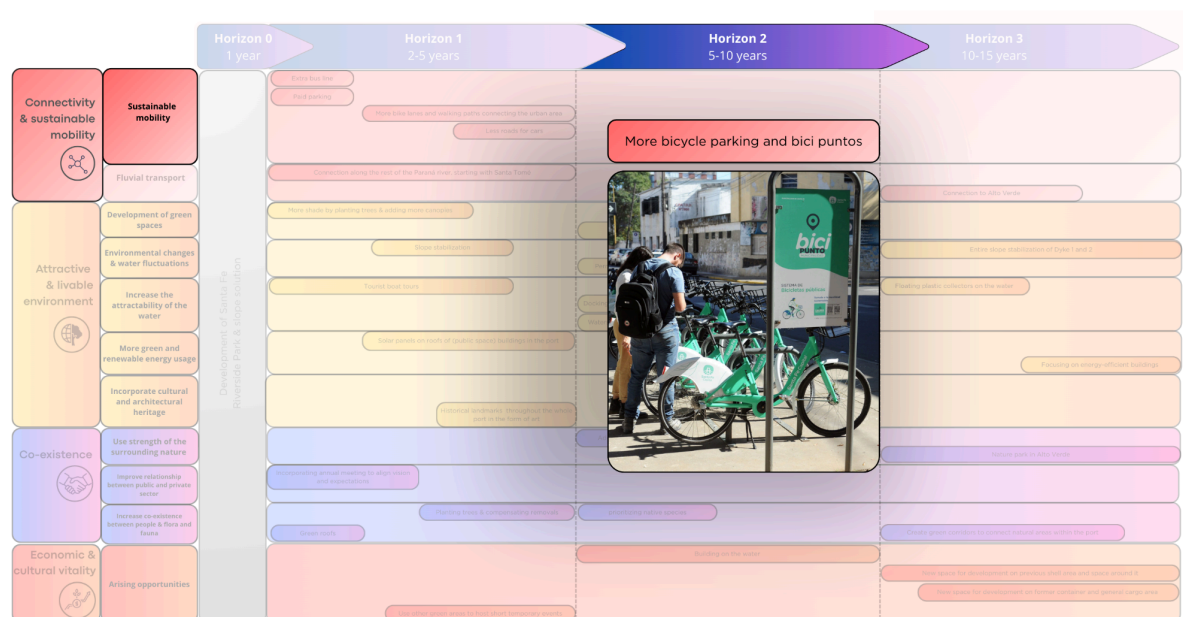


Figure 11.3: Implementation of more bici puntos

Concerning fluvial transport, the first implementation which could be done in the near future is building on the existing project: water-based transportation between the Port of Santa Fe and the rest of the Paraná river, starting with Santo Tomé. This would have the effect of new connections and more people visiting the port of Santa Fe. A second goal is to establish a physical connection between Santa Fe and Alto Verde, but this can only be realised after strengthening the social relationship between both areas. As mentioned in the analysis of Phase 1, this relationship is complex, marked by long-standing social and economic inequalities, mistrust, and physical isolation. Therefore, rebuilding this relationship requires municipal leadership, dialogue and community engagement. The municipality will play a crucial coordinating role in facilitating trust-building between the two communities.

Attractive & livable environment

The second pillar, *Attractive & Livable Environment*, focuses on improving the port's environmental quality and overall comfort. The main goal is to enhance existing green spaces and strengthen the connections between them. An initial and ongoing action is the planting of native trees to provide shade and increase biodiversity. Over time, these efforts can be expanded through the development of connected green spaces with walking paths, benches, lighting, and other amenities, transforming fragmented areas into a connected, accessible, and comfortable network of public spaces.

Building stronger defences against environment and water changes is another important aspect. Another suggestion for the near future would be to use as much permeable concrete for construction of roads and paths to limit water runoff. Lastly, a long-term implementation could focus on stabilizing the slopes throughout the entire port area, including Dyke 1 and Dyke 2.

The attractiveness of the water will increase gradually as new recreational functions are introduced. Tourist boat tours can expand immediately, as one route already exists, allowing for growth of river-based tourism.

Additionally, to increase the attractiveness of the water, the amount of the trash and waste which is currently in the water should be decreased. A great way to tackle this is by introducing floating plastic collectors in the water, similar to how they are used in Rotterdam (Clear Rivers, n.d.) which you can see in Figure 11.4.

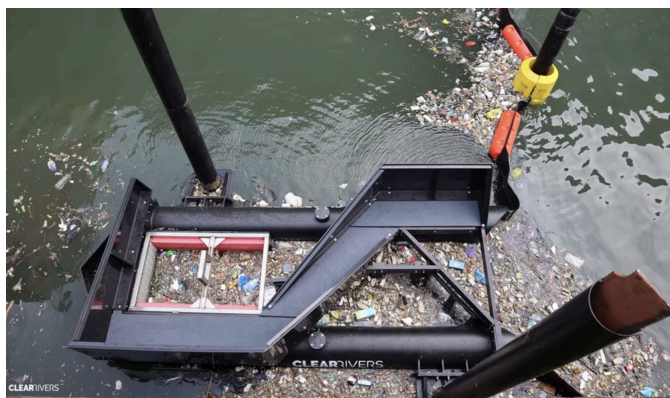


Figure 11.4: Floating plastic collectors

The livability strategy also includes more renewable energy use, such as solar panels on roofs, energy-efficient design standards for new constructions, and electric vehicle charging stations, which can be implemented after three years. The cultural and architectural heritage can be further incorporated through adding more art installations in the entire port area.

Co-existence

The third pillar, *Co-existence*, focuses on strengthening the relationship between the different functions of the port, the social relationships within and outside of the port, and between the people, nature, and most importantly: the water.

This vision can be realized through eco-friendly design strategies that encourage interaction between people, flora, and fauna. Building on the strength of the surrounding landscape, educational information points can be introduced throughout the port to raise awareness of local ecology. These could be developed alongside the green space infrastructure.

An important long-term project within this pillar could be the Alto Verde Nature Park. The area surrounding Alto Verde contains valuable nature landscapes that are not yet discovered by most of the people, but hold significant potential for ecological and recreational development. Tourist tours could start from the Port of Santa Fe and include guided tours through Alto Verde and the nature surrounding it. The possible interesting points for tourism in Alto Verde can be seen in Figure 11.5.



Figure 11.5: Connecting the Alto Verde Nature Park

This allows people from Santa Fe a reason to visit the other side of the river. It thereby creates co-existence between Alto Verde and the port as well as co-existence between nature and people. This park could begin development in 10 years, after the social connection between Alto Verde and Santa Fe

has been strengthened. Its development should include educational paths, observation decks, and ecological restoration zones that allow visitors to experience and learn about the river's ecosystem.

In the coming years, planting native trees and expanding natural areas will strengthen biodiversity and support coexistence by allowing wildlife, such as the capybaras living along the Santa Fe waterfront, to move freely and safely through the port.

For the co-existence between the public and private sector an annual meeting could be organized to align the vision and expectations of the parties, resulting in transparency and shared responsibility for the port's redevelopment. It is advised to start these meetings in horizon 1, which can be seen in Figure 11.6.

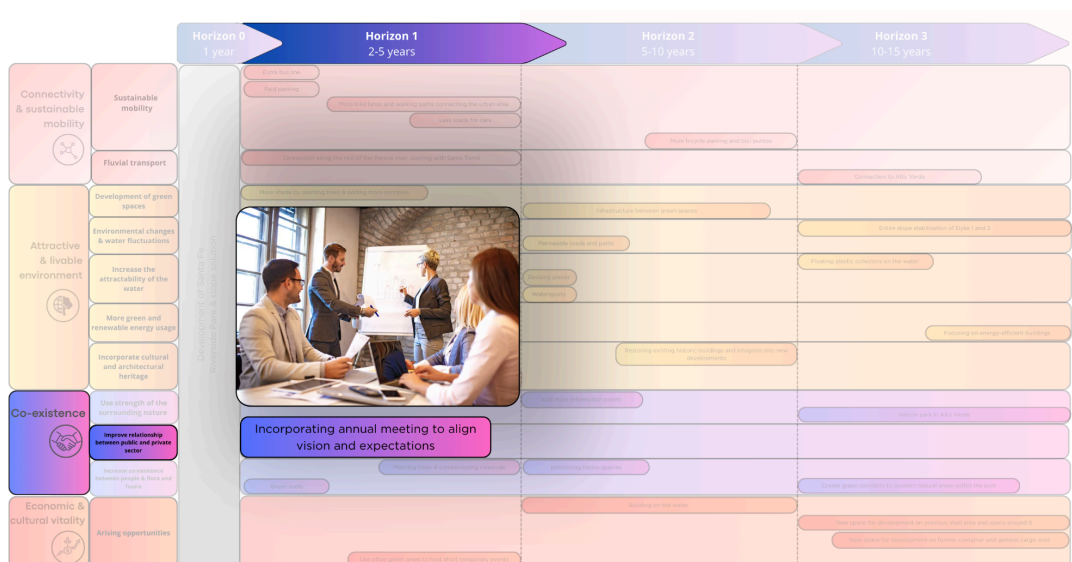


Figure 11.6: Implementation of annual meetings

Economic & cultural vitality

The fourth pillar, Economic & Cultural Vitality, focuses on strengthening the port's dual role as a business and a cultural landmark for Santa Fe. This pillar explores how the area can evolve to support new functional opportunities that enrich both the local economy and community life. Other developed green areas within the port could host temporary events too, additional to the event space on the project site. Within approximately five years, the contract with Raízen will end. Given the port's shifting priorities, there is a possibility that this contract will not be renewed. In that case, the Raízen area could be repurposed for recreational, residential, and commercial development.

The grain terminal will remain operational, as it continues to generate traffic and has shown solid performance in recent years. Meanwhile, the container and general cargo terminals are expected to be decommissioned within five years; they could be gradually replaced by commercial and river-transport functions. In this evolving landscape, the waterfront could also become a site for further urban innovation, featuring floating houses and restaurants that highlight Santa Fe's connection to the river.

12. Discussion & conclusions

12.1 Discussion

Balancing vision and reality

From the beginning, this project aimed to combine urban planning with technical slope stabilization. This proved to be an ambitious task given the physical, institutional, and financial constraints of the Port of Santa Fe. Designing in a context where engineering, ecology, and governance overlap required continuous considerations between different priorities. Finding this balance required trade-offs between ideal visions and what could realistically be achieved on site.

Governance and stakeholder complexity

The institutional structure of the Port presented another difficulty. The Port Authority board operates under the influence of the provincial government, meaning that future actions must align with existing provincial policies and funding priorities. This results in very slow and politically driven decision-making. The overlapping responsibilities of the Port Authority, the Municipality, and private investors also led to differing agendas and objectives. Balancing these conflicting goals made it difficult to create a unified vision that was both ambitious and realistic. This division is most visible in the long-term vision for the port itself: some stakeholders see the port's future as a primarily functional logistics hub that must remain productive, while others advocate for a transition toward a more public and tourism-oriented waterfront. It was therefore not possible to keep all the stakeholders satisfied, but the project attempted to find a balance by maintaining essential port functions while gradually opening space for recreation, culture, and public use.

Communication between parties also presented challenges. All stakeholders were Spanish-speaking, while the team primarily worked in English. As a result, communication often relied on automatic translation tools such as Google Translate. This sometimes caused misunderstandings, particularly in technical or policy-related talks. All critical details were shared with our project supervisor to ensure accuracy, but the translation barrier still slowed collaboration and occasionally led to misinterpretations.

Strategic and logistical uncertainties

The project also encountered limitations related to information and data access. Many operational and financial details about the port are confidential, which restricted the ability to assess detailed implementation strategies or maintenance costs. For this reason, the proposed design remains conceptual and therefore adaptable so that it can be refined once more information becomes available. An important strategic moment in the future development of the port is the expiration of the Raízen oil storage terminal contract in 2030. This could open valuable opportunities for redeveloping industrial areas into public, residential, or recreational spaces. However, the feasibility of such redevelopment remains uncertain. It will depend on legal decisions and future economic possibilities. Because of these uncertainties, it is difficult to make detailed plans at this stage.

The planned connection with Alto Verde represents another long-term ambition. The strong social inequalities and mistrust between the communities in Alto Verde and the rest of Santa Fe mean that social engagement must be established before any physical connection can be made. The long-term roadmap reflects this by prioritizing communication and municipal leadership before construction of any physical link.

Technical and material feasibility

The technical development of the project was shaped by the financial and logistical limitations of the Port of Santa Fe. Within these conditions, one of the main challenges was to design a slope protection system that balanced ecological ambitions with structural reliability and economic feasibility. Fully

nature-based solutions were considered, but the unstable hydraulic dynamics of the Paraná River, combined with limited availability of materials and technical expertise, made these alternatives hard to implement.

The chosen Articulated Concrete Block mattress system was therefore a pragmatic solution. It ensures slope stability under fluctuating water levels and provides a robust, cost-efficient structure suited to the port's environmental conditions. Although less ecological than originally envisioned, its open-cell configuration allows for partial vegetation growth and the creation of small aquatic habitats. This approach illustrates how technical choices were influenced by the broader institutional and financial constraints surrounding the project.

Technically, the project achieved its primary goal of improving slope stability. However, feasibility extends beyond structural safety. The limited local availability of riprap, high transportation costs, and lack of nearby production capacity create significant implementation challenges. These findings suggest that long-term success will depend not only on design and engineering quality but also on stronger institutional coordination and innovation in material sourcing and production.

Although the total investment, roughly estimated at around 4 million euros based on local material costs and transport conditions, was considered reasonable for a project of this scale and technical complexity, it also highlights the financial dependency of the Port of Santa Fe. The Port Authority lacks the internal capacity to fund such works independently and therefore relies on municipal financial support. This dependency underlines the importance of developing sustainable funding mechanisms for future infrastructure works.

Within the site design, several material types and construction details were proposed to demonstrate the project's technical feasibility. Material choices were made based on a balance between technical feasibility, long-term durability, and visual appearance. Furthermore, these choices must be re-evaluated against the realities of availability and pricing. Material costs and supply conditions in Santa Fe vary a lot, this could make implementation financially unrealistic. Further assessment is therefore required to confirm whether the proposed details can be executed within the port's budget and logistical capacities. Ensuring that these practical aspects are aligned with the strategic vision will be essential for transforming the conceptual design into a feasible, long-term development framework.

Concluding reflection

The discussion shows that the project's main achievement lies in its ability to adapt to complex and changing conditions. *The Santa Fe Riverside Park* proposal provides a resilient framework capable of responding to political, environmental, and economic change. Within a context defined by provincial influence, material shortages, and social challenges, lasting progress in the Port of Santa Fe will depend not only on technical solutions, but also on cooperation, transparency, and long-term institutional commitment.

12.2 Conclusion

This project has developed both a final design and a strategic long-term roadmap for the redevelopment of the project site area, *Santa Fe Riverside Park*, and the Port of Santa Fe. The final design provides a concrete proposal for the slope stabilization and urban design of the project site, while the long-term roadmap outlines how the area can continue to develop in a sustainable and inclusive way in the future. The design addresses current needs of visitors, investors, and residents, while the overall vision looks ahead to guide long-term transformation and adaptability.

The design and long-term vision are structured around four guiding pillars: *Connectivity & Sustainable Mobility, Attractive & Livable Environment, Co-existence, and Economic & Cultural Vitality*. Together, these aim to reconnect the port with the city and the river, improve accessibility and environmental quality, promote functional and social integration, and strengthen Santa Fe's economic and cultural identity. By integrating the perspectives of local authorities, the Port Authority, and community representatives, the project lays the foundation for a phased redevelopment process that aligns long-term ambitions with feasibility.

In terms of slope protection, the project addresses one of the port's most urgent challenges, the instability of the waterfront's bank. Multiple weak soil layers have been identified, while the fluctuating water levels and river dynamics of the Paraná River cause rapid drawdown and erosion that contribute to its gradual degradation. The chosen Articulated Concrete Block mattress system offers a cost-efficient, durable, and locally feasible solution that ensures stability under the site's hydraulic conditions. Its open-cell design enables limited vegetation growth and sediment retention, improving ecological value and the riverbank's visual integration.

The resulting concept, *Santa Fe Riverside Park*, embodies both the protection of the slope as the four pillars. It includes elements supporting these pillars and with this integrates public spaces, river access, and green infrastructure, while enhancing economic vitality. This is done by integrating elements including a walking bridge, a stepped terrace, a viewing tower and a multi-purpose building providing spaces where people can slow down, gather, and rediscover the value of the water for visitors and residents.

Together, the strategic and technical components form a durable and inclusive waterfront. The design addresses current needs, while the long-term roadmap looks ahead to guide long-term transformation and adaptability. Ultimately, the Port of Santa Fe can evolve into a combination of industry, ecology, and community life, reaffirming the river as a shared public space.

13. AI usage statement

ChatGPT and Google Gemini were selectively used during the project to support writing, visualization, and presentation. They helped create detailed and realistic visualizations of our concept, allowing us to clearly show and communicate our design ideas in a visual way. These AI-generated images were used to complement our written descriptions and to present the concept in greater detail, also for presentations we have given. Additionally, both tools assisted in rephrasing certain sections for clarity and improving the overall structure of the report. All technical reasoning, design development, and final decisions were made independently based on our own research and engineering judgment. The AI tools therefore served as helpful aids for improving clarity and visualization, without influencing the project's technical content or outcomes.

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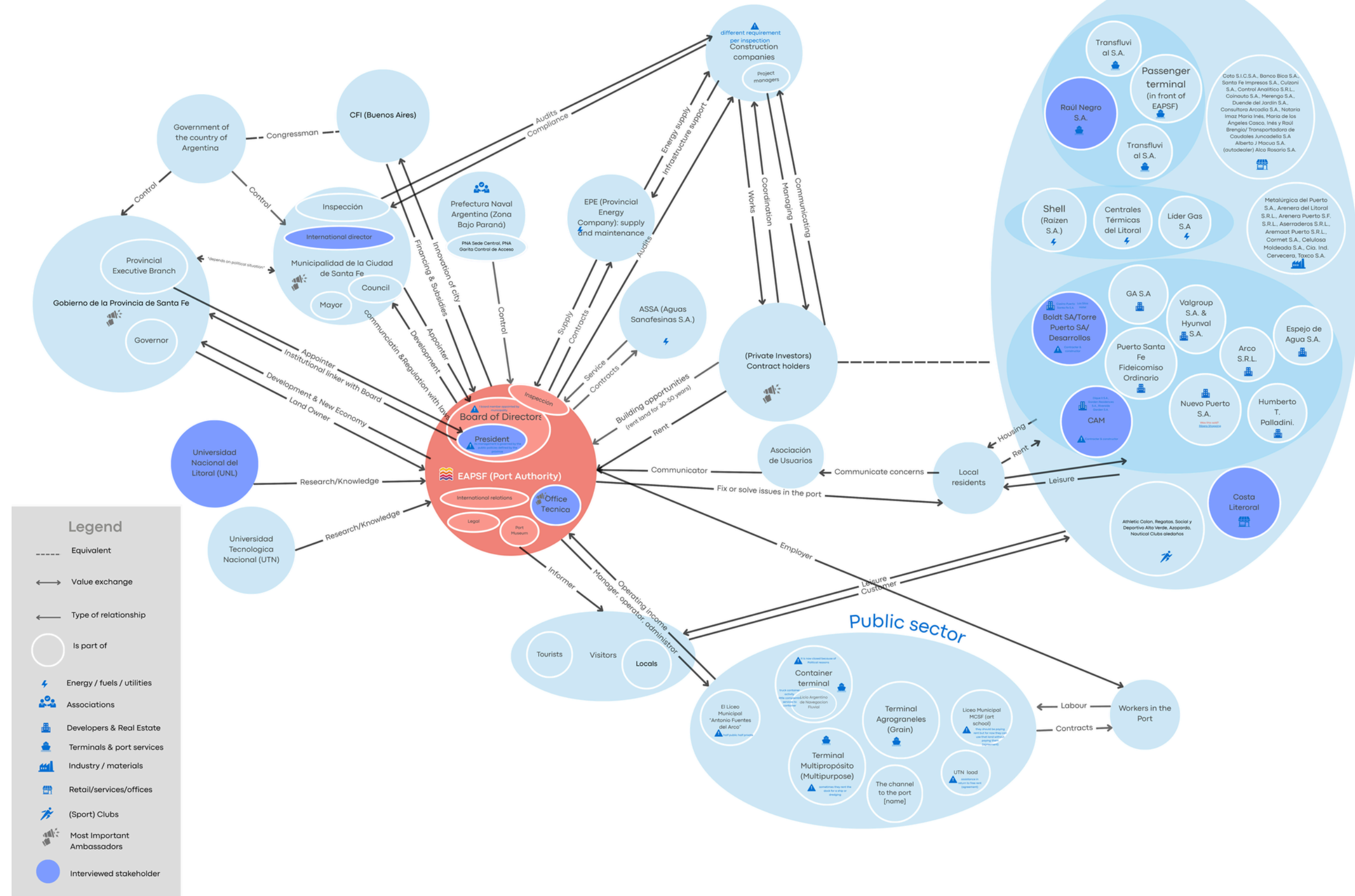
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Appendix A

Stakeholder relationships map



Appendix B

Summary of interviews

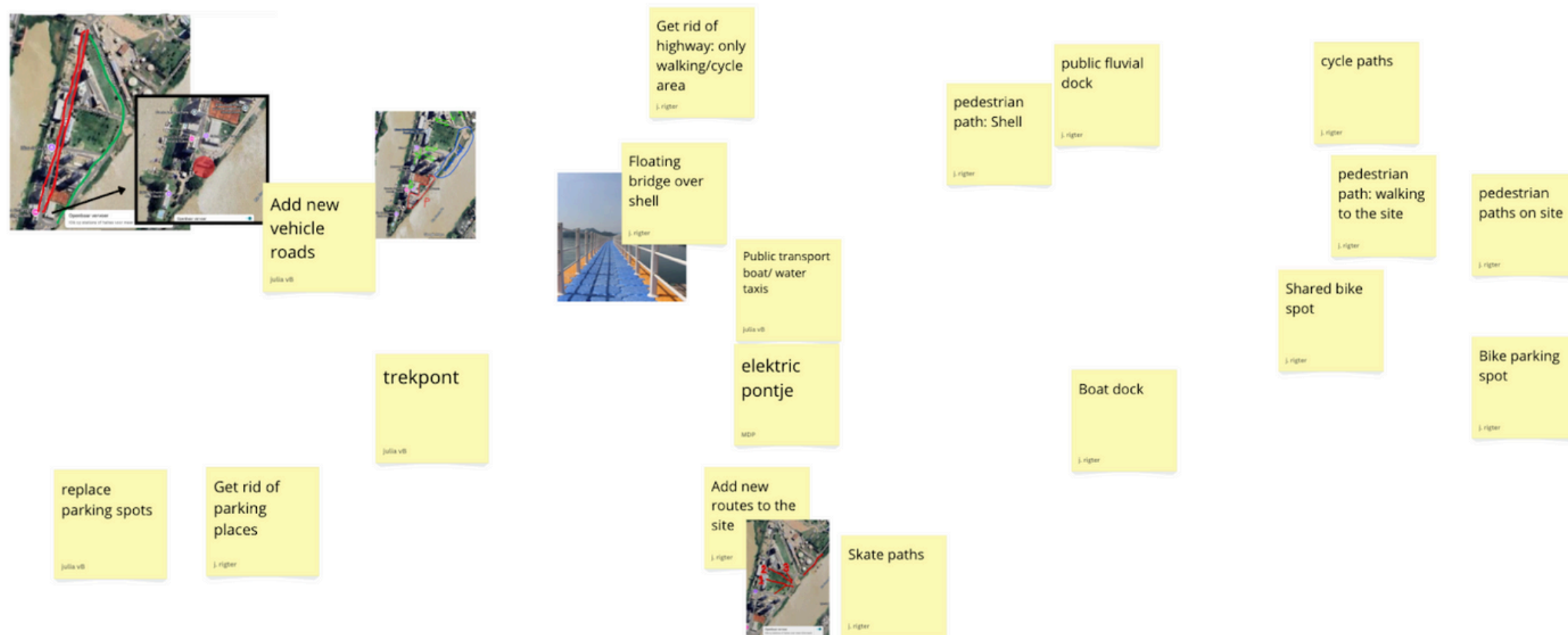
		M. J. Correa	D. Arditti	C. Fertoni	C. Paz	L. Gonzales	J. and M. Weiss	L. Garcia	UNL	J. Reyt	EASPF - Technical Team		concludes
	Function	CEO van Torre SA (BSA), real estate developer (private)	CEO CAM Group, real estate developer (Private)	Owner of costa litoral and several restaurants in Sant Fe (private)	Director Raul Negro-Group (salvage, private)	President of the Ente Administrador Puerto Santa Fe (EAPSF), public	Mayor of Santo Tomé (public)	Director of International cooperation and trade, public (municipality)	Public university, technical and scientific advisor (water science, engineering, ecology), public/academic	Architect and professor of Urbanism and History, academic	The technical team of the Port Authority		
	vision	Sees port as prime waterfront real estate location. Emphasizes public-private interdependence (state=rules + infrastructure, private actors invest). 15-minute city concept with strong connections and green lungs (sustainability). Tourism and hospitality are key drivers of growth. Integration with A.V. is important, but government responsible, shell terminal is incompatible with urban redevelopment.	Sees port as an alternative waterfront real estate location, with housing towers as main driver (e.g. Amarras, Garden Residences, Tower). Emphasizes public-private complementarity (state provides order, planning, and stability; private sector invests). Stresses the need for urban order and enforcement (traffic, waste, coexistence). Supports river access and floating constructions. Green spaces and public parks are essential to distinguish the port and improve quality of life. Integration with Alto Verde is important but a long-term, state-led process.	Sees port as a hub for tourism, gastronomy, and leisure, with restaurants and river tours as key drivers. Emphasizes the need for more green spaces, promenades, and public areas that generate empathy with nature. Supports fluvial transport for tourism and regional trips, but rejects a direct boat link to Alto Verde as impractical (prefers promenades on both shores). Advocates for better mobility inside the port (tram, buses, bikes) to reduce car congestion and parking problems. Criticizes current designs for lacking greenery and attractiveness. Believes tourism can help bridge divides and promote Santa Fe's history and natural assets.	Sees the port mainly through a logistics and infrastructure lens, emphasizing cargo movement, salvage operations, and industrial functionality. Advocates for greater use of the waterway for regional cargo (barges over trucks) but is realistic that dredging to Santa Fe is not viable. Stresses the importance of functional separation: oil depots and heavy industry should not coexist with residential and commercial development. (Sees Alto Verde as a valuable labor pool, already employing locals, and stresses training and education as tools for social recovery. Skeptical about fluvial public transport due to safety and cost concerns. Critical of inadequate slope protection and calls for more ecological, biodiversity-sensitive solutions instead of traditional concrete works.)	Sees the port as a place where productive operations and urban development must coexist. Highlights the port's historical role in Argentina's agro-export boom and acknowledges its later crises. Advocates for consensus-building among municipality, province, private sector, and citizens, stressing the need for clear rules and long-term planning. Emphasizes integration of Alto Verde and reducing symbolic barriers between communities and the port. Supports green public spaces (10% of land reserved) as key for accessibility and coexistence. Recognizes the potential of fluvial transport, but underlines legal and financial challenges. Sees his role as providing strategic direction while balancing productive capacity with the urban Masterplan.	Sees Santo Tomé as "three cities in one" (middle-class, poorer, wealthier north) and wants to strengthen social integration. Describes Santo Tomé as a "sleeping city" since most cultural and social life happens in Santa Fe, and aims to make it more dynamic and independent. Believes the industrial role of Santa Fe's port is largely outdated, as competing cities already dominate. Instead, sees tourism and small-scale fluvial transport as the port's main opportunities. Supports step-by-step development: first tourism projects, then expanding to river connections with Santa Fe. Advocates for a clear strategic vision from government to guide investments and tenders. Also developing a nature reserve project with international funding to showcase biodiversity and attract visitors.	Sees Santa Fe as a future commercial and logistics hub for the north of the province, with strong potential in barge transport to Paraguay, Brazil, and Uruguay. Argues that dredging is too costly, so development should focus on making the port commercially attractive and shifting to barge-based trade. Supports fluvial public transport (Businú project) to connect Alto Verde and the port, emphasizing social inclusion, since residents already cross illegally by boat. Highlights the lack of a shared vision between municipality, province, and port as a barrier to progress. Draws on international examples (Rotterdam, Monteria, Peru) and stresses alignment with sustainability goals (SDGs, EU agreements). Believes mobility improvements, multimodal transport, and accessibility are key for both development and social equality.	Focuses on the hydrological and ecological dynamics of the Paraná and Salado rivers, providing expertise on slope stability, erosion, and climate risks. Emphasizes that floods, droughts, and low water levels pose major challenges for the port and city. Advocates for nature-based solutions (vegetation, floating gardens, ecological buffers) combined with engineering approaches to stabilize slopes. Highlights the impacts of pollution (agriculture, sewage) on water quality and biodiversity. Sees an opportunity to integrate ecological restoration with urban design, making the waterfront more resilient to climate change.	Sees Santa Fe shifting from an industrial port identity toward a green/blue city focused on public space, ecology, and design. Believes industrial functions will gradually disappear and should be replaced by residential, commercial, and recreational uses. Advocates for nature-based, low-maintenance solutions (floating gardens, rain gardens, chinampas, fishing farms) instead of heavy concrete. Calls for reclaiming public access to the riverfront (at least 50m should remain public). Sees Alto Verde as an opportunity for inclusive tourism (fishing village, gastronomy, ecological corridors) rather than displacement. Supports river transport and pedestrian-first design with less cars, more walking routes, and cultural/tourism infrastructure (markets, kayak routes, eco-parks).	greenspaces, problem car congestion 10-30 year fixed term contracts Vision: waterfront connection to the river		
Vision and History	General	"The Port of Santa Fe is today a laboratory of the 15 minute city: where the industrial past is redefined and the urban future is designed through proximity. (...) The contemporary paradigm of the 15-minute city, where working, living, shopping, learning and enjoying life converge in one territory." The objective is to "revitalize an abandoned port and return it to the city" after the port was closed off from the city by a physical wall for many years.	developer + construction (70% real estate)		Uruguay and Argentina, salvage, boat removal, cleaning	agro-export boom late 19th/early 20th c.), then permanent crises. 1983: democracy, lack of continuity in state policies. 2000s: masterplan	Santo Tomé: 3 cities in onw (middle-class, m poor and wealthy), sleeping city: more happens in santa fe	director of international cooperation. Sees Santa fe as possible commercial center of the north of the province. 80% is international cooperation, 20% trade	collaborates with port for river behavior, slope stability, ecological impacts. Consulted after events, but also proactive monitoring and stability projects.	architect and prof urbanism and history. Santa fe is shifting from industrial to green/blue city. Reimagine port: public space as a right rather than "open space"	EASPF's overarching vision is to transform the port into a multifunctional urban and fluvial hub that maintains its logistical relevance while opening up to the city and promoting sustainable coexistence between port operations, tourism, and public life		Contradictin and different views
	Historic value	Heritage preservation. Using the industrial past of the port.		heritage preservation, with tourism	skeptical on tourism, river lacks safety and infrastructure					Important as context, should not be marketed as sole identity. Ships will disappear in the next 15 years.	The Ente Administrador Puerto Santa Fe (EAPSF) was established to manage and modernize the Port of Santa Fe, historically a key logistics hub connecting inland Argentina to the Paraná-Paraguay waterway. Historically, the port's role has been strongly industrial and logistical, serving grain exports,		everyone thinks the history can be used, expect for jose reyt
	(Private) developments	Casino Santa Fe, Hotel Los Silos, Convention and events center, gastronomic and cultural spaces, mall, McDonalds (source: gouden boekje)	Puerto Amarras, Amarras center, garden residences, Tower	4 restaurants, costa litoral	fluvial accidents is a key business driver	co-existing productive operations and urban/real estate				Inspired by Turenscape (Kongjian Yu), West 8, MVRDV, Sasaki (Wuhan), Bulla Paisaje			
	Housing focus in the port	Yes, high value waterfront	Yes, alternative real estate location, high value. Chronic housing shortage	-	-					yes with commercial			3 stakeholders want more housing
	Public-private relations	General	Port = public, private results in growth	port = public, private results in growth	no competitors in argentina, m only one suffering full salvage + infra services	state thinks of citizens and private of own interest	projects are politically and economically feasible, challenge is attract investors with a vision. Private investments is key	port is private, municipality owns no land?		industrial will disappear, mix residential with commercial	at the center, mediating between public and private interests and enabling value exchange among actors		everyone says port is public excep for L. Garcia
		Coexistence	yes	yes		requires agreements and trust, clear rules needed		dredging is less important than making the port commercially attractive			tension between economic pressure and public goals		everyone finds coexisting important in a way
		Collaboration	yes, mutually dependent	yes, port, commerce, and tourism must work together	not much collaboration with other private investors	dialogue-based leadership, consensus among actors		is difficult; port looks local, municipality/province subnational/global			key communication link		mutually dependent, but difficult relationship
	Municipality and government	General	is complex (always present), do not always align	long-term policy would be better	wants tax reductions/exemptions		provincial government is now a coalition of parties, good relationship, strategic outlook is missing (for fluvial transport)	municipality is focused on international cooperation and SDGs, national less important. No shared vision is the problem, hard to align actors.			bridge between public and private.		complex relationship, sometimes different views
		order, planning, control	land is leased, state should provide rules.	government preconditions = crucial, strengthen frameworks and controls	government should finance public transport and infrastructure	lack of contracts and opportunities in argentina	port proposes plans (important!) -> province owns the land		more industrial/ commercial: with barges (no dredging required). Sees it as a logistics hub		poor planning and reliance on concrete, more nature-based and low maintenance solutions should be integrated		port brings ideas, governemer should intervene and provide rules, frameworks and control
		shell	not compatible with redevelopment of port		oil depots should not co-exist with residential					the dirty water needs to be filtered with plants and soil (when the leave)	Contract will likely end in 2030		everyone that talked about it wanted it gone
		city - port relationship	-	should be fully integrated		urban planning is important: citywide				city should reclaim public spaces.	should be better, more connection		reclaim public spaces and integrate
Projects/ future	River tours	-	-	launching river tours his september		For children in A.V.							some people had plans fo it already

Summary of interviews

	M. J. Correa	D. Arditto	C. Fertoni	C. Paz	L. Gonzales	J. and M. Weiss	L. Garcia	UNL	J. Reyt	EASPF - Technical Team	conclues
Fluvial public transport	open to invest	contact with river and boat acces important QoL	yes, support	skeptical, unsafe with big ships, mayor investment needed	good idea, people dont know the water. Need legal clarity and provincial support and possible international funds.	after tourism development	Businé: 2 stops in santa fe, under the bridge and liceo argentina, funding is unclear but plan is there.		yes. less cars, underground parking	Crucial element for the port's future development	everyone agreed, expect for C. Paz (skeptical, unsafe with big ships)
Connecting Alto Verde	state should intervene, socially segmented, poor mobility	long-term, state policy and coordination first, legal and infrastructure barriers	promenade at A.V. as well as at port, not yet boat connection, they could sell fish on promenade	low-educated population, 30 employees from A.V. at RN, helps with social connection	Giving river tours, integration is important, city is one.	and to other connecting neighborhoods (investing)	very important, by boat. People already cross illegally		activities like fishing markets, kayak routes, national park near Alto Verde. not displace residents, create tourism jobs. 20.000 registered and 10.000 not. Inclusive projects: protection + interaction	Very important, but difficult, the municipality should intervene and first socially the connection need to be improved before a physical connection can happen.	difficult but important, should be done step by step, and the government should that the lead
Replacing terminals					potentially to Paraná, but this is very costly and requires private investments.					shell contract ends in 2030.	maybe long time from now
15 minute city	Yes, connectivity										Maria jose, yes
projects on water		floating constructions (houses)		more cargo on the water, dredging will not happen		500 hectares waterfront real estate (houses on stils and lagoon protection)	barge transport projects: north argentina, paraguay/brazil, santa fe (redistribution)		floating gardens, fishing farms, rain gardens, green/concrete stepped terraces, floating sidewalks, bridges, viewing tower		some people liked floating houses or other things, only Garcia wanted barges
future	more offices, puerto market, private boats				developing an investement plan, likely be insufficient	fluvial transport, but first tourism (riverboat service). New road bridge.	more industrial/ commercial: with barges (no dredging required). Sees it as a logistics hub. Tourism a later goal				private want to develop more
tourism and nature						nature reserve project (2 Mil french funding) pier with passenger boats for island tours, flora and fauna, bus links needed, once active will be linked with the port of santa fe.			eco-tourism!! hiking, glamping, fishing, boats. Info boards, viewpoints, cultural areas (asado, food stalls), public spaces that invited people to stay.	key opportunities	eco-tourism was interesting for 2 stakeholders
other	Development of the port's old power plant (sensitive topic).	10-12 towers, would like more if possible				industrial infrastructure is largely unused, more potential in tourism and smaller-scale fluvial transport. Santa Tomé also has a master plan: schools, health care, logistics..	interested in rotterdam practices. Sustainability goals		no more McDonalds sign, see through structures and avoid concrete		random ideas, interesting
Public spaces	Green spaces	yes, crucial	yes, crucial; generate empathy with nature, biodiversity	-	10% is designated green. Support coexistence (residents and city), should be preserved and equipped.		amarras/dock 2: municipality doesn't manage green area (private), not central for her, but connection and accessibility are		focus on greenery.	Green spaces are a must and should be better developed.	everyone wanted it expect for L. Garcia
	mobility and transport	Developing a new 15-minute city in suburban ("country") areas, creating connections with bike paths, roads, plazas. Needed for 15 minute city: access, openness, and infrastructure, regardless of mobility mode.	traffic management and parking	only public transport in port, parking is a big problem		public spaces are provincial land	connect city areas better. Mobility is essential for social development and tourism. Multimodal solutions needed (not only buses)		pedestrians first, more sidewalks, wider paths, water-absorbing pavements.	problems with car congestion	public transport, less cars, more pedestrians
	digital transformation					Transformación digital: efficiency and transparency in provincial governance					weiss talked about it
Slope protection	plans	-	-	-	calls for new ecological and biodiversity-sensitive solutions			environmental impacts (farmers' chemicals, urban sewage, --> influence biodiversity and ecosystems)	nature based: vegetation floating gardens, chinampas. dyke 1: concrete, dyke 2: mroe natural (less maintenance), not a fan of concrete		-
	Previous research	-	-	-	variable river conditions, dumping concrete and debris --> political mismanagement		slope damage is not seen as urgent by municipality, outside their jurisdiction.	main drivers water leven: rainfall + water use brazil. Climate risks (floods, droughts, low water levels), erosion factors (river current, construction, water level fluctuations, wind)		need for safe, ecological slope protection. The makeshift rubble fillings do not work now	-
	info/future							dramatic slope changes: -2-->-10. local acceleration of currents. Nature-based solutions could work here (vegetation especially): Gabions (not strong enough), espigones (groynes), bermejo project (el colorado), flow direction to reduce erosive forces. probably no further deepening at base: on lateral slopes. Variability in river discharge and precipitation. Suggested integration ecological restoration with slope protection. hybrid approaches: combining engineering + ecological solutions			-

Appendix C.1

Ideas Generated per pillar using the "How Can We?" method



1) Connectivity & sustainable mobility



Appendix C.2

Ideas Generated per pillar using the "How Can We?" method

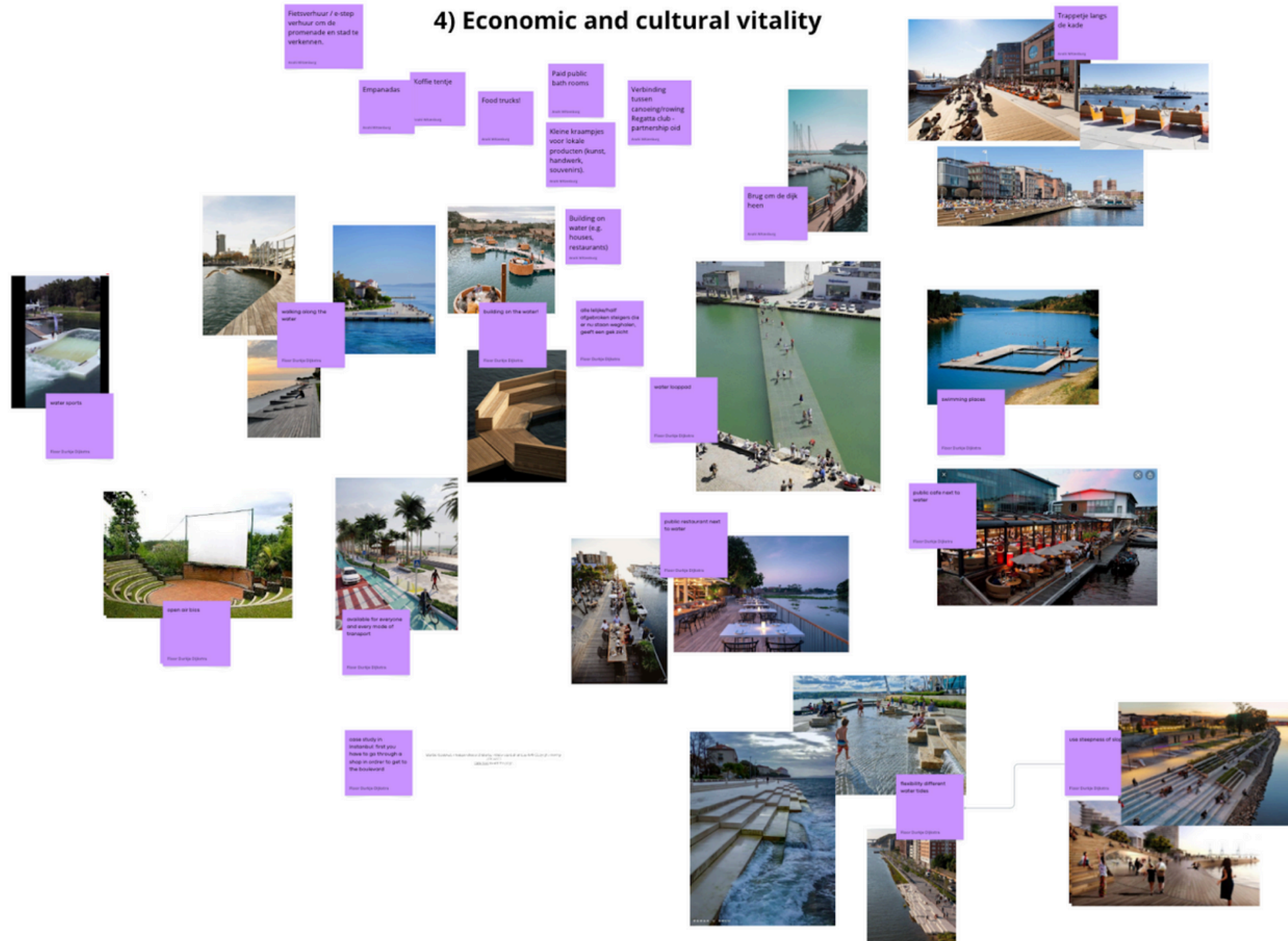


2) Attractive & livable environment



Appendix C.4

Ideas Generated per pillar using the "How Can We?" method



Appendix C.5

Complete overview of ideas

1. Connectivity & Sustainable Mobility

- Public fluvial transport (pontje / water taxis) linking Alto Verde, Santo Tomé and Paraná.
- Floating bridge and walking bridge over Raízen connecting promenade areas.
- New walking, cycling, and skate paths through the port.
- Interactive and nature-based routes (e.g. Komoot trail).
- Shared bike and e-step rental points, improved bike parking.
- Integrated bus, tram, and bike parking hubs.
- Removal of car roads, fewer parking places; southern part as pedestrian zone.
- Floating platforms and small boat docks.
- Steps and terraces creating direct access to the river.
- Covered walkways and shaded resting points.
- Dog-friendly design with pet bins and drinking fountains
- Public viewing points and shaded paths with natural materials

2. Attractive & Livable Environment

- Ecological restoration of the slope as a green buffer.
- Nature park with rain gardens, floating gardens, and mangroves.
- Floating gardens and chinampas for biodiversity and water filtration.
- Shaded areas with trees, flowers, and shadow sails.
- Benches, picnic tables, asado spots, and outdoor gym equipment.
- Dog park, soccer field, and family play zones.
- Water fountains, Solar Trees, and drinking spots.
- Steps and terraces along the water and flexible landscapes responding to tide levels.
- Lanterns and soft lighting for nighttime ambience (make it romantic at night).
- Art installations and sculptures (e.g., capybara motif).
- Clean-water swimming area and beach
- Urban waterfront park and rain gardens with different plant heights.
- Concrete tiles with holes for plants to grow.
- Restaurants, cafés, bathrooms, and info points for everyday comfort.

Complete overview of ideas

3. Co-existence

- Palafito (stilt houses) and adaptive edges for changing water levels.
- Fishing village and urban farms along the river.
- Nature-based solutions: mangroves, rain gardens, and chinampas.
- Educational and cultural trails linking the port and Alto Verde.
- Graffiti and art that depict the bond between Santa Fe and Alto Verde.
- Information boards explaining local history and ecology.
- Library hub and small “street libraries”.
- Public park accessible by boat from Alto Verde.
- Participatory co-creation sessions with Alto Verde (Appreciative Inquiry).
- Shared sports and recreational spaces (e.g., skate park and Regatta Club connection).
- Inclusive events such as cooking classes and tug-of-war competitions.
- “Living with the flood” design using terraces and resilient landscapes.

4. Economic & Cultural Vitality

- Empanada store, food trucks, kiosks, maté/coffee shops and small cafés
- Market stalls for local products, handicrafts, and souvenirs.
- Floating restaurants and terraces on the water.
- Adaptive reuse of heritage buildings (e.g., old electricity house as café or gallery).
- Case study-inspired concept: enter the boulevard through shops (Istanbul reference).
- Public events: open-air bioscope, cooking classes, cultural festivals.
- Swimming and rowing events with the Regatta Club.
- Shared cultural activities merging heritage and contemporary identity.
- “Instagram hotspots” and urban landmarks to promote local tourism.
- Library or reading pavilion accessible by boat.
- Urban waterfront park hosting markets and performances.
- Partnerships with creative industries and local artists.
- Paid public bathrooms and support facilities.
- Fietsverhuur / e-step rental to explore port and city.
- “Building on the water” concept (e.g., restaurant or club on a floating dock).

Appendix D.1

Survey questions - concept 1

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

Protection of natural slopes and redevelopment in the Port of Santa Fe

We have discussed three different concepts:

1. The active riverside
2. The urban waterfront park
3. The cultural port

First, you will get a few questions about each concept separately. Afterwards, there will be a few questions comparing the three concepts and lastly some questions about the connection with Alto Verde.

* Indicates required question

1. The first few questions will be about **concept 1: The active riverside.** *

Question 1:

How likely do you think it is that people from Santa Fe or Argentina would make use of the facilities in this concept (kayak rental, docking, jeux de boules, stepped terrace, shaded areas, cafés)?

Please rate on a scale from 1 to 5, where 1 = very unlikely and 5 = very likely."

Mark only one oval.

1 2 3 4 5
Very Very likely

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

2. Questions about **concept 1: The active riverside.** *

Question 2:

Please rank the different elements of this concept:

- Kayak rental
- Docks for visitor's boats
- Jeux de boules/bochas
- Stepped terrace
- Shaded areas
- Cafés

from 1 to 6, where 1 = the element you like the most and 6 = the element you like the least.

Mark only one oval per row.

	1	2	3	4	5	6
Kayak rental	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Docks for visitor's boats	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Jeux de boules/bochas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stepped terrace	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shaded areas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cafés	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. Questions about **concept 1: The active riverside** *

Question 3:

Do you feel this concept is in line with what you imagined for this area?

Please rate on a scale from 1 to 5, where 1 = not at all in line and 5 = yes, very much in line

Mark only one oval.

1 2 3 4 5
Not Yes, very much in line

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

4. Questions about **concept 1: The active riverside** *

Question 4:

Is there anything in this concept that you think **should not** be included?

5. Questions about **concept 1: The active riverside** *

Question 5:

Is there anything in this concept that is missing?

6. The next few questions will be about concept 2: **The urban waterfront park** *

Question 1:

How likely do you think it is that people from Santa Fe or Argentina would make use of the facilities in this concept (Walking bridge, info viewpoint, kiosk, nooks, art, shadow places) ?

Please rate on a scale from 1 to 5, where 1 = very unlikely and 5 = very likely."

Mark only one oval.

1 2 3 4 5
Very Very likely

Survey questions - concept 2

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

7. Questions about **concept 2: The urban waterfront park** *

Question 2:

Please rank the different elements of this concept:

- Walking bridge
- Info viewpoint
- Kiosk
- Cozy corner
- Art
- Shadow places

from 1 to 6, where 1 = the element you like the most and 6 = the element you like the least.

Mark only one oval per row.

	1	2	3	4	5	6
Walking bridge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Info viewpoint	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Kiosk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cozy corner	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Art	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shadow places	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

8. Questions about **concept 2: The urban waterfront park** *

Question 3:

Do you feel this concept is in line with what you imagined for this area?
Please rate on a scale from 1 to 5, where 1 = not at all in line and 5 = yes, very much in line

Mark only one oval.

1 2 3 4 5

Not Yes, very much in line

9. Questions about **concept 2: The urban waterfront park** *

Question 4:

Is there anything in this concept that you think **should not** be included?

10. Questions about **concept 2: The urban waterfront park** *

Question 5:

Is there anything in this concept that is missing?

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

11. The next few questions will be about **concept 3: The cultural port** *

Question 1:

How likely do you think it is that people from Santa Fe or Argentina would make use of the facilities in this concept (Dock, fluvial transport, fences, asado point, info viewpoint, space for events, water points)?
Please rate on a scale from 1 to 5, where 1 = very unlikely and 5 = very likely."

Mark only one oval.

1 2 3 4 5

Very Very likely

Survey questions - concept 3

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

12. Questions about **concept 3: The cultural port** *

Question 2:

Please rank the different elements of this concept:

- Dock
- Fluvial transport
- Fences
- Asado point
- Info viewpoint
- Space for events
- Water points

from 1 to 6, where 1 = the element you like the most and 6 = the element you like the least.

Mark only one oval per row.

	1	2	3	4	5	6	7
Dock	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fluvial transport	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fences	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Asado point	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Info viewpoint	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Space for events	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Water points	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

13. Questions about **concept 3: The cultural port** *

Question 3:

Do you feel this concept is in line with what you imagined for this area?
Please rate on a scale from 1 to 5, where 1 = not at all in line and 5 = yes, very much in line

Mark only one oval.

1 2 3 4 5

Not Yes, very much in line

14. Questions about **concept 3: The cultural port** *

Question 4:

Is there anything in this concept that you think **should not** be included?

15. Questions about **concept 3: The cultural port** *

Question 5:

Is there anything in this concept that is missing?

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

16. The next few questions will be about the **three concepts** *

Which concept do you think the port authority would prefer?

Mark only one oval.

- Concept 1: The active riverside
- Concept 2: The urban waterfront park
- Concept 3: The cultural port

17. Which concept do you think the investors would prefer? *

Mark only one oval.

- Concept 1: The active riverside
- Concept 2: The urban waterfront park
- Concept 3: The cultural port

18. Which concept do you think the municipality would prefer? *

Mark only one oval.

- Concept 1: The active riverside
- Concept 2: The urban waterfront park
- Concept 3: The cultural port

19. Which concept do you think the residents would prefer? *

Mark only one oval.

- Concept 1: The active riverside
- Concept 2: The urban waterfront park
- Concept 3: The cultural port

Survey questions - general

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

20. Rank the three different concepts based on feasibility (1 being most feasible and 3 the least feasible) *

Check all that apply.

	1	2	3
1: The active riverside	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2: The urban waterfront park	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3: The cultural port	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

21. Do you think the 4 different pillars (connectivity & sustainable mobility, attractive & livable environment, co-existence, economic & cultural vitality) properly reflect what residents, investors and the port want? *

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

22. Please rank the three different concepts according to your own preference (1 being most feasible and 3 the least feasible) *

Mark only one oval per row.

	1	2	3
1: The active riverside	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2: The urban waterfront park	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3: The cultural port	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

23. In your opinion, which elements from different concepts could be combined into one to create a stronger vision? *

24. If you had to recommend one concept for Santa Fe, which one would it be? *

Mark only one oval.

Concept 1: The active riverside

Concept 2: The urban waterfront park

Concept 3: The cultural port

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

25. The next few questions will be about the **out of the box ideas** and the **connection with alto verde** *

Do you think a nature park near the port would attract people from Santa Fe and Alto Verde?

Mark only one oval.

Yes

Maybe

No

26. Do you find a small boat link (pontje) a reasonable and useful way to connect the two sides? *

Mark only one oval.

Yes

Maybe

No

27. Do you think the natural environment in Alto Verde is attractive enough to visit and enjoy? *

Mark only one oval.

Yes

Maybe

No

Survey questions - general

10/27/25, 9:58 AM

Protection of natural slopes and redevelopment in the Port of Santa Fe

28. Thank you for filling in the survey! If you have any other comments or recommendations, please comment them here!

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Google Forms

Appendix D.2

Survey results

Protection of natural slopes and redevelopment in the Port of Santa Fe
8 responses

[Publish analytics](#)

Las primeras preguntas serán sobre el Concepto 1: La ribera activa. [Copy](#)

Pregunta 1:
¿Qué probabilidad crees que haya de que las personas de Santa Fe o de Argentina utilicen las instalaciones de este concepto (alquiler de kayaks, muelles, cancha de bochas, terraza escalonada, áreas sombreadas, cafés)?
Por favor califica en una escala del 1 al 5, donde 1 = muy improbable y 5 = muy probable.

8 responses

Rating	Percentage
1	0 (0%)
2	0 (0%)
3	0 (0%)
4	2 (25%)
5	6 (75%)

Preguntas sobre el Concepto 1: La ribera activa. [Copy](#)

Pregunta 2:
Por favor ordena los diferentes elementos de este concepto:

- Alquiler de kayaks
- Muelles para barcos de visitantes
- Bochas
- Terraza escalonada
- Áreas sombreadas
- Cafés

del 1 al 6, donde 1 = el elemento que más te gusta y 6 = el que menos te gusta.

Element	1	2	3	4	5	6
Alquiler de kayaks	0	1	3	4	0	0
Muelles para barcos de visitantes	2	1	3	1	1	0
Bochas	0	1	0	1	0	6

Preguntas sobre el Concepto 1: La ribera activa [Copy](#)

Pregunta 3:
¿Sientes que este concepto está en línea con lo que imaginabas para esta zona?
Por favor califica en una escala del 1 al 5, donde 1 = nada en línea y 5 = sí, totalmente en línea.”

8 responses

Rating	Percentage
1	0 (0%)
2	1 (12.5%)
3	0 (0%)
4	2 (25%)
5	5 (62.5%)

Preguntas sobre el Concepto 1: La ribera activa

Pregunta 4:
¿Hay algo en este concepto que crees que no debería incluirse?

8 responses

- No
- Bochas
- juego de bochas, no es usualmente jugado en santa fe, creo que la gente prefiere sentarse a tomar mates
- All good
- No estoy del todo de acuerdo con la propuesta de bochas
- Actividad de bochas no me parece relevante
- Me encanta me parece una idea genial que se pueda utilizar el espacio para tiempo de oseo
- Considero que la activación de la ribera no depende necesariamente de un sector para juego de bochas. Creo que es una actividad que podría desarrollarse en cualquier predio o espacio público, no necesariamente sobre la ribera.

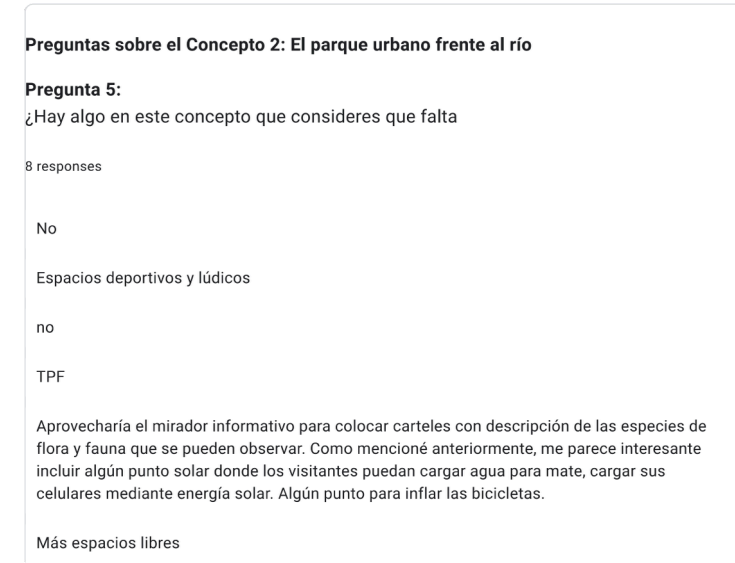
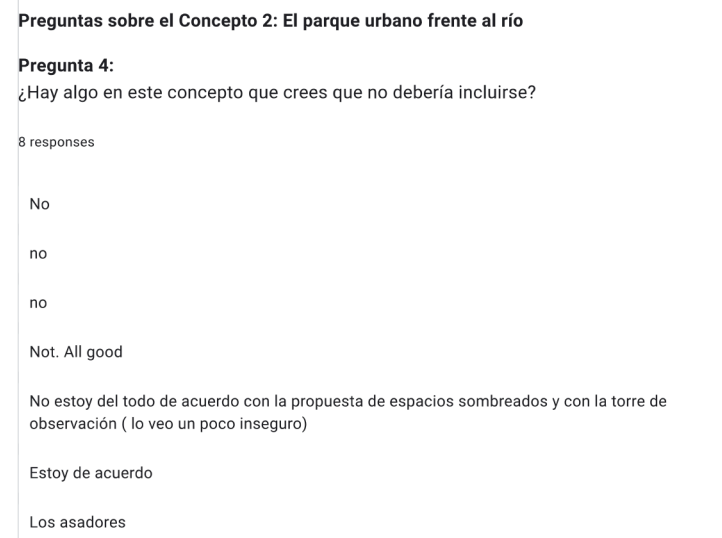
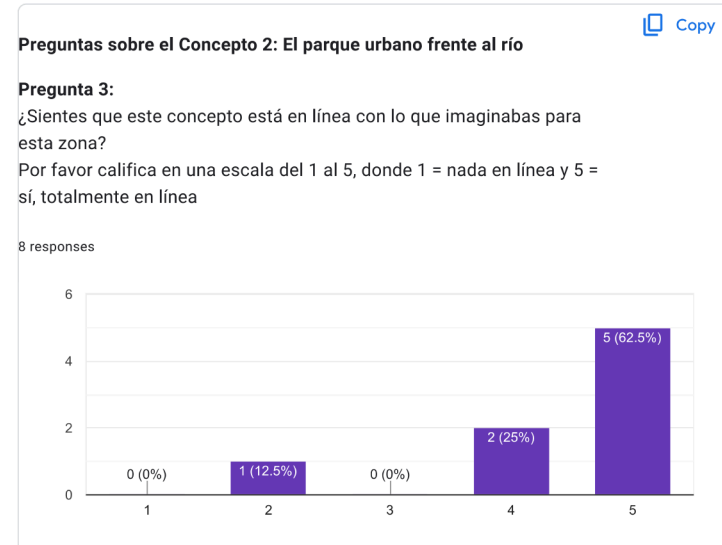
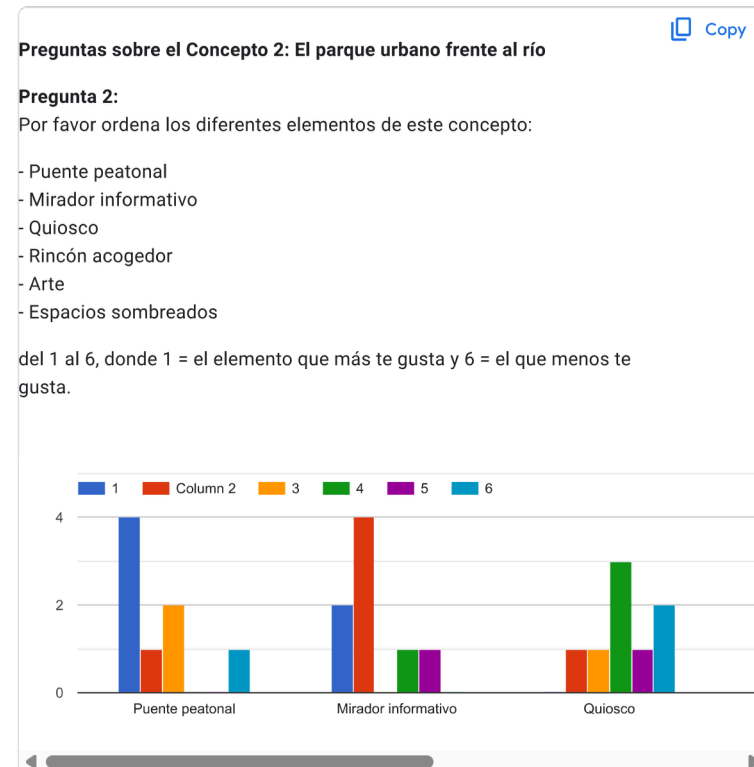
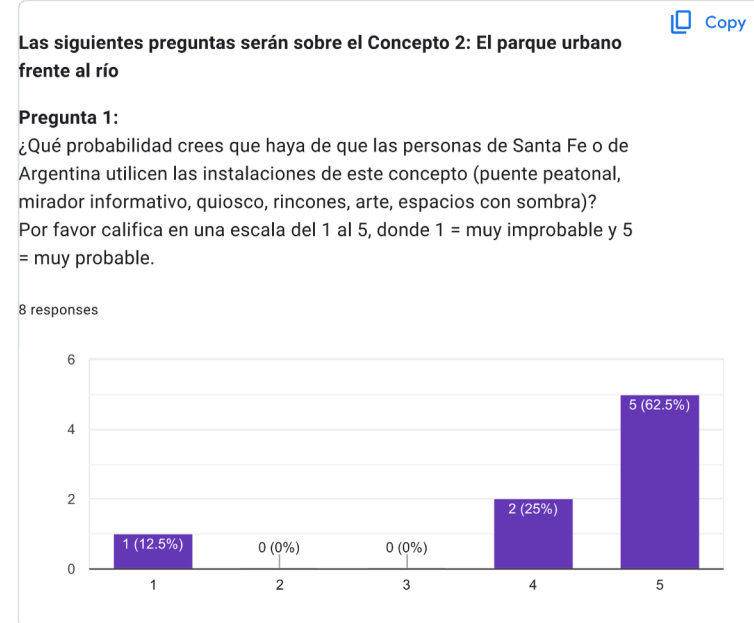
Preguntas sobre el Concepto 1: La ribera activa

Pregunta 5:
¿Hay algo en este concepto que consideres que falta?

8 responses

- Más opciones gastronómicas
- Incluiría deportes acuáticos en general (remo, SUP, ski náutico, nado etc) y bar restaurante
- estacionamientos de bicicletas
- TPF
- Me gustaría incorporación de especies arbóreas y lograr la sombra con estas especies. También me parece interesante incluir algún punto solar donde los visitantes puedan cargar agua para mate, cargar sus celulares mediante energía solar. Algún punto para inflar las bicicletas.
- Alternativa a bochas
- Me gustaría más espacios para descansar y tomar mate
- No

Survey results



Survey results

Las siguientes preguntas serán sobre el Concepto 3: El puerto cultural

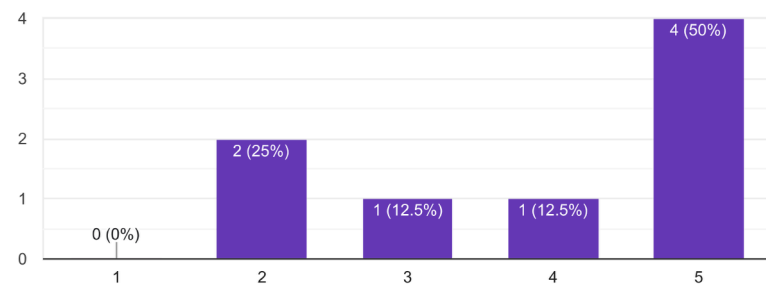
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Pregunta 1:

¿Qué probabilidad crees que haya de que las personas de Santa Fe o de Argentina utilicen las instalaciones de este concepto (muelle, transporte fluvial, cercas, punto de asado, mirador informativo, espacio para eventos, puntos de agua)?

Por favor califica en una escala del 1 al 5, donde 1 = muy improbable y 5 = muy probable.

8 responses



Preguntas sobre el Concepto 3: El puerto cultural

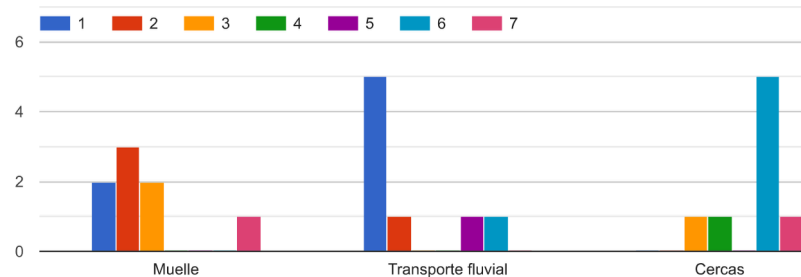
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Pregunta 2:

Por favor ordena los diferentes elementos de este concepto:

- Muelle
- Transporte fluvial
- Cercas
- Punto de asado
- Mirador informativo
- Espacio para eventos
- Puntos de agua

del 1 al 7, donde 1 = el elemento que más te gusta y 7 = el que menos te gusta.



Preguntas sobre el Concepto 3: El puerto cultural

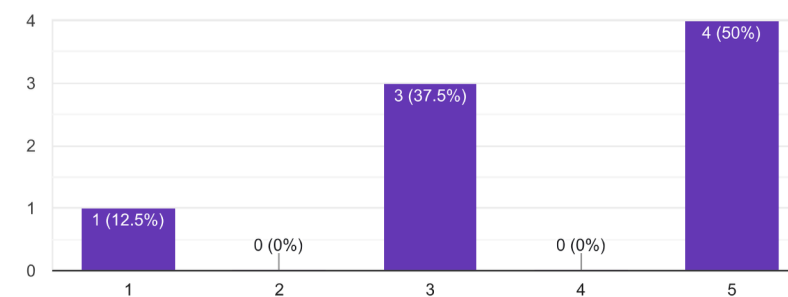
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Pregunta 3:

¿Sientes que este concepto está en línea con lo que imaginabas para esta zona?

Por favor califica en una escala del 1 al 5, donde 1 = nada en línea y 5 = sí, totalmente en línea.

8 responses



Preguntas sobre el Concepto 3: El puerto cultural

Pregunta 4:

¿Hay algo en este concepto que crees que no debería incluirse?

8 responses

Asadores

Asado

paseo cultural, punto de asado

Cercas

El punto de asado por el riesgo que puede generar y porque creo que a los residentes de la zona no les gustaría.

Punto de asado

Debería incluirse más espacios vacíos

Parrillas públicas para asado. Considero que es peligroso por el fuego y que la gente aún no está educada lo suficiente para manipularlo con cuidado.

Preguntas sobre el Concepto 3: El puerto cultural

Pregunta 5:

¿Hay algo en este concepto que consideres que falta?

8 responses

No

Haría un mix de todas las propuestas

ok

.

Mini golf

Aprovecharía el mirador informativo para colocar carteles con descripción de las especies de flora y fauna que se pueden observar. Como mencioné anteriormente, me parece interesante incluir algún punto solar donde los visitantes puedan cargar agua para mate, cargar sus celulares mediante energía solar.

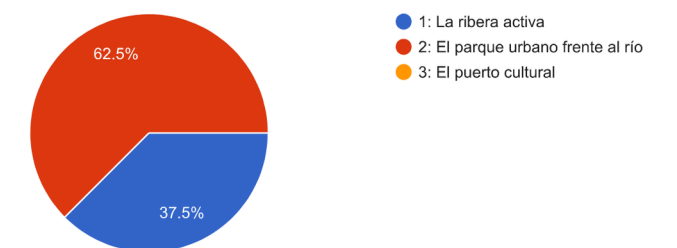
Espacios de descanso y mate

Las siguientes preguntas serán sobre los tres conceptos

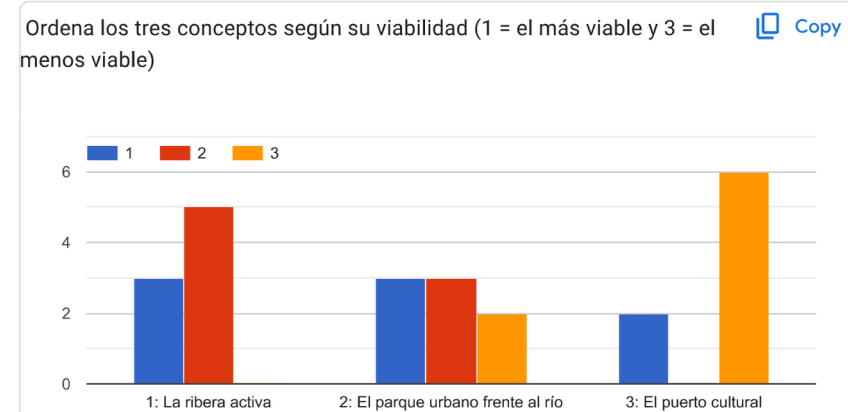
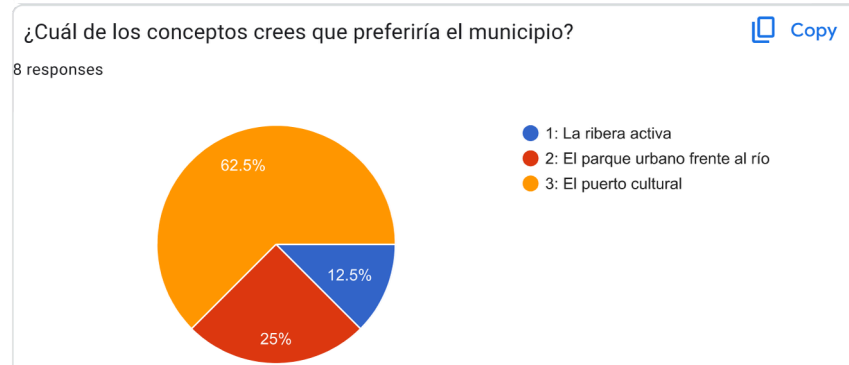
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¿Cuál de los conceptos crees que preferiría la autoridad portuaria?

8 responses



Survey results



¿Crees que los cuatro pilares (conectividad y movilidad sostenible, entorno atractivo y habitable, convivencia, vitalidad económica y cultural) reflejan adecuadamente lo que quieren los residentes, los inversores y el puerto?

8 responses

Si

Si bastante

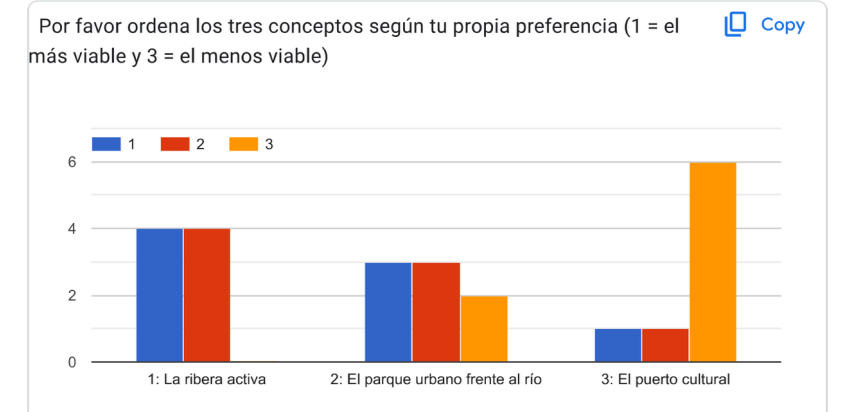
si

I think yes

Si.

Siiii

Si y no, creo que cada uno sabe qué es lo mejor para el área puerto-ciudad y qué es lo correcto. Sin embargo, pocos poseen la capacidad de pensar a largo plazo y asumir las consecuencias de sus decisiones, optando en cambio por priorizar intereses particulares y conformarse con resolver el día a día.



En tu opinión, ¿qué elementos de los diferentes conceptos podrían combinarse en uno solo para crear una visión más sólida?

8 responses

Juegos, deporte, miradores

Creo que los 3 conceptos desarrollados se deben unificar en uno solo

deberían combinarse los deportes acuáticos, con un paseo, miradores, espacios de sombra y quiosco.

La ribera activa y el puerto cultural

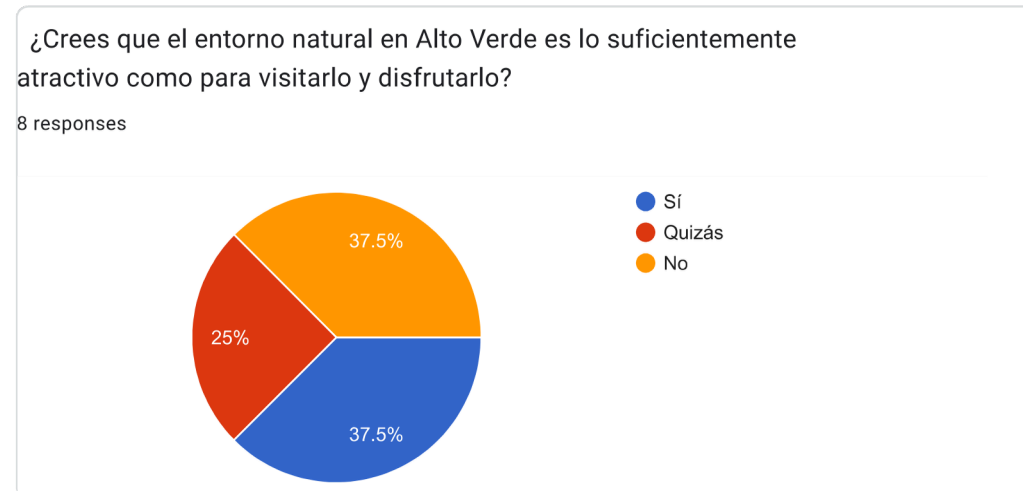
Muelle peatonal, alquiler de kayacs, mirador informativo, cercas, puntos de agua, café, terraza escalonada y transporte fluvial

2 y 3

Fusión entre opción una y dos

Considero que estos aspectos son interdependientes y se potencian mutuamente. La generación de actividades y atractores en la ribera requiere necesariamente de espacios de permanencia y descanso, infraestructura y equipamiento urbano de calidad, servicios adecuados y, sobre todo, un sentido de apropiación e identidad colectiva.

Survey results



¡Gracias por completar la encuesta!
Si tienes algún otro comentario o recomendación, por favor escríbelo aquí.

8 responses

No

Gracias!

<3

Excelente trabajo chicos, los felicito!!

Buen trabajo

Son genios XOXO Mari

No tengo observaciones.

Appendix E.1

List of requirements

ID	Requirement	Priority	Source (analysis/stakeholder)
R1. Ecological, Cultural & Social Integration			
R1.01	The final concept could integrate cultural identity (silos, cranes, port heritage) whereas the historical value of the port could be preserved.	Could	Cultural Analysis
R1.02	The final concept could create links to the surrounding neighborhoods. E.g. Alto Verde, Santo Tomé.	Could	Location Analysis
R1.03	The final concept could celebrate river culture (boat access, viewpoints).	Could	Cultural Analysis
R1.04	The final concept could reduce polarization by ensuring local residents and city citizens and tourists benefit from development.	Could	Cultural Analysis
R1.05	The final concept could include the flora fauna and local habitats.	Could	Ecological Analysis
R1.06	The final concept should integrate the different suggested tree species that could be planted in the 'espacios verdes'.	Should	Ecological Analysis
R1.07	The final concept should reduce human impact on the green areas as much as possible (e.g. incorporate waste management solutions to tackle river trash).	Should	Ecological Analysis
R1.08	The final concept could act as a pilot for fluvial transport integration.	Could	Mayor of Santo Tomé
R1.09	The final concept should integrate tourism facilities (waterfront promenades, cultural attractions).	Should	Mayor of Santo Tomé
R1.10			
R1.11	The final concept could include flexible infrastructure that can adapt to fluctuating river levels and traffic (avoid risks of inactive terminals).	Could	Economical Analysis
R1.12	The project could embrace the "15-minute city" concept (well-connected bike paths, plazas, access roads, and integrated green spaces).	Could	CEO of CAM - Maria Jose
R1.13	The project should enable infrastructural connectivity (e.g. fluvial transport)	Should	Porth Authority- other stakeholders
R1.14	The project could acknowledge and integrate the existing square green space next to the site as part of the overall design.	Could	
R1.15	The final concept must integrate public access green zones.	Must	Porth Authority
R2. Economic & Functional			
R2.01	The final concept should contribute to (national, international) tourism and recreational economy	Should	Economic Analysis
R2.02	The final concept must ensure compatibility with ongoing port developments and operations	Must	Problem Statement; Masterplan
R2.03	The final concept must attract investments (clubs, cafés, kiosks, local businesses)	Must	Puerto Ciudad insights
R2.04	The final concept must to the utmost extent maintain open public access: no privatization	Must	Port Authority
R2.05	The final concept must not add to port congestion.	Must	Location Analysis
R2.06	The final concept should promote river tourism.	Should	Port Authority
	The project should explore new revenue streams (tourism, recreation, fluvial transport) to reduce dependency on port terminal revenue loss.	Should	Economic Analysis
R3. Contractual Requirements			
R3.01	The project must ensure safe and efficient internal circulation.	Must	Contractual Analysis
R3.02	Vehicle and pedestrian routes inside concession areas are required to follow uniform signage and design standards approved by EAPSF.	Must	Contractual Analysis
R3.03	Each development must provide sufficient parking spaces for staff, clients, and suppliers, reducing pressure on public infrastructure.	Must	Contractual Analysis
R3.04	Projects located next to common-use spaces (such as streets, sidewalks, or green areas) are obliged to adapt to them, without blocking or privatizing access.	Must	Contractual Analysis
R3.05	Users are liable for any contamination of land, water, or air, and must provide systems for waste management, fire prevention, and safety.	Should	Contractual Analysis
R3.06 Plan de Gestión Ambiental (PGA)	Sustainable design (permeable sidewalks, renewable energy, rainwater reuse, green roofs and walls).	Should	Contractual Analysis
R3.06 Plan de Gestión Ambiental (PGA)	Efficient use of water and energy.	Should	Contractual Analysis
R3.06 Plan de Gestión Ambiental (PGA)	Forestation, prioritizing native species and compensating removals by planting three new specimens for each one extracted.	Should	Contractual Analysis
R3.06 Plan de Gestión Ambiental (PGA)	Spill prevention in water areas and effluent/emission control.	Should	Contractual Analysis
R3.06 Plan de Gestión Ambiental (PGA)	Comprehensive solid waste management (reduction, separation, recycling; no incineration).	Should	Contractual Analysis
R3.06 Plan de Gestión Ambiental (PGA)	A contingency plan for environmental or safety emergencies.	Should	Contractual Analysis
R3.07	Projects must showcase and reinforce the port landscape and identity.	Must	Contractual Analysis
R3.08	Architectural and urban design should reference port symbols such as cranes, railways, and containers.	Should	Contractual Analysis
R3.09	Should ensure public safety: barriers, safe lighting, no steep drops	Should	Port Authority
R3.10	Safe pedestrian paths.	Must	Contractual Analysis
R3.11	Adequate vehicle circulation.	Must	Contractual Analysis
R3.12	Landscaping that integrates with surroundings.	Must	Contractual Analysis
R3.13	Strong physical links between the port, the waterfront, and the city.	Must	Contractual Analysis
R3.14	Developers must preserve and incorporate cultural and architectural heritage, reinforcing the long-term identity of the Puerto City district.	Must	Contractual Analysis
R3.15	Making underground electrical connections consistent with port standards.	Must	Contractual Analysis
R3.16	Connecting to the Port's sewer network (Desagües Cloacales) and contributing proportionally to shared infrastructure such as pumping stations and main sewer lines.	Must	Contractual Analysis
R3.17	Carrying out complementary works, most notably the stabilization and filling of riverbank slopes (taludes) where relevant.	Must	Contractual Analysis
R3.18	If the concession borders the waterfront, maintaining the coastal edge entirely at their own expense, compensating the Port Authority against liability.	Must	Contractual Analysis
R3.19	Preserving non-built areas as green zones, kept free of commercial use and in hygienic condition.	Must	Contractual Analysis
R3.20	<u>Dedicating at least 5% of the total project investment to improvements in common-use infrastructure outside the concessioned plot.</u>	Must	Contractual Analysis
R3.21	The project should integrate safe bicycle lanes & connect to city cycle paths	Should	Contractual Analysis
R3.22	The project should integrate inclusive access: wheelchair, elderly seating, safe crossings	Should	Contractual Analysis
R3.23	The final concept should include connections of the site to bus stops & public transport routes	Should	Contractual Analysis

List of requirements

R4. Stakeholder Involvement

R4.01	The project must be formally approved by the Board of Directors (9 members) of EAPSF.	Must	Stakeholder analysis
R4.02	The project must comply with provincial authority (Governor/Ministry of Production).	Must	Stakeholder analysis
R4.03	The project and final concept must incorporate input from municipality (traffic, planning, tourism).	Must	Stakeholder analysis
R4.04	The project should balance public objectives with private investors' priorities, recognizing that their financial capital is essential for realization.	Must	Port Authority
R4.05	The project should bridge fragmented visions between municipality, EAPSF, and other stakeholders	Should	Municipality International Relationships Coordinator
R4.06	The project could leverage universities and knowledge institutions (UNL, UTN) for technical expertise and cultural integration.	Could	-
R4.07	The project could involve local residents and workers as co-creators (participatory design workshops, consultations).	Could	Stakeholder analysis
R4.08	The project should strengthen public-private synergies.	Should	CEO Boldt SA
R4.09	The design should avoid dependence on any single political coalition: it must remain viable and flexible across changing administrations.	Should	Stakeholder analysis

R5. Slope - Design

R5.01	The design should combine structural work with nature based solutions.	Should	Port Authority
R5.02	The design must respect navigation channel constraints.	Must	Prefectura Naval Argentina / PIANC
R5.03	The design must be applicable to blue zone and green zone.	Must	Current slope stability
R5.04	The design could be applicable for red zone.	Could	Current slope stability
R5.05	The project must have low maintenance.	Must	Port Authority
R5.06	The design should be practically integrated with the promeneda - options to connect with water.	Should	Port Authority
R5.07	The slope must stabilize and fill the riverbank slopes where relevant.	Must	Contractual Analysis
R5.08	The materials used for the project should be easily available.	Should	Port Authority
R5.09	The design should be accessible from land.	Should	Port Authority
R5.10	could be estatically be integrated with the promenda	Could	-

R6. Slope - Protection

R6.01	Design must protect the slope against rapid drawdown.	Must	From soil structure to slope failure
R6.02	Design must protect the slope against erosion.	Must	From soil structure to slope failure
R6.03	Design must protect the slope against circular failure.	Must	From soil structure to slope failure
R6.04	Design must have a sliding factor of safety > 1.	Must	Slope dimensions
R6.05	Protection must have an erosion factor of safety of 2.	Must	Protection layer
R6.06	Protection should resist max current of 2.13 m/s.	Should	Protection layer
R6.07	Protection should resist significant wave heights of 1.3 m.	Should	Anchoring of protection
R6.08	Design should withstand extreme water-level variability.	Should	Ecological situation

R7. Slope - Ecology

R7.01	The project should include flora into the slope.	Should	Ecological situation
R7.02	The project could include fauna into the slope.	Could	Ecological situation
R7.03	The project could help water filtering of the river.	Could	Ecological situation

Appendix E.2

Requirements final concept

R1. Ecological, Cultural & Social Integration		
R1.01	The final concept could integrate cultural identity (silos, cranes, murals, port heritage) whereas the historical value of the port could be preserved	Cultural Analysis
R1.02	The final concept could create links to the surrounding neighborhoods. E.g. Alto Verde, Santo Tomé	Location Analysis
R1.03	The final concept could celebrate river culture (boat access, viewpoints)	Cultural Analysis
R1.04	The final concept could reduce polarization by ensuring local residents and city citizens and tourists benefit from development.	Cultural Analysis
R1.05	The final concept could include the flora fauna and local habitats	Ecological Analysis
R1.06	The final concept should integrate the different suggested tree species that could be planted in the 'espacios verdes'	Ecological Analysis
R1.07	The final concept should reduce human impact on the green areas as much as possible (e.g. incorporate waste management solutions to tackle river trash)	Ecological Analysis
R1.08	The final concept could act as a pilot for fluvial transport integration	Mayor, 1.4.2
R1.09	The final concept should integrate tourism facilities (waterfront promenades, cultural attractions)	Mayor of Santo Tomé
R1.10	The final concept could stimulate (local) businesses by enabling services.	1.6.2 Provincial/city services; tourism potential
R1.11	The final concept should include flexible infrastructure that can adapt to fluctuating river levels and traffic (avoid risks of inactive terminals).	1.6.3 Port economy – container terminal issues
R1.12	The project could embrace the "15-minute city" concept (well-connected bike paths, plazas, access roads, and integrated green spaces)	
R1.13	The project should enable connectivity, primarily encouraging sustainable mobility.	
R1.14	The project could acknowledge and integrate the existing square green space next to the site as part of the overall design.	
R1.15	The final concept must integrate public access green zones	
R2. Economic & Functional		
R2.01	The final concept should contribute to (national, international) tourism and recreational economy	Economic Analysis
R2.02	The final concept must ensure compatibility with ongoing port developments and operations	Problem Statement; Masterplan
R2.03	The final concept must attract investments (clubs, cafés, kiosks, local businesses)	Puerto Ciudad insights
R2.04	The final concept must to the utmost extent maintain open public access: no privatization	
R2.05	The final concept must not add to port congestion.	
R2.06	The final concept should promote river tourism.	
R2.07	The project should explore new revenue streams (tourism, recreation, fluvial transport) to reduce dependency on port terminal revenue loss.	
R3. Contractual Requirements		
R3.01	The project must ensure safe and efficient internal circulation.	1.3.1 Key requirements; Mobility and Circulation
R3.02	Vehicle and pedestrian routes inside concession areas are required to follow uniform signage and design standards approved by EAPSF.	1.3.1 Key requirements; Mobility and Circulation
R3.03	Each development must provide sufficient parking spaces for staff, clients, and suppliers, reducing pressure on public infrastructure.	1.3.1 Key requirements; Mobility and Circulation
R3.04	Projects located next to common-use spaces (such as streets, sidewalks, or green areas) are obliged to adapt to them, without blocking or privatizing access.	1.3.1 Key requirements; Mobility and Circulation
R3.05	Users are liable for any contamination of land, water, or air, and must provide systems for waste management, fire prevention, and safety.	1.3.1 Key requirements; Environmental Management
R3.06 Plan de Gestión Ambiental (PGA)	Sustainable design (permeable sidewalks, renewable energy, rainwater reuse, green roofs and walls).	1.3.1 Key requirements; Environmental Management
R3.06 Plan de Gestión Ambiental (PGA)	Efficient use of water and energy.	1.3.1 Key requirements; Environmental Management
R3.06 Plan de Gestión Ambiental (PGA)	Forestation, prioritizing native species and compensating removals by planting three new specimens for each one extracted.	1.3.1 Key requirements; Environmental Management
R3.06 Plan de Gestión Ambiental (PGA)	Spill prevention in water areas and effluent/emission control.	1.3.1 Key requirements; Environmental Management
R3.06 Plan de Gestión Ambiental (PGA)	Comprehensive solid waste management (reduction, separation, recycling; no incineration).	1.3.1 Key requirements; Environmental Management
R3.06 Plan de Gestión Ambiental (PGA)	A contingency plan for environmental or safety emergencies.	1.3.1 Key requirements; Environmental Management
R3.07	Projects must showcase and reinforce the port landscape and identity.	1.3.1 Key Requirements; Integration with the Urban-Port Context
R3.08	Architectural and urban design should reference port symbols such as cranes, railways, and containers.	1.3.1 Key Requirements; Integration with the Urban-Port Context
R3.09	Should ensure public safety: barriers, safe lighting, no steep drops	EAPSF
R3.10	Safe pedestrian paths.	1.3.1 Key Requirements; Integration with the Urban-Port Context
R3.11	Adequate vehicle circulation.	1.3.1 Key Requirements; Integration with the Urban-Port Context
R3.12	Landscaping that integrates with surroundings.	1.3.1 Key Requirements; Integration with the Urban-Port Context
R3.13	Strong physical links between the port, the waterfront, and the city.	1.3.1 Key Requirements; Integration with the Urban-Port Context
R3.14	Developers must preserve and incorporate cultural and architectural heritage, reinforcing the long-term identity of the Puerto City district.	1.3.1 Key Requirements; Integration with the Urban-Port Context
R3.15	Making underground electrical connections consistent with port standards.	1.3.1 Key Requirements; Technical and Construction Responsibilities
R3.16	Connecting to the Port's sewer network (Desagües Cloacales) and contributing proportionally to shared infrastructure such as pumping stations and main sewer lines.	1.3.1 Key Requirements; Technical and Construction Responsibilities
R3.17	Carrying out complementary works, most notably the stabilization and filling of riverbank slopes (taludes) where relevant.	1.3.1 Key Requirements; Technical and Construction Responsibilities
R3.18	If the concession borders the waterfront, maintaining the coastal edge entirely at their own expense, compensating the Port Authority against liability.	1.3.1 Key Requirements; Technical and Construction Responsibilities
R3.19	Preserving non-built areas as green zones, kept free of commercial use and in hygienic condition.	1.3.1 Key Requirements; Technical and Construction Responsibilities
R3.20	Dedicating at least 5% of the total project investment to improvements in common-use infrastructure outside the concession plot.	1.3.1 Key Requirements; Technical and Construction Responsibilities
R3.21	The project should integrate safe bicycle lanes & connect to city cycle paths	1.3 physical access
R3.22	The project should integrate inclusive access: wheelchair, elderly seating, safe crossings	1.3 physical access
R3.23	The final concept should include connections of the site to bus stops & public transport routes	1.3 physical access
R4. Stakeholder Involvement		

Requirements final concept

R4.01	The project must be formally approved by the Board of Directors (9 members) of EAPSF.	1.4.1 Institutional Structure
R4.02	The project must comply with provincial authority (Governor/Ministry of Production).	1.4.1; 1.4.2
R4.03	The project and final concept must incorporate input from municipality (traffic, planning, tourism).	1.4.1; President & municipality cooperation
R4.04	The project should balance public objectives with private investors' priorities, recognizing that their financial capital is essential for realization.	1.7.3 Private sector
R4.05	The project should bridge fragmented visions between municipality, EAPSF, and other stakeholders	1.7.3.; Municipality International Relationships Coordinator
R4.06	The project could leverage universities and knowledge institutions (UNL, UTN) for technical expertise and cultural integration.	1.7.1 Public sector cluster incl. universities
R4.07	The project could involve local residents and workers as co-creators (participatory design workshops, consultations).	1.7.2.
R4.08	The project should strengthen public-private synergies.	CEO Boldt SA, ch. 1.4.2
R4.09	The design should avoid dependence on any single political coalition: it must remain viable and flexible across changing administrations.	

This is the list of requirements that is used to assess the final concept. Not all requirements from the list in D.1. are used. All "must" requirements were considered, as these define the most important conditions the design must meet. Most of the "should" requirements are also taken into account, however, some "should" requirements that are indicated in red in the overview, were deemed too detailed or technical for this design phase, but will be taken into account later in Phase 3. For example, requirements regarding tree species and utility connections. All "could" requirements were not taken into account in the composition of the final concept.

In the Excel, the different concepts are listed stating if the requirement is met (yes), if the requirement is not met (no), or if the requirement is partially met (medium). Appendix D.2. shows that concept 2 does not meet all the requirements, it also shows some elements from the other concepts that do meet the requirements that concept 2 fails to satisfy. To ensure the final concept meets the requirements list, elements are added or changed. By combining various elements, the final concept becomes a whole that aligns with the vision and the four pillars.

Appendix F

Multi-criteria decision analysis middle zone and toe zone

Criterion type	Type weight	Criterion	Weight - toe part	Rock and block armouring			Armoured slope blankets			Retaining system								
				Riprap	Gabions	Concrete armor units	Grouted riprap	Geocells	Concrete block mattresses	Gravity walls	Sheet piles	Filled sandbags						
Protection	30	Failure mech 1: rapid drawdown prevention	0															
Protection		Failure mech 2: wave and wind erosion prevention	0															
Protection		Failure mech 2: current erosion prevention	17	8	7	9	8	3	7	6	7	5						
Protection		Performance under extreme water-level variability	3	8	6	8	5	2	7	5	6	3						
Protection		External loads from land and water	10	8	7	9	7	2	7	7	8	2						
			30	240	207	267	221	77	210	187	217	134						
Ecosystem	20	Include flora	8	6	6	3	2	9	4	2	2	6						
Ecosystem		Include fauna	2	6	5	3	3	7	5	2	3	4						
Ecosystem		Habitat quantity	5	6	5	3	2	9	5	2	2	6						
Ecosystem		Water filtering	2	5	5	2	1	7	3	1	1	5						
Ecosystem		Biodiversity	3	6	5	3	2	7	4	2	2	6						
			20	118	108	58	40	166	85	38	40	114						
Constructability	25	Material availability	14	3	6	8	4	8	9	8	6	8						
Constructability		Hydraulic fill needed	3	8	4	8	4	9	8	3	3	5						
Constructability		Toe extension	8	7	7	6	6	4	7	8	8	6						
Constructability		Feasible with drainage points (stormwater outlets)	0	8	8	6	4	8	7	4	6	8						
				25	122	152	184	116	171	206	185	157	175					
Costs	15	Material and construction costs	5	7	5	6	4	7	8	6	4	9						
Costs		Maintenance burden	5	5	6	8	5	6	8	5	9	2						
Costs		Service life	5	8	6	9	5	6	8	8	9	2						
				15	100	85	115	70	95	120	95	110	65					
Usability	10	Attractiveness	5															
Usability		Pedestrian accessibility	5															
			10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total	100		100	580	552	624	447	509	621	505	524	488						

Criterion type	Type weight	Criterion	Weight - middle part	Rock and block armouring			Armoured slope blankets			Engineered Soil Reinforcement and Drainage			Nature-based solutions						
				Riprap	Gabions	Concrete armour units	Grouted riprap	Geocells	Concrete block mattresses	Drainage system	Hydraulic fill	Vegetated riprap	Vegetation blank	Brush matresse	Afforestation				
Protection	30	Failure mech 1: rapid drawdown prevention	12	7	8	5	4	7	6	10	3	7	6	6	8				
Protection		Failure mech 2: wave and wind erosion prevention	7	8	8	9	9	6	9	3	4	7	5	5	4				
Protection		Failure mech 2: current erosion prevention	5	7	8	9	9	5	9	4	4	6	3	5	3				
Protection		Performance under extreme water-level variability	4	6	7	7	5	7	7	9	3	8	5	8	6				
Protection		External loads from land and water	2	7	8	9	8	6	8	7	5	6	3	5	4				
			30	213	236	214	192	191	224	211	106	207	148	174	171				
Ecosystem	20	Include flora	8	6	5	3	2	9	5	1	2	9	8	9	10				
Ecosystem		Include fauna	2	7	5	4	3	7	6	1	2	8	7	8	8				
Ecosystem		Habitat quantity	5	7	5	3	2	9	6	1	2	8	8	8	9				
Ecosystem		Water filtering	2	5	4	2	1	7	4	8	3	7	8	7	8				
Ecosystem		Biodiversity	3	6	5	3	2	7	5	2	2	9	9	9	10				
			20	125	98	60	40	166	105	37	42	169	161	169	187				
Constructability	25	Material availability	7	4	6	9	4	8	9	9	9	6	9	8	8				
Constructability		Hydraulic fill needed	4	7	4	8	4	9	8	10	3	7	9	9	8				
Constructability		Toe extension	7	7	7	8	6	4	7	3	5	6	3	3	2				
Constructability		Feasible with drainage points (stormwater outlets)	7	8	8	6	4	8	7	10	6	8	8	8	7				
				25	161	163	193	114	176	193	194	152	168	176	169	151			
Costs	15	Material and construction costs	5	7	5	6	4	7	8	9	4	7	9	7	8				
Costs		Maintenance burden	5	5	6	9	5	6	8	7	8	6	7	7	6				
Costs		Service life	5	8	5	9	5	6	8	7	8	6	4	8	8				
				15	100	80	120	70	95	120	115	100	95	100	110	110			
Usability	10	Attractiveness	4	6	7	5	4	7	7	6	5	9	9	9	7				
Usability		Pedestrian accessibility	6	3	6	3	5	7	7	4	3	5	8	3	3				
			10	42	64	38	46	70	70	48	38	66	84	54	46				
Total	100		100	641	641	625	462	698	712	605	438	705	669	676					

Appendix G

Material costs estimation slope

Slope part	Specification	required material	unit	material costs	transport cost	Total (ARS)	Total (euro)	Total (dollar)
hydraulic fill	sand	40651,8	m^3	\$363.061.225,80	-	\$363.061.225,80	€ 242.040,82	€ 280.767,35
geotextile	geotextile	28002,857	m^2	\$126.012.856,49	-	\$126.012.856,49	€ 84.008,57	€ 97.449,94
block mattress	concrete	2528,96913	m^3	\$397.048.153,36	-	\$397.048.153,36	€ 264.698,77	€ 307.050,57
block mattress	PP rope (16mm)	244994,3744	m	\$220.249.942,61	-	\$220.249.942,61	€ 146.833,30	€ 170.326,62
toe anchor	riprap	3814,2	m^3	\$223.740.972,00	\$381.420.000,00	\$605.160.972,00	€ 403.440,65	€ 467.991,15
crest anchor	backfill sand	60	m^3	\$16.800.000,00	-	\$16.800.000,00	€ 11.200,00	€ 12.992,00
block mattress	vegetation soil	58,5294957	m^3	\$16.388.258,80	-	\$16.388.258,80	€ 10.925,51	€ 12.673,59
block mattress	rounded gravel	1307,158737	m^3	\$95.422.587,82	-	\$95.422.587,82	€ 63.615,06	€ 73.793,47
Drainage		12	m^3	\$1.884.000,00	-	\$1.884.000,00	€ 1.256,00	€ 1.456,96
Total							€ 1.163.147,6	€ 1.349.251,22
Prices	ARS	ref						
Dredge + transport	8931	(van 't Hoff & t Nooy van der Kolff, 2013)						
Geotextil	4500	(COSTOS - CIFRAS ON LINE, n.d.)						
Rope 16 mm	899	(Mercado Libre, n.d.)						
Riprap	58660	(Granite Rock Rip Rap 36", n.d.)						
Transport riprap	100000	(Granite Rock Rip Rap 36", n.d.)						
Fill soil/backfill sand	280000	(Sustrato Para Huertas Terraferil X 50 Dm3, n.d.)						
Fill gravel	73000	(PIEDRA PARTIDA X M3, n.d.)						
Concrete	157000	(COSTOS - CIFRAS ON LINE, n.d.)						
Slope dimensions	height	width		Fill soil mattress	holes in block area	solid part block		
blue zone	26	65			0,027870912	0,065032128		
green zone	26	65			covered area	open area		
	depth	length			12514,85708	15487,99992		
blue zone	70,00714249	150		ropes	total vertical rope	total horizontal rope		
green zone	70,00714249	250			163329,583	81664,79148		
	angle	-			total rop	-		
blue zone	21,8				244994,3744			
green zone	21,8							
Concrete block	length	width		riprap	depth	width		
	0,305	0,305			1,63	5,85		
	n blocks x-axis	n blocks y-axis		trench	depth	width		
	1166,520852	204,1619787			0,3	0,5		
	height	space between blocks		Hydraulic fill	fill needed	vertical settlement		
	0,1143	0,0381			38716	1,05		
	n blocks needed	-						
	238159,2052							
Drainage	pipe diameter	wall height						
	0,4	1						
	wall width	wall thickness						
	4	0,5						
	wall volume	n walls						
	2	6						
	total volume							
	12							

Appendix H

[Link to autoCAD file final concept](#)

Appendix I

Implementation Roadmap

