Delft University of Technology

CIE4061-09 Multidisciplinary Project

Preliminary design of a marina in San Antonio Este

For recreational and touristic uses, and a nautical connection with San Antonio Oeste

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Abstract

This design report presents the outcomes of a multidisciplinary project undertaken by a team with diverse backgrounds in civil engineering. The project focuses on a preliminary design for a new marina in San Antonio Este, Argentina, with the purpose of serving as a recreational spot and a terminal for a nautical connection to San Antonio Oeste. Recreational activities include whale watching and swimming with sea lions. Sustainability is a key guiding principle, aiming to blend the marina with the natural environment and add value to the region.

The report starts with an introduction outlining the project's background, goals, and scope, followed by a detailed methodology for the design process. The area study section highlights the environmental and hydrometeorological conditions of the project location, emphasizing the challenges posed by a significant tidal range. It also discusses the choice of a water bus stop location in San Antonio Oeste and provides recommendations for further data collection and development.

The design stage presents the chosen preliminary design, detailing the pier, floating pontoon, gangway, mooring field, and boat ramp. Finally, the need is noted for more precise data, environmental assessments, and geotechnical investigations to improve the design.

Preface

In this report, the findings and outcomes of our multidisciplinary project are presented. This collaborative project involved team members with diverse backgrounds in the field of civil engineering. Jip Nooy van der Kolff specialized in geotechnical engineering, Coen Rijna, Femke Middeldorp, and Lisanne Kluft in structural engineering, and Rosita Vos in hydraulic engineering.

The project is centered in San Antonio Este, a tiny city located in the Argentine province of Rio Negro. The primary objective of this project was to develop a preliminary design for a new marina in San Antonio Este. This marina holds dual significance, serving as a recreational hub while also acting as a terminal for a nautical connection to San Antonio Oeste.

Notably, the marina being close to the habitats of whales and sea lions shows the importance of maintaining the natural environment. Sustainability was a key guiding principle throughout our design process, ensuring the creation of a functional marina that harmonizes with the environment and adds value to the area. To come to a feasible design in such a complex environment, a systematic approach was adopted, including an area study, a stakeholder analysis, a market study, and much more. In addition, the team undertook a research trip from Buenos Aires to the project site, for several days. This visit provided valuable insights and data crucial to our project's success.

This multidisciplinary project (15EC) was part of the second-year master's program of civil engineering at the TU Delft. We would like to thank our supervisors J.R.(Roelof) Moll, P.W.C. (Paul) Chan, Pablo Arecco and Bruno Maggiolo for their guidance and support throughout the project. We also want to thank Niek Boot and all involved parties who helped us during the process of the project.

Buenos Aires, October 2023

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Acronyms

MDP: Multidisciplinary project
SAE: San Antonio Este
SAO: San Antonio Oeste
MSL: Mean Sea Level
LAT: Lowest Astronomical Tide]
MCA: Multi-criteria analysis

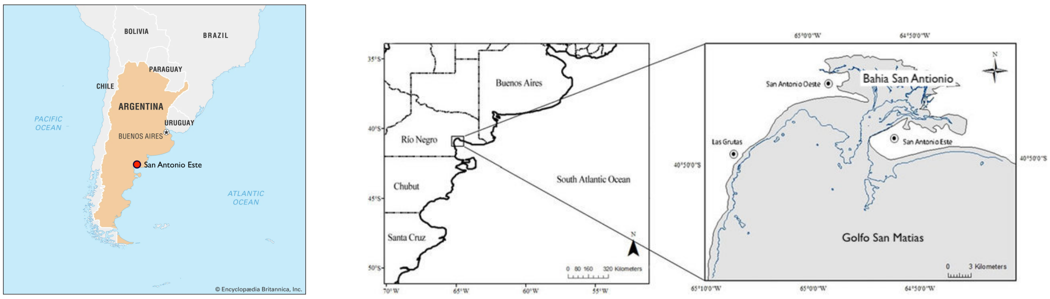
1 | Introduction

This introduction will give some background information about the project and the reason for setting up this research. The goals and the corresponding scope will also be described.

1.1 Project description

1.1.1 Bahía San Antonio

In the heart of Argentina, in the province of Rio Negro, lies the town of San Antonio Oeste (West), with a population of approximately 17,000 residents (Wikipedia contributors, 2023). It is situated on the shores of the Bahía San Antonio, and its main economic activities revolve around fishing, mineral exploitation, and tourism. The harbour of San Antonio Oeste, under the name Punta Verde, was the leading port for the large wool export industry of Patagonia. However, the collapse in the wool market during the 1930s and 1940s led to the port's closure in 1944, where only minimal fishing activity remained. This would be the case until a new deep-water port, San Antonio Este, was inaugurated on the eastern bank. The deep-water harbor on the east bank of San Antonio Este is a crucial part of the city's economy, primarily exporting fruits from the upper Río Negro valley, known for apple and pear production. The port features four berths, two on the pier for ocean-going vessels, and two on a floating landing stage near the causeway, with varying depths to accommodate different types of vessels.



(a) San Antonio Este within Argentina

(b) The location within province of Rio Negro, including the bahía San Antonio and the Golfo San Matias

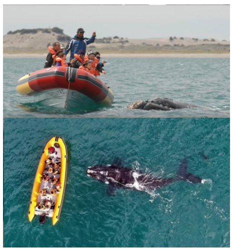
Figure 1.1: The location of San Antonio Este on the map

1.1.2 Recent developments in the area

Growth of tourism

A growing commercial source of income in the town and the area is tourism. Close to San Antonio Oeste lies the touristic town Las Grutas, which is known for its beaches. The beaches close to San Antonio Oeste and Este are quieter alternatives, where nature lovers can make large walks "on the ground of the sea" as Bahía San Antonio loses nearly all its water when the tide is low. A great attraction to tourists in the area is the nature and wildlife. Sea lion colonies live close to San Antonio Este, with groups consisting of about 30 or 40 lions, lying on the beach or sandbar that emerges at low tide. A trending activity is swimming with them. Close to Las Grutas, people can go scuba diving in the Parque Subacuático Las Grutas, and finally, guided whale watch tours take place in the Golfo San Matias.

(a) A busy day on the beach of Las Grutas



(b) Whale watching in Golfo San Matias

(c) Sea lions near SAE

Figure 1.2: Various touristic activities in the area of SAE

Over the years, the number of tourists visiting the area has significantly increased, from 190,000 tourists in the 2004/2005 season to 410,000 tourists in the 2019/2020 season, marking more than a doubling in the past 15 years (Andrini, Arecco, Cucci, & Veleda, 2021). In the years 2020/2021, approximately 200,000 tourists visited the area. Even during the pandemic period with COVID-19-related restrictions, the number of tourists coming to the area remained substantial, reaching approximately 286,500 tourists in the 2020/2021 season. In surrounding beach towns like Bahia Blanca, Viedma or Puerto Madryn, nautical clubs have been opened which can host up to 120 vessels per city. The cities have active yacht clubs and organize regattas and events that attract many people.

Declining Export

While the tourism industry has reached very high levels in the area, the existing port has experienced a significant drop in export volumes, primarily attributed to the fruit segment's loss of competitiveness and underlying sectoral weaknesses (Andrini et al., 2021). Historically, cargo movements peaked at nearly 660,000 tons in 2005 but gradually declined to 200,000 tons in 2020—a 70% decrease. This decline severely impacts the financial stability of the port, reducing its revenue streams and economic contributions to the region.

1.2 Redevelopment of the area

The recent developments in the area as described above, have motivated the government of the province of Río Negro, through the Ministry of Production and Agro-Industry, the Ministry of Tourism and Sports, and the Bioceanic Corridor, to initiate a Technical Study to examine the feasibility of a possible proposal for the "Comprehensive Development of the Port of San Antonio Este: Development of a Logistics Fisheries and Nautical Sports Hub" (Andrini et al., 2021). This development would encompass the establishment of a marina and a connection between San Antonio Oeste and San Antonio Este. The marina would play into the recent developments in the area by:

- Providing storage for vessel owners in the area. Currently, there are very few to zero facilities to store vessels in the area. In Las Grutas, the construction of a marina is not possible because of the hydraulic conditions.
- Supporting touristic companies by offering them a haven for vessels. This eliminates the need to get vessels out of the water for every new group of tourists, especially in challenging locations like Bajada 3.
- To create employment opportunities: The declining trend in fruit exports has led to a need for alternative employment possibilities. The marina has the potential to boost the local economy and support livelihoods by offering employment opportunities in various roles.

In addition, the connection between SAE and SAO would be very valuable, because it:

- Promotes eco-tourism in the area, thus creating awareness of the precious natural environment among more tourists. For example, it would be much easier for tourists from Las Grutas to visit San Antonio Este and the surrounding beaches, but the connection would prevent SAE from becoming overly commercialized, safeguarding the natural beauty of the region.
- Improves the efficiency of transportation: presently, people commuting between San Antonio Oeste and San Antonio Este face a 70-kilometre road journey. For port workers, who currently drive around the entire bay by car or through a bus connection, the water connection would significantly reduce travel time.

1.3 The multidisciplinary project

The technical study was performed by Besna, an engineering firm in Buenos Aires, which wrote several reports on the matter. Through Pablo Arecco, who is working for Besna as well as for the University of Buenos Aires and the TU Delft, a group of 5 students was contacted to perform a multidisciplinary project with as goal of creating a preliminary design for a marina in San Antonio Este. This research performed by this group as well as the final preliminary design for a marina lies before you.

1.4 Scope

The main goal of the project is to deliver a preliminary design of a new marina in San Antonio Este. This marina will be designed mainly for recreational purposes, but must simultaneously act as a terminal for a future connection to San Antonio Oeste. The detailed design of this connection is outside of the scope of the project, but the size of the vessel of this connection will be indicated based on the needs of the area. The design of the recreational part of the marina will be based on the requirements of the stakeholders since they will be making use of the marina in the future. Our objective is to design a port that suits the users. Our preliminary design will contain visuals, some calculations, and a small business case of the offshore area. Our focus will lie on the needs of the stakeholders and the technical possibilities of the area, this includes the nature around the marina. Minimising the harm to the environment is a high priority. The onshore area will only be developed in a conceptual layout, based on the requirements and constraints.

2 | Methodology

The process of designing a marina demands a systematic and comprehensive approach to ensure the creation of a functional, aesthetically pleasing, and economically feasible structure. The following methodology outlines the step-by-step process for the design of the marina.

2.1 Research stage

2.1.1 Area study and site visit

A detailed study of the area, considering geographical features, climate, and environmental factors, was conducted. Additionally, a three-day visit to the area of SAE was organized to gain a better understanding of the local culture and the motivations for the wanted redevelopment.

2.1.2 Stakeholder analysis

Extensive research with stakeholders, including local residents, businesses, environmentalists, and government bodies, was undertaken. This facilitated a thorough understanding of their concerns, expectations, and contributions to the marina project.

2.1.3 Philosophy: sustainable development

A design philosophy was formulated based on the gathered insights. Emphasizing sustainability, community integration, and economic growth, this philosophy served as the guiding principle throughout the design process.

2.1.4 Market study

A comprehensive analysis of market demands and trends related to maritime tourism, recreation, and commercial activities was conducted. This study helped identify potential users and their specific requirements for the marina facilities.

2.1.5 Deriving functional requirements

Insights from the area study, stakeholder analysis, and market study were synthesized to establish clear and detailed functional requirements for the marina. These requirements formed the foundation for the subsequent design stages.

2.2 Design stage

2.2.1 Development of three layout alternatives (conceptual level)

Three distinct layout alternatives for the marina were conceptualized, each reflecting different design approaches while meeting the defined functional requirements. These alternatives served as the starting point for the evaluation process.

2.2.2 Multi-criteria analysis (MCA) using experts

Experts in maritime engineering, environmental sustainability, architecture, and community development were engaged. A multi-criteria analysis (MCA) was conducted, evaluating the layout alternatives based on predetermined criteria, such as functionality, sustainability, and aesthetics.

2.2.3 Selection of design

The most suitable design, aligned with the project's philosophy and stakeholder expectations, was chosen based on the results of the MCA. The chosen design formed the basis for the subsequent development stages.

2.2.4 Integration of useful aspects from other designs

Valuable elements from the alternative designs were identified and integrated into the chosen design. This process ensured that the final design was optimized, incorporating the best aspects of each alternative.

2.2.5 Transition from conceptual level to preliminary design

Detailed structural designs were developed for the marina pier and ramp, considering materials, loads, dimensions, and sustainability. Simultaneously, a conceptual design for the land area was created, featuring an overview map, precise functional allocations, building dimensions (to scale), vivid artistic impressions, and detailed descriptions of integrated functions.

2.2.6 Final product - preliminary design

The culmination of the process resulted in the presentation of the preliminary design. This included a detailed structural design of the pier and ramp, specifying materials, load calculations, dimensions, and cost estimates. Additionally, the conceptual design of the land area was presented, providing a clear vision of functional zones, building dimensions, artistic impressions, and descriptions of integrated functions.

3 | Area study

The area study investigates the characteristics of the environment in which the project will be implemented. Elaborating these aspects results in physical requirements that the new design must meet.

3.1 Design location

After consulting with several stakeholders, the area that can be used as a design area was determined. It runs from a fence approximately 140 metres west of the residential home of Agustín Sánchez (one of the stakeholders, see section 4.3) to a small group of trees, approximately 200 metres east of the house. In figure 3.1 the onshore design area is depicted. It was shortly considered to use the sandbar as a base to build the marina on, but the conclusion was quickly drawn that this was not a possibility. The sand might not be strong enough to provide adequate support. Also, as can be seen in figure 3.7, the area onshore at the level of the sandbar is a "Zona Primitiva", which means that human intervention needs to be minimized. This is an area where shorebirds and sea lions are present, and an area that is sensitive to impacts derived from human activities, mainly in the intertidal zone (Gobierno de la Provincia de Río Negro, 2013).

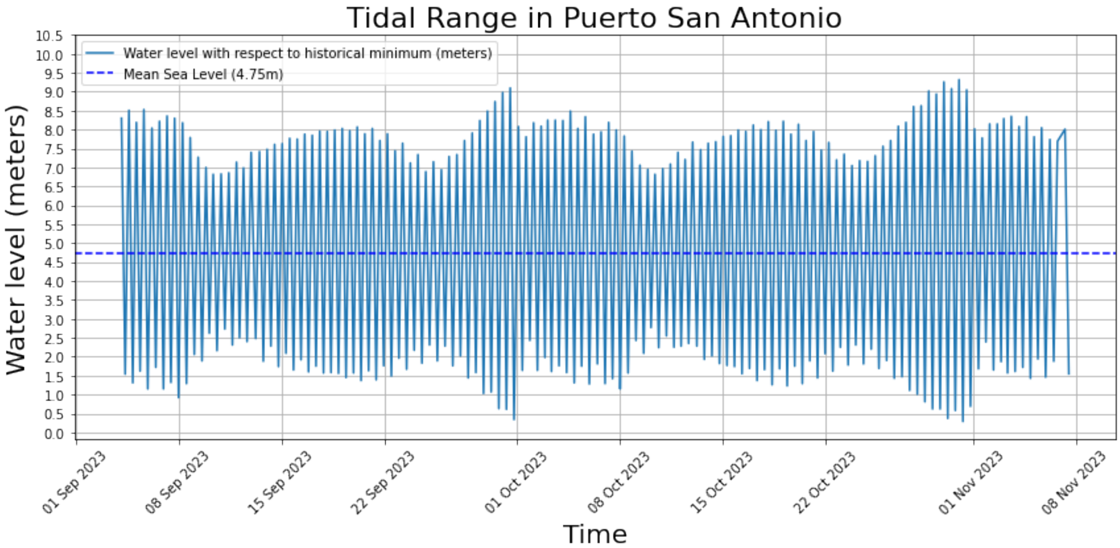
Figure 3.1: Borders of the onshore design area (*Google Earth*, 2023)

3.2 Hydrometeorological conditions

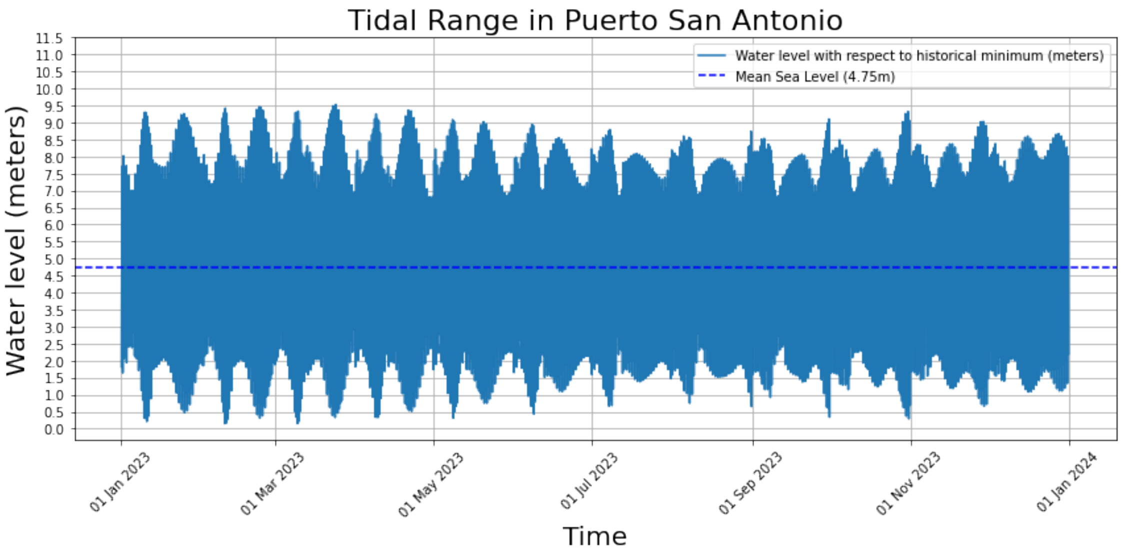
Hydrometeorological conditions are to the atmospheric and weather-related factors that are influenced by both the presence of water (hydro) and the atmosphere (meteorology). Different aspects are elaborated.

3.2.1 Tidal character

Bahía San Antonio is a bay with a tidal character of mixed, mainly semi-diurnal components. This implies two high waters and two low waters can be observed daily. The diurnal component can be noticed by the daily inequality, resulting in a different tidal range every day. The tidal range in this bay has an average amplitude of around 6 metres but can reach amplitudes higher than 9 metres. The extreme and mean tidal amplitudes of the years 2022 and 2023 are given in A.1 (Servicio de Hidrografía Naval, 2023). The tidal behaviour can be observed in the bay by the beach ridges and the tidal channels. In figure 3.2 the tidal range is plotted for two periods of time: the period of the project and the whole of 2023.



(a) Tidal range in Puerto San Antonio during the period of the project



(b) Tidal range in Puerto San Antonio in 2023

Figure 3.2

The big tidal range also has an influence on the current speed. There is no data available about current speeds, so an indication will be made. This will be done based on a high tidal range and the movement of the water level having a sinus shape. This is combined with an amplitude of 4500 metres and a period of 12 hrs. Taking the maximum slope gives a maximum current speed of 0.65 m/s. Because this is a rough estimation and lots of factors are not taken into account, a safety factor of 2 is added to the estimated value. So, the maximum current speed is estimated at: $2 \times 0.65 = 1.3$ m/s.

3.2.2 Bathymetry

The bathymetry of the area of Bahía San Antonio can be found in figure A.5. The bathymetry of the design area is obtained from the Official Nautical Chart(Servicio de Hidrografía Naval, n.d.) and Navionics (Navionics, 2023). The official nautical Chart is the most reliable data for the bathymetry of this area. As figure A.6 shows, both maps are the same so both sources can be used as data. Navionics works with depth lines as shown in figure 3.3, making it more accurate to work with.

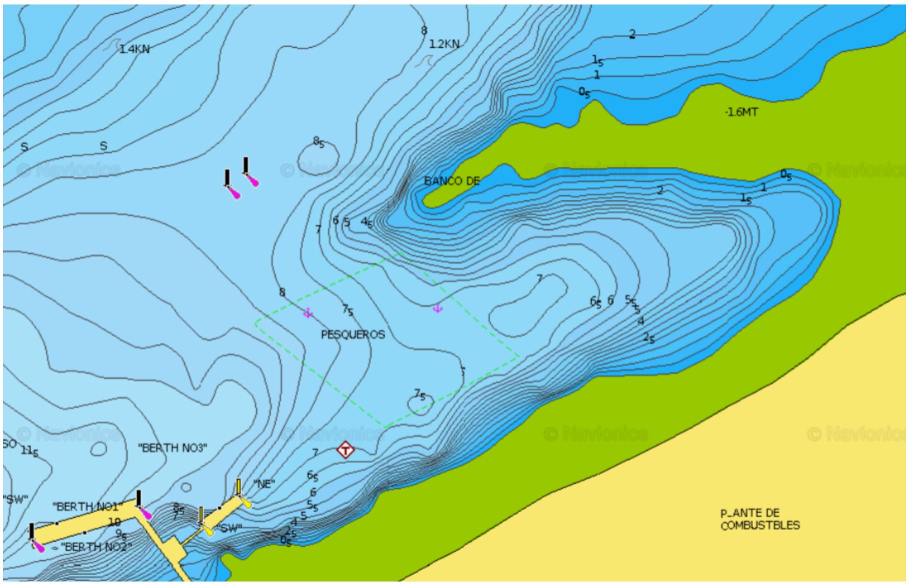


Figure 3.3: Bathymetry at SAE

The bathymetry map of Navionics uses the MSL (Mean Sea Level) as a reference level and indicates the depth beneath it. The bathymetry is combined with elevation profiles obtained from *Google Earth* to get a clear overview of the area in 3D, given in figure 3.4.

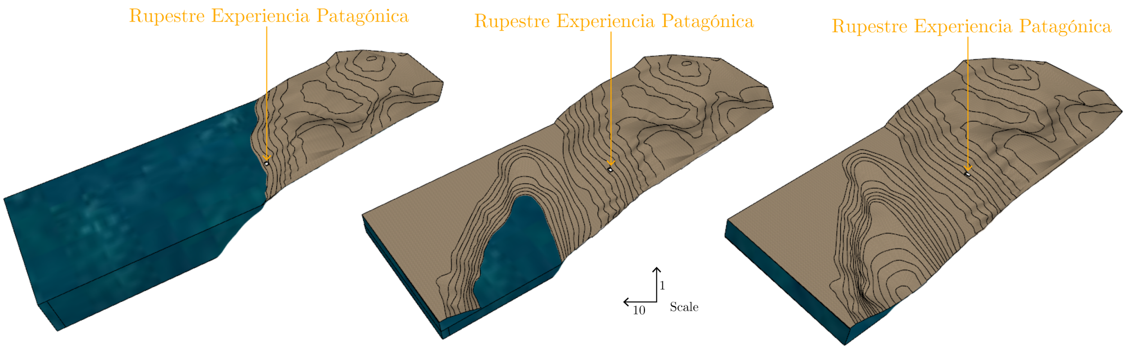


Figure 3.4: Showing the 3D area respectively during high tide, low tide, and without water.

The high tide and low tide are also shown in the figures. The water levels used in the design of the marina are the lowest and highest water levels observed from the tides in 2023, respectively 0.15m and 9.53m with respect to LAT(Lowest Astronomical Tide). These numbers can be found in figure A.2. The tidal range table uses the LAT as a reference level. This information can be combined with the 3D area to obtain the water level, using the equation given below.

$$\text{water depth} = \text{bathymetric level} - 4.75 + \text{tidal water level} \tag{3.1}$$

3.2.3 Wind conditions

Bahía San Antonio is protected by waves created outside the bay due to peninsula Villarino, the peninsula in which San Antonio Este is located. This protection doesn't apply to wind coming from the west, which can lead to a more extreme wave climate. (Andrini et al., 2021) The wind conditions at the bay are shown in A.3. It can be observed the wind is coming from the West and North directions the majority of the time. The monthly charts show that the summer months have less high wind speeds than the winter months. The longshore current in Bahía San Antonio is anti-clockwise, meaning the longshore current at San Antonio Este is to the northeast. This circulation occurs due to the beach being located from SW to NE and the strong western winds. These winds generate waves with relatively big wave heights entering at a high angle on the beach, stimulating the longshore current (Paula Nogueira Machado Schffer, 2023). The longshore and tidal currents can cause sedimentation or accretion. A.9 provides an overview of the areas where accretion or sedimentation has occurred over the past years. The big tidal range can create strong currents during changes in tide.

3.2.4 Wave conditions

There is no data on wave heights in Bahìa San Antonio. To be able to make a design, estimations have to be made. The significant wave height and wave period can be estimated using the average water depth, the effective fetch, and the corresponding wind speeds according to (Velzen, Beyer, Berger, Greese, & Schelfhout, 2007). Swell waves will be neglected, due to the sheltered position of the bay. Only the most favourable conditions for generating waves will be taken into account. These conditions occur during high tide and high wind velocities coming from the West. This direction has the longest fetch and can therefore create the highest wind waves. This is also the reason for extreme events only occurring during high tide. The fetch is interrupted during low tide by sand bars, resulting in less high waves. The main fetches of WNW(West North West), W(West), and WSW(West South West) are respectively 10.5 km, 15 km, and 22.8 km (see figure A.7). The highest wind velocities of WNW and W are taken into account. Waves generated by wind coming from WSW, approach the coast at an angle of almost 90 degrees. Even though the fetch of this direction is the longest, the wave height will be reduced a lot by the time it reaches the marina due to refraction and shoaling. Because of this processes, this direction will not be taken into account when observing the highest wave conditions.

Figure 3.5: Fetches (*Google Earth*, 2023)

The four highest wind velocities measured at the site will be used to calculate the corresponding wave characteristics. These velocities are 19, 28, 38 and 50 km/h. The depth used for the calculations is the average depth in front of the location of the marina during the spring tide. The depth is therefore set on: 7-4.75+8 = 10.25 metres. The effective fetch takes into account the fetches around the main wind direction. The fetches with the corresponding angles are the input for the equation given below.

$$\mathrm{F_e} = \frac{\Sigma R(\theta) \cdot \cos^2 \theta}{\Sigma \cos \theta} \tag{3.2}$$

The effective fetches are 8.21 km for WNW and 12.27 km for W. The depth and fetch are made dimensionless, so the dimensionless wave heights and wave periods can be calculated.

$$\widetilde{\mathrm{F}} = \frac{\mathrm{Fg}}{\mathrm{u}^2} \tag{3.3}$$

$$\overline{\mathrm{d}} = \frac{\mathrm{dg}}{\mathrm{u}^2} \tag{3.4}$$

$$\widetilde{\mathrm{H}} = 0,283 \operatorname{tgh}\left(0,35\widetilde{\mathrm{d}}^{0.75}\right) \operatorname{tgh}\left[\frac{0,0125\widetilde{\mathrm{F}}^{0.42}}{\operatorname{tgh}\left(0,35\widetilde{\mathrm{d}}^{0.75}\right)}\right] \tag{3.5}$$

$$\widetilde{\mathrm{T}} = 2,4\pi \operatorname{tgh}\left(0,833\widetilde{\mathrm{d}}^{0,375}\right) \operatorname{tgh}\left[\frac{0,077\widetilde{\mathrm{F}}^{0,25}}{\operatorname{tgh}\left(0,833\widetilde{\mathrm{d}}^{0,375}\right)}\right] \tag{3.6}$$

These dimensionless wave heights and wave periods can eventually be converted into the actual estimations using the equations given below.

$$\widetilde{\mathrm{H}} = \frac{\mathrm{H}_{\frac{1}{5}}\mathrm{g}}{\mathrm{u}^2} \tag{3.7}$$

$$\widetilde{\mathrm{T}} = \frac{\mathrm{T}_{\frac{1}{5}}\mathrm{g}}{\mathrm{u}} \tag{3.8}$$

The highest expected significant wave heights and wave periods are shown in A.4. The corresponding wavelengths are also shown using 3.9.

$$L = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L}\right) \tag{3.9}$$

The hours of exceeding a wind speed during a year gives the probability given in the graphs. However, these conditions assume the highest wind speed in combination with a high tidal amplitude during high tide. So the exceedance probability of these conditions is lower than indicated in the graphs. Another factor that reduces the probability is the sand banks located in the given fetches. These fetches are below sea level during high tide but can still cause shoaling, which reduces the wave height. A wave also needs approximately an hour to develop completely over the maximal fetch. These factors make the probabilities of exceedance even lower. Conditions that could increase the water level, and therefore change the water depth, are sea level rise and storm surge. These changes are expected not to change as much as it has a big influence on the wave conditions that are estimated.

3.3 Geotechnical conditions

Geotechnical conditions explain the physical properties and conditions of the soil at the invested area.

3.3.1 Geology

The area of study is shown in a geological map in figure 3.6, which was published by Segemar, the institute of geology and minerals in Argentina (Gobierno de la Provincia de Río Negro, 2013). For the project, three stratographic areas are important to consider as they are on or near the location of the marina:

- **nr 15. San Antonio Formation**: Sands and gravels with varying presence of shells.
- **nr 12. San Matías Beacon Formation**: Formation created in a marine environment. It consists of two rock types: conglomerates, which are sedimentary rocks made up of rounded or angular clasts (fragments or pebbles) that are larger than sand-sized but can vary in size, held together with sandy matrix (1) and coarse conglomerated sandstones with pebbles and shells (2).
- **nr 22. Eolian Deposits**: Fine to medium sands, deposited through wind to form dunes. sands and gravels with varying presence of shells.

Looking at figure 3.6, one can conclude that at the location of the possible marina, the San Antonio formation can be found. On the other hand, looking at each of the possible locations of the water bus pier on the west side of the bay, one can see that either the more rocky San Matías Beacon Formation or the more sandy Eolian Deposits can be found. This could be of importance for the construction of a foundation for a pier.

A more geomorphologic aspect of the bay that can be identified is the tidal flat, containing mostly fine sediment depositions. These tidal flats can be found in the whole bay. The sediments enter the bay as the tides change and partially block it, turning it into an intertidal mudflat with a dense and branching network of tidal channels. Some of these channels are extensions of river channels.

Figure 3.6: Geology of the bay (Segemar, 1999)

3.3.2 Geotechnical investigations

In 2005, site investigations were performed (Vazquez, 2005) in order to derive geotechnical properties important for the construction of the pier at the ALPAT factory in San Antonio Oeste and the jetty of the deepwater harbour in San Antonio Este. A quick summary of the findings is presented in this section.

In the study about the jetty in SAE, results are presented of Standard Penetration Tests (SPT) and laboratory tests. In the SPT, a sample barrel is driven into the ground within a borehole using a standardized hammer weight. The measurement taken is the number of blows required to penetrate the sampler 300 mm (1 foot) into the ground. This is referred to as the blow count, denoted as N, and expressed in blows per foot (Verruijt, 2001). In this case:

1. Standard Penetration Tests (SPT):
    - Dynamic penetration resistance measurements were carried out
    - Blow count (N) was recorded
    - Drop hammer weight is 49 kg
    - Blow count was measured at a depth of 30 cm
2. Laboratory Tests to determine:
    - Moisture content (soil dried at 105-110 degrees Celsius)
    - Atterberg limits (plastic and liquid limits)
    - Particle size distribution
    - SUCS soil classification
    - Visual description of the samples
    - Soil parameters via triaxial tests

The SUCS (Sistema Unificado de Clasificación de Suelos) or USCS (Unified Soil Classification System) is a soil classification system used to describe the texture and grain size of soil. The classification system can be applied to most unconsolidated materials and is represented by a two-letter symbol (ASTM, 2017). An explanation of this system can be found in appendix B.1.
The soil investigation conducted by Vazquez (2005) consists of twelve tested samples (sondeo nº 1-13, with sondeo nº 12 missing). Although the sketch with the sample locations has been lost, a rough estimate can be made of the consistency of the soil in the area. For a detailed structural calculation of the foundation of the marina, tests need to be performed at the location of the marina. The vast majority of the soil is type SP or SM (or a combination). This means that most of the subsoil is made up of silty, poorly graded sand. Locally some silt lenses can be found, it is unclear whether these will have an impact on the strength of the soil after construction. The friction angle does not diverge much, and lies between 28°and 34°.

3.4 Natural Environment

The expansion of the marina must be harmonious with nature. During the MDP, it will be a top priority to explore the relationship between nature and the marina's expansion. Therefore, it is important to understand the different ecosystems and habitats of animals in the area. This knowledge ensures the protection of biodiversity and minimizes environmental impact, fostering a harmonious relationship between development and nature.

3.4.1 Nutrient-rich inter-tidal zones

Around and in the Bahia San Antonio, rich nature and wildlife can be found. The bay hosts many animal species that visit the area to rest, mate, or feed. Due to the characteristics of the bay, which are highly influenced by the large tidal changes, several macro and micro-ecosystems can be found. In tidal pools, various invertebrates and fish larvae and juveniles are often found, causing several seabirds to use the tidal area as a foraging ground. A lot of mussels can be found in the inter-tidal zone: although they may not hold significant economic value due to their size, they serve as a crucial food source and contribute to stabilizing the water quality in the environment. Various other invertebrates are also present in the bay, including scallops, oysters, oyster mussels, purple mussels, snails, and octopus, providing livelihood to local communities.

3.4.2 Birds

During spring and summer, several migratory birds from the northern hemisphere enter the bay, such as the Red Knot and the Sanderling, which nest in the region before heading back north. Additionally, species like the Chorlito de las Malvinas and the Snowy Sheathbill breed in Argentina and migrate northward in winter. Many other coastal and seabird species use the bay as a resting place or foraging ground, including flamingos, various tern species, and the Neotropic Cormorant. Some also breed in the area.

3.4.3 Fish

Most of the fish larvae and juveniles in the Bahia San Antonio that serve as food for the birds are spawned by dominant fish species including sea bream, Patagonian blenny, silverside, yellowtail silverside, southern silverside, silverside, and anchovy. Other fish species that are of commercial importance in the area are hake, elephant fish, flounder, mullet, zebra perch, rock cod, croaker, and sea bream. Anchovy, in particular, holds importance both in terms of abundance and its role as prey for other species. The Patagonian seahorse is a vital species for conservation, inhabiting the warm to temperate shallow waters in the bay. Their populations, while localized, play a significant role in the ecosystem. They face threats from habitat destruction due to coastal development.

3.4.4 Mammals

The marine mammal population in the Golfo San Matías, especially within the Bahía San Antonio area, has received the most attention throughout the years. Not only has it been the focus of research since the late 1980s, but it also is one of the main reasons why the region attracts tourists. One of the most common and visible species in the bay is the fur seal, often observed as individuals or groups of mostly young males during the spring and summer. Younger male fur seals tend to inhabit the western area of the Villarino Peninsula and the Reparo Bank. Interestingly, recent evidence has shown that these areas are also used for breeding purposes, as isolated births of fur seal pups have been recorded. Another significant species is the bottlenose dolphin, which forms relatively stable groups throughout the year, including those with calves. Their presence in the shallow waters of the bay suggests that these areas are favorable for calving and raising their young. Bottlenose dolphins primarily feed in the region around the bay's entrance, Banco Reparo, and Las Grutas during high tide. This highlights the importance of the bay's environment as both a foraging ground and a crucial habitat for the various life stages of these dolphins. Common dolphins and dusky dolphins, as well as certain whale species, are generally spotted in the outer regions of the bay or near its entrance. However, the irregularity of their presence and their mobile nature limit their role as environmental quality indicators. Notably, the franciscana, also known as the Plata dolphin, is a critically important species within the Golfo San Matías. Its southernmost distribution limit is within this gulf, making it a vital habitat for these small dolphins. The franciscana is classified as vulnerable by the IUCN, reflecting its endangered status in South America. Some of these marine mammals are permanent residents of the gulf, while others visit periodically or are exceedingly rare.

3.4.5 Legal framework

In the past, the different species that inhabit the area or visit the area frequently have been identified and studied by biologists and governmental organisations. In the 'Plan de manejo área natural protegida bahía de san antonio', the provincial government has documented and classified each species, using different classifications from the following organisations: CARPF (Convention for the Conservation of Antarctic Marine Living Resources), IUCN (International Union for Conservation of Nature), CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), SAREM (South American Society for Research in Mammals). For this reason, the government of Rio Negro assigned different nature reserves. Since 1993, the protection of the area was enshrined in Provincial Law No. 2670 (Gobierno de Río Negro, 2019). The Secretariat of Environment and Sustainable Development (SAyDS) assigned different zones to areas of the protected Bahía San Antonio Protected Natural Area under different categories of use, which are established in its management plan. The main objective of these protected areas is to safeguard the reproductive and resting spaces of seabirds and natural processes without human interference. Certain bird species, such as the South American tern, are sensitive to human presence, and disturbances during the breeding season. This results in the abandonment of clutches, dispersion of chicks, and increased predation on them. In the so-called "Intangible Zones" of the area, permitted activities include surveillance, control, and monitoring by the authorized authority, as well as environmental research and monitoring by permitted equipment.

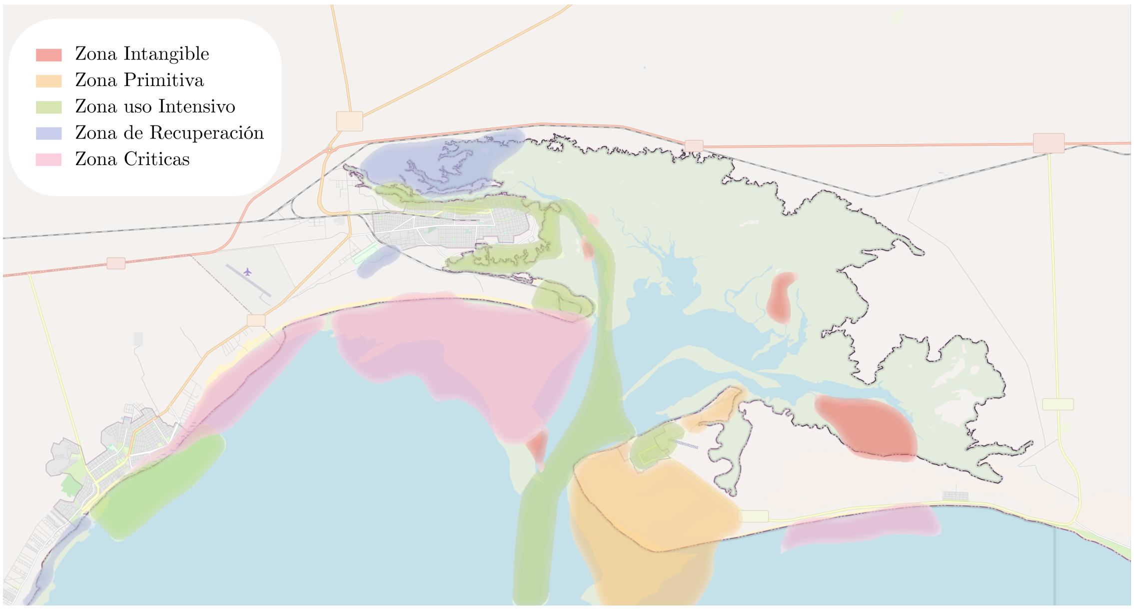


Figure 3.7: Zones with different levels of protection as assigned by the Secretariat of Environment and Sustainable Development

3.5 Conclusion

The designated area is determined to run from a fence west of Agustín Sánchez's residential home to a small group of trees to the east. Building on the sandbar was considered but ruled out due to inadequate support and environmental sensitivity. The study area experiences an extremely large tidal difference, reaching over 9 metres, impacting current speeds, estimated at a maximum of 1.3 m/s. Bathymetric data was collected from official nautical charts. The majority of winds come from the west and north, with the highest wave conditions expected during high tide and high wind velocities from the west. SPT and laboratory tests show a dominant soil type of silty, poorly graded sand, with a friction angle ranging from 28° to 34°. Many species live in the area, like birds, fish, sea lions, dolphins, and whales. This constricts the building permission in some areas.

4 | Stakeholder Analysis

The purpose of the stakeholder analysis is to identify, assess, and understand the various stakeholders who have an influence on the design of the marina. Through interviews with the various stakeholders, information is gained about the area of San Antonio. But also the interests of the stakeholders have become clear. In order to understand how decisions about a new marina design are made, the chapter starts with an explanation of the important actors in Argentina's governmental system.

4.1 Management model

For the development of a marina a Public Private Partnership, in short a PPP, is very important. Through a PPP arrangement the tasks and risks are divided between private and public parties (Arecco, Zivojnovic, & Veleda, 2019). There are different models that can be used for the management of a marina. The distinction between the models is based on who carries the financial risk, but also the financial gain. For the design of the marina in San Antonio Este, the choice is made for a fully privatized marina, since this will increase the flexibility in the design and it will make a concession agreement superfluous. Only the permits would be required from the government in this case.

4.2 Governmental system

4.2.1 National State Government

The highest power in Argentina is the Gobierno Nacional (National State Government). The National State Government is divided into three pillars; the executive power, the legislative power, and the judicial power. Within the executive power, the president of the nation acts together with the ministries. It's their task to enforce the laws made by the legislative power. The legislative power consists of two chambers, the Chamber of Deputies and the Senate. Their responsibility is writing, changing, and approving federal laws. The highest judicial power is the Supreme Court of Justice, which applies the laws and oversees the judicial branch throughout the country.

Ministry of Transport
Argentina has nineteen ministries. Three of them are important for the development of a marina in San Antonio Este; the Ministry of Transport, the Ministry of Environment and Sustainable Development, the Ministry of Tourism and Sports, and the Ministry of Security. The Ministry of Transport is divided into departments that are all responsible for different types of transportation. Within the Ministry of Transport, three entities are important for the new marina: the Administración General de Puertos (General Administration of Ports), the Subsecretaría de Puertos y Vías Navegables (Undersecretariat of Ports and Waterways), and the Direccion Nacional de Puertos (National Ports Directorate). The main responsibility of the General Administration of Ports is the direct management and regulation of the port of Buenos Aires (*Administración General de Puertos*, n.d.). The Undersecretariat of Ports and Waterways has a more overarching role with departments that deal with construction, logistics, and transport on waterways (*Puertos, Vías Navegables y Marina Mercante*, n.d.)(den Brave et al., 2022). One of those departments is the National Ports Directorate, which approves permits for construction at the waterfront (den Brave et al., 2022).

Ministry of Environment and Sustainable Development
This ministry has several secretaries concerning climate change, environmental planning and policies, waste management, sustainable water management, and enforcement of environmental laws (Argentina - Ministerio de Ambiente y Desarrollo Sostenible, 2023). Since the marina will be located in a nature reserve it is important to know what the environmental laws are, so they

can be obeyed. Important to note is that this ministry does not have to approve the plans for the design, since the nature reserve lies within the province´s jurisdiction.

Ministry of Tourism and Sports
The primary objective of this ministry is to foster growth in all regions of the country. In the tourism sector, they achieve this by enhancing tourist services nationwide (*Ministerio de Turismo y Deportes de Argentina*, n.d.). The new marina design will be a part of this effort. The approval of this ministry is not obligated in order to make the design a reality.

Prefectura Naval Argentina
The Prefectura Naval Argentina is a maritime authority that is concerned with maritime safety. It is a part of the Ministry of Security of the nation. Their approval is required regarding the vessel that will be used for the water bus in the bahía San Antonio(*Prefectura Naval Argentina*, n.d.).

4.2.2 Province of Río Negro

Argentine has twenty-three provinces with each their own authority divided into the same three pillars: executive power, legislative power, and judicial power. The executive power of Río Negro exists out of the governor and thirteen ministries or secretaries of state. From these ministries and secretaries of state, the following might be important regarding the development of the marina in San Antonio Este: the Ministry of Tourism and Sports, Secretary of Environment and Climate Change, and the Secretary of State of Planning (Gobierno de Río Negro, 2023).

The Ministry of Tourism and Sports has to give the license for the tourism activities in the marina. Since the nature reserve is owned by the province, the Secretary of Environment and Climate Change from the Province has to give the license for building in such a reserve and using it for certain purposes. For construction on the lands that are in provincial jurisdiction, the Secretary of State of Planning is the permit-issuing entity.

Corredor Bioceanico Norpatagónico
The Biocoeanic Corridor Norpatagónico refers to a transportation connection between the Atlantic Ocean and the Pacific Ocean. The main goal of the organisation behind it is the development of the Bioceanic Corridor Norpatagónico infrastructure by projects with sustainable development and environmental conservation as a premise. The Corredor Bioceanico Norpatagónico is a public-private partnership. Meaning that representatives from the province, as well as private entities, are on the board of directors of the organisation. This provides an advantage since the province is integrated into the project from the start. On a provincial level, this entity gives the approval regarding the water bus crossing the bahía San Antonio.

Regarding the marina in San Antonio Este, their aim results in them wanting this area to develop further and bring prosperity. Certainly, fruit export has been dropping tremendously over the years (Andrini et al., 2021). A marina in San Antonio Este that boosts the economy and creates jobs would fit their goal.

4.2.3 Municipality of San Antonio Oeste

According to Ley Provincial N Nº2353, Artículo 15 (Provincial Law N Nº2353, Article 15) municipalities are "independent of any other authority in the exercise of their own functions, enjoying political, administrative, and economic autonomy"(de la Provincia de Río Negro, 1990). Furthermore, Artículo 16 (Article 16) speaks of the job description of a municipality, which can be summarized as that they should do everything in their power to take care of their community on all fronts (de la Provincia de Río Negro, 1990). The municipality has multiple departments and the following need to be considered for the design of a new marina in the area: Undersecretary of

Commercial Control, Traffic and Transport, Tourism and Culture Agency, Secretary of Urban Planning and Development, and the Agencia de protección ambiental bahía San Antonio (San Antonio environmental protection agency) (*Gabinete Municipal - San Antonio Oeste*, n.d.).

The Undersecretary of Commercial control, traffic and transport will have to approve the plans regarding the addition of a water bus to the area. The Directorate of Tourism Service and Tourism Quality Control needs to approve the planned tourism activities that are included in the design of the marina. The secretary of Urban planning and development will have to issue the permit for the construction on land if the lands are in their jurisdiction. The Agencia de protección ambiental bahía San Antonio doesn't give any important licenses, since the nature reserve is not in their jurisdiction.

4.3 Non-governmental stakeholders

Terminal de Servicios Portuarios Patagonia Norte S.A.
This company is the manager of the Puerto San Antonio Este. Additionally, the port administration belongs to the Province of Río Negro and the regulatory entity is under the responsibility of the Corporación para el Desarrollo Portuario (the Port Development Corporation). The regulatory task is to make sure Patagonia Norte is adhering to the contract between the Province and Patagonia Norte.

The new marina results in a water bus going from San Antonio Este to San Antonio Oeste and the goal is to make San Antonio Este more attractive to recreational activities. This will make Bahía San Antonio more crowded, which makes it important to keep having transparent communication with Patagonia Norte S.A. about the ideas and developments of the new marina. The new marina should not interfere with the daily operations of the Puerto San Antonio Este. On the other side, the connection makes it easier for their employees to cross the bahía San Antonio. Therefore the new marina can also be seen as an advantage.

Local residents in the area
The local residents are the very reason the marina needs to include a water bus as well. From January till July (Andrini et al., 2021) the Puerto San Antonio Este is used for the export of fruit. The people working here currently use a bus service to bring them to San Antonio Este from San Antonio Oeste at 7 a.m. or 12 a.m. and to be brought back at 8 p.m. at night. This bus has to drive around Bahía San Antonio, which takes approximately an hour. Local residents told us that a service with a higher frequency would be beneficial for these port employees. The wish is for the bus to transport 50 passengers at a time. San Antonio Este itself is a small town that includes some restaurants and hotels. The people working here would also benefit from a faster and more flexible connection between the two cities.

Secondly, the marina could also be beneficial to local residents who own vessels but have no marina to keep their vessels in. Meaning that every time they want to use their vessel, they have to use a tractor and trailer to get their vessel in and out of the water.

Tourists
Tourists often stay in Las Grutas or San Antonio Oeste, but in order to enjoy the beautiful beaches and whale-watching tours they need to get to San Antonio Este as well. A quick transfer service would make this very easy for them. Additionally, a sailing route that starts in Buenos Aires and goes to the south of Argentina is much used by tourists (Sánchez & Giordano, 2023). Currently, they sail by San Antonio, but a marina in San Antonio Este would make it possible for these tourists to have a break here and stay the night. Moreover, the regatta is the third category of tourists that could benefit from the marina. The bahía San Antonio would make an interesting spot for a regatta race.

Parador Rupestre
Parador Rupestre is a company owned by Agustín Sánchez. He organises trips for whale watching and swimming with sea lions from San Antonio Este. Currently, he is the only tourist-based company in San Antonio Este, so he is most definitely interested in building a marina right at his doorstep. Currently, he doesn't have a berth to leave his vessels in the water during the day. They stay at a vessel trailer and once he needs a vessel he has a tractor to put the vessel in the water. People board the vessel just before the vessel is in the water and the tractor pushes it in and pulls it out. In high season this costs him a lot of time and effort and he would prefer a marina, so his vessel can stay in the water for the day. At night he would take them out because the salty water damages the vessel and makes the steel of the vessel deteriorate faster. The problem for Agustín is that he doesn't have the means to fund such a project on his own, so additional investors would be required (Sánchez & Giordano, 2023).

Tourist companies in Las Grutas
Las Grutas revolves around tourism. This is where other tourist companies are located. For example Cota Cero, a company that gives scuba diving tours and lessons, or Triton Tourism, a company that organizes different tours on land and in water. Las Grutas has one concrete ramp that all tourism companies use to put their vessels in the water with a tractor in a similar way as Agustín does for Parador Rupestre. The difference with San Antonio Este is that the beach of Las Grutas has a much more gentle slope, which means that it becomes even harder to pull the vessels in and out of the water. The second difference is the fact that the beach of Las Grutas is full of people during summer, which makes it unsafe when there are a lot of vessels that need to be pulled out of the water during low tide. During low tide, the concrete ramp can't be used, since it isn't long enough. These tourist companies located in Las Grutas could be the needed investors for the marina in San Antonio Este. This would be an opportunity for them because they wouldn't have to sail as far to the sea lions and they could leave their vessels in the water as well during the day (Sánchez & Giordano, 2023).

Fundación Inalafquen
Fundación Inalafquen is an organization that stands for environmental management and ecotourism. An important stakeholder to listen to when it comes to protecting the natural reserve and not harming the animals. The fear of this organization would be that the peaceful San Antonio Este would turn into another Las Grutas and that the natural reserve would be damaged. The water bus connection would contribute to their aim because it would result in fewer people driving to San Antonio Este by car and so fewer cars crushing the shells on the beaches in San Antonio Este. Also, the number of tourists would be more regulated this way. Additionally, adding the interpretation center to our design would educate tourists about the environment and the animals in the area. Since plastic garbage in the sea is a big problem in Bahía San Antonio creating awareness about this issue will help to solve it (Sánchez & Giordano, 2023).

Transporte Las Grutas S.A.
This company currently organises the bus that brings people from San Antonio Oeste to San Antonio Este and the other way around. Presently on weekdays, the bus from San Antonio Oeste to San Antonio Este leaves at 7 a.m., 12 a.m., and 7 p.m.. The bus from San Antonio Este to San Antonio Oeste leaves at 8 a.m. and 8 p.m. on weekdays. The only difference on weekends is that the bus from San Antonio Oeste to San Antonio Este at 12 a.m. doesn't go. Making a connection over water between the two cities will make this bus unnecessary, resulting in a decrease in revenue for this company. On the other hand, depending on the location of the terminal in San Antonio Oeste, a bus connection is possibly still needed to bring people from the center of San Antonio Oeste to the terminal. Additionally, the connection could be expanded by the bus company to include a bus from Las Grutas to the terminal in San Antonio Oeste. The connection might also create an opportunity for Transporte Las Grutas S.A. to broaden its horizon and organise the connection between the two cities over water (Clerico, 2023)(Sánchez & Giordano, 2023).

ALPAT
ALPAT produces sodium carbonate and has its factory in San Antonio Oeste by the water. Furthermore, ALPAT already has a big pier which currently has no use. In the future, this pier could be used as a terminal for the water bus to San Antonio Este. ALPAT made it clear that they see this as an investment and are motivated to give the existing pier a new purpose. Moreover, the company has security issues with the pier, meaning that often trespassers are spotted there. A problem they see disappearing once the pier has a new purpose. Furthermore, the pier was originally built as a means for them to receive limestone, a resource they use to produce sodium carbonate. Later a mine for limestone was found nearby, so the pier was left unused. Nowadays they found out the quality of limestone from the mine is quite low, so in the future, they still see the pier used for the transportation of limestone. Of course, it would come in handy if the pier is restored and ready to use by that time. Another advantage ALPAT sees in adding the connection over water from their pier. The benefits ALPAT sees could also persuade them to invest even more than only using their pier (Clerico, 2023).

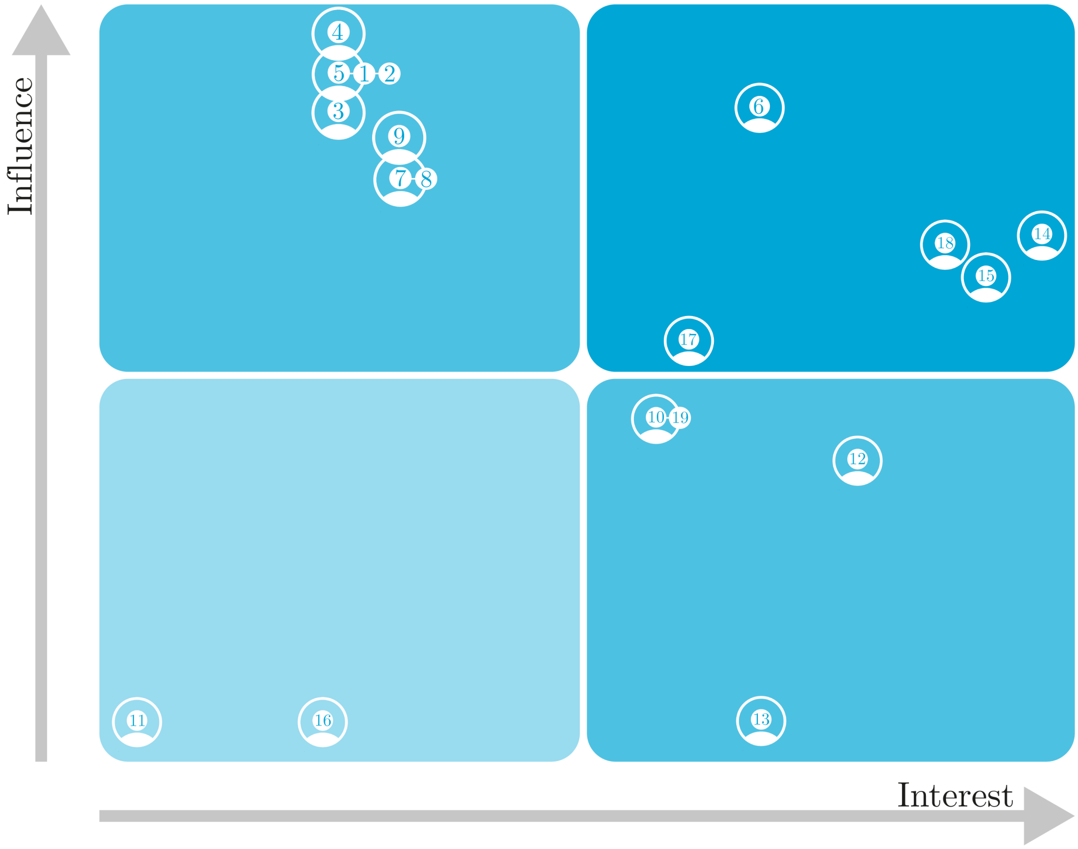
Private investors
It would be beneficial for the project if stakeholders with a considerable amount of interest also create influence by becoming an investor. These investors are explained above. There is a big chance more investments are required and independent investors need to be added as a stakeholder. In order to draw in private investors the project should be economically and financially feasible (Arecco et al., 2019). The business case should be appealing.

4.4 Stakeholder matrix

In order to clearly identify the stakeholders involved in the development of the marina design a stakeholder matrix is made. The explanation of the stakeholder matrix is given in the table in the Appendix C. In this matrix, a distinction is drawn between the degrees of interest and influence held by different stakeholders. Interest is defined as "potential interest in the programme outcomes" (Snowden, 2007). Interest can be determined by impact or accountability (ITtoolkit.com, 2023). When an outcome of the project has a lot of impact on the stakeholder, their interest is higher. Furthermore, once the stakeholder feels accountable for the project's outcome their interest is also higher. A stakeholder with influence is defined as "who has the power to make a difference" (ITtoolkit.com, 2023) and/or who is a part of the decision-making-process.

Based on the stakeholder analysis, it can be concluded that having government entities responsible for providing permits and approvals on board is essential for the realisation of the marina. They are placed in the upper left corner of the stakeholder matrix with the highest influence and are identified as the "approvers". Another important group of stakeholders for the realization and the design of the marina are the potential private investors and initial clients. They are placed in the right upper corner of the stakeholder matrix and are identified as the 'key players' for the design. The stakeholders in the right lower corner do have interest in the outcome of the design, but "who on the face of it they appear powerless" (Snowden, 2007). However, it is important to include these stakeholders in the stakeholder analysis, because once supported by a powerful advocate, their influence grows. They are identified as the "subjects". The stakeholders placed in the lower left corner are stakeholders that need to be updated on the progress of the project and are identified as the "crowd" (ProductPlan, 2023).

Concluding, the initial design is rooted in the preferences and requirements of the "key players", with due consideration given to the needs of the "subjects". Once plans for a design are made, the "approvers" come into play. It is smart to involve them earlier on, so the design can be based on their principals and within their boundaries. Currently the principles and boundaries of the "approvers" are not known, but this would be a wise next step to find out.



1. National Ports Directorate
2. Prefectura Naval Argentina
3. Ministry of Tourism and Sports of Río Negro
4. Secretary of Environment and Climate Change of Río Negro
5. Secretary of State of Planning of Río Negro
6. Corredor Bioceanico Norpatagónico
7. The Undersecretary of Commercial control, traffic and transport of San Antonio
8. Tourism and Culture Agency of San Antonio
9. The secretary of Urban planning and development of San Antonio
10. Agencia de protección ambiental bahía San Antonio
11. Terminal de Servicios Portuarios Patagonia Norte S.A.
12. Local residents
13. Tourists
14. Parador Rupestre
15. Tourist companies from Las Grutas
16. Transporte Las Grutas S.A.
17. ALPAT
18. Private investors
19. Fundación Inalafquen

Figure 4.1: Stakeholder matrix

4.5 Conclusion

Several important conclusions of this chapter will be taken into account when determining the requirements and making decisions for the final preliminary design. The need for a better connection with a higher frequency is there. This connection will be used mostly by tourists and locals who work and live on different sides of the water. There is also a desire to find a better solution to get the tourist vessels in and out of the water, especially during the high season. Next to the discomfort, these actions are also environmentally unfriendly. Shells are ruined during the process. Making people aware of garbage and having a central place in the area to manage the garbage could also make a positive impact on the environment, this is something the marina can also serve. In addition, the marina will be located in a nature reserve which is important to take into account. And finally, to involve private investors the project should be economically and financially feasible.

5 | Philosophy: the marina as a sustainable development

To create a design for the marina, it is important to consider factors that increase its value. Globally, increasing attention is given to sustainable development, which is a development that meets the needs of the present generation without compromising the ability of future generations to meet their needs (Jonkers & Ottelé, 2022). Sustainability is a principle that was guiding during the design process and served as the foundation to support the design choices. An investigation was performed during the design process, into the different possibilities to make a construction, specifically in the case of a marina, sustainable. For this investigation, each of the three main pillars that form sustainable development (1. Environmental protection and enhancement, 2. Social progress, and 3. Economic development (Jonkers & Ottelé, 2022) according to the Brundtland Commission) were studied. The conclusions and design choices following this investigation are presented below.

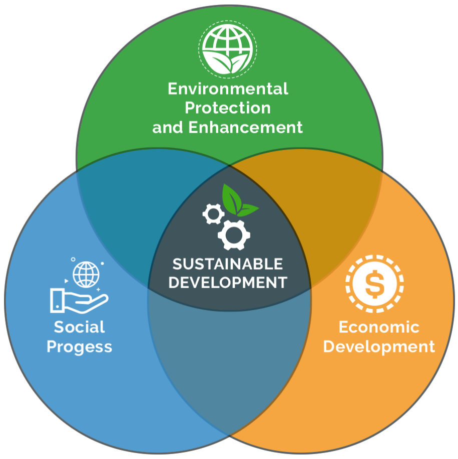


Figure 5.1: Sustainable development triangle (Arena Solutions, n.d.)

5.1 Environmental protection and enhancement

Environmental protection and enhancement focuses on preserving and enhancing the health of the planet. The marina will be located in a sensitive coastal ecosystem. The design must minimise the negative impact on this ecosystem. The following points that should be incorporated in the design were identified in the additional research in appendix D.1:

- In multiple ways, awareness should be created among tourists and visitors in the area about the ecologic value of the area. This should be done in the form of:
  - *An interpretation center* for the education of visitors through interactive exhibits, displays, educational programs, and trained staff to help them better understand and appreciate the significance of the surrounding environment.
  - *Educational signs* should be placed with information about local flora, fauna, and tidal conditions. These signs should also promote environmentally friendly behaviour in the area.
  - *Recycled items* should be added to the marina, like benches. Plastic pollution is one of the main causes of pollution in the area. An example of a company creating benches

from recycled plastic is Dangen from Neuquen, a town in the vicinity of San Antonio Este (Dangen S.A., 2023).

  - *Confrontation* should also be sought with visitors, meaning they should be confronted with the impact negative behaviour could have. A good example is the plastic-eating whale in Punta del Este, Uruguay (see figure 5.2.

- The use of appropriate building materials can make a difference in the environmental footprint. Over 35% of our global greenhouse gas emissions are attributable to the built environment. Sustainable forest management allows us to use timber while preserving forests by taking ecological and social, as well as economic factors into account. Sustainably sourced timber can store carbon, both in forests and in buildings. Therefore, the use of timber is advisable.

- Several options exist for using renewable and natural energy sources, but many of them are very expensive and therefore not considered feasible. However, due to the climate conditions in San Antonio Este, the use of solar energy could be possible, under the condition that investors with enough capital can be found to pay for the initial costs.

- Pollution in the area, especially by plastic, should be prevented as much as possible. Some measurements that are advised:

  - Managing waste in a proper way is vital to reducing pollution on beaches. Installing enough trash cans and making sure they cannot be accessed by animals in the area such as seagulls is a must.
  - A system for the collection, temporary storage, treatment, and proper disposal of sewage reduces contamination of seawater and should be built on one of the docks where vessels can lay temporarily.
  - Water taps with drinking water should be installed, as it reduces plastic bottles being used, with that plastic pollution of the beaches.
  - Therefore, the selling of single-use plastics should be prohibited in all shops and restaurants in the marina.
  - Light pollution should be avoided. Light pollution disrupts the natural rhythms of animals, plants, and humans. A solution is the Dark Sky strategy, which is to use efficient light fixtures with shielded cut-off lenses, and strategically place light only in areas that need to be lit. However, This is an option that should be included in the final design.
  - To reduce noise pollution, one could think of using sound-absorbing materials during construction, but also avoid moving parts in the design, which will create sounds when subjected to wind and wave loads.
  - Monitoring the ecological impact of the marina is essential because it helps understand the environmental consequences of the marina, allowing it to identify areas where improvements can be made to reduce harm to ecosystems, conserve resources, and minimize pollution. Monitoring can be done by installing gas analyzers at key emission sources, collecting water samples, and testing soil samples.

(a) Confronting visitors with their bad behaviour, like leaving plastic waste in the environment, could reduce the negative impact (own picture).

(b) Benches produced by Dangen, a plastic recycling company. These benches have previously been placed in

Figure 5.2: Several ways to increase awareness (Dangen S.A., 2023).

5.2 Social progress

The social progress in sustainability development aims to improve the quality of life for all individuals and communities within the marina. Points that should be incorporated in the design were identified in the additional research in appendix D.1:

- There should be spaces devoted to cultural events or recreational activities to contribute to a higher sense of community and a sense of ownership, which leads to higher participation and public support of the marina. Spaces like this could include:
  - Opportunities for residents to engage in recreational activities like boating, fishing, swimming, water sports, or wellness activities like waterfront yoga.
  - Cultural events like markets, movie nights, workshops, races, art exhibitions, tours, etc.
  - Well-designed public space where people engaging in the different marina activities can meet, wait, rest, or play, such as a park, viewpoint, or square.
- In the marina, there should be multiple opportunities for people to educate themselves. We discussed the improvement of awareness about the natural environment, but boating or sailing schools could be a great addition to increase navigational safety.
- A boat club could where vessel owners can gather should be built to create a sense of community, encouraging participation in various activities within and around the marina. Furthermore, it provides an environment for the exchange of knowledge among members.
- The marina should increase employment opportunities. Jobs created in our marina should include marina staff, vessel maintenance and repair professionals, hospitality and tourism workers, and suppliers of goods and services. This point is in line with the economic development section below.

5.3 Economical development

The design should promote the economic development of the area. This is one of the primary objectives of this study, as it increases feasibility. The biggest challenge concerning the feasibility is the financial viability. Therefore, it is vital to not only create a functional design but also to add value to attract investors who are willing to cooperate toward the realization of the project. To achieve high return on investment rates, high commercial value should be added to the area. In terms of our marina, commercial value could be added in the form of:

- Paid berthing spots for vessels, which could lead to either daily, monthly, or yearly income for the owners of the marina.
- There should be places to eat (in the form of one or more restaurants, snack bars, food trucks, and coffee shops) and places to buy (souvenir shops, boat shops, kiosks, etc.) should be added to the area. The buildings for these activities should reflect the environment and should be either owned or rented out by private investors. These will also create monthly or yearly income possibilities.
- There should be a place for the organisation of events, such as hosting (nautical) sports events, markets, and other open-air activities. These events will enhance the marina's name recognition and attract more visitors, which leads to more income for local businesses. A large, public space should be available for this and designed such that it could easily adapt to the requirements of the event.
- There should be places for businesses in the tourism sector to establish themselves and facilitate the provision of docking spaces (on land and water), access areas, office space, and ticket sales facilities. This will create a vibrant marina with many possibilities to do business and will create higher user appreciation
- There should be places for vessel maintenance, where vessel owners can let their vessel be repaired or washed, buy items and components

5.4 Conclusion

In this chapter, various design recommendations have been discussed that could create a more sustainable marina. The recommendations respond to the requirements of sustainability, which concern economic, social, and environmental development in the area. The most important recommendation is to have as a goal in the marina the creation of more awareness of the environment among visitors, to enhance ecotourism. In addition, there should be many possibilities for economic activities like restaurants and shops, which also make it more interesting for private investors to invest in the project. Last but not least, the marina should be publicly accessible and serve as a catalyst in the sense of community in the area by offering spaces for (nautical) events and games and places for vessel owners to gather and exchange knowledge.

6 | Market study

A small market study has been performed to determine the vessel design parameters such as the number of vessels and vessel size distributions, as well as what services should be offered by the marina when accommodating these vessels. Important to note is that in the area, it is hard to find statistically valid, quantitative data. Therefore, qualitative data has mainly been gathered in stakeholder interviews to come to a result. A larger, more intensive market research could provide a more accurate result.

6.1 Existing market

First, the market for recreational navigation along the coast of Argentina was researched. Then, the relation between the market in the San Antonio municipality and the national market was analysed.

6.1.1 Argentina

According to D'Elia (2021), approximately 90% of all marinas are built in the Buenos Aires and Litoral area. When going increasingly south, only a handful of other marinas can be found. Of these, Mar del Plata and Ushuaia are the only ones with berths on water. In Viedma (storage of +/- 55 vessels) and Bahia Blanca (storage of +/- 75 vessels), all vessels are stored on land. An overview can be found in Figure 6.1.

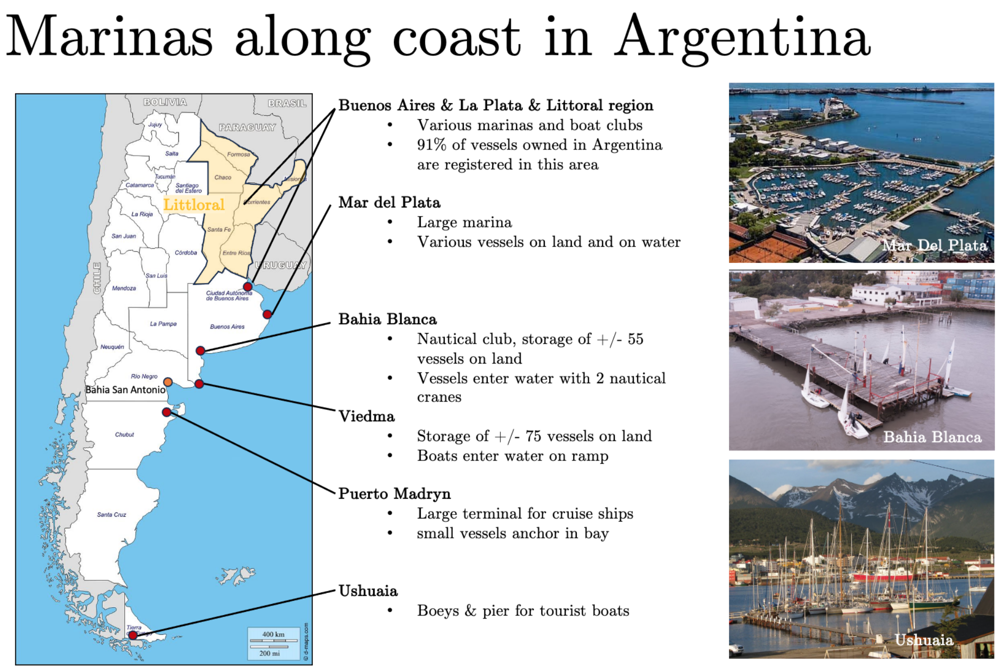


Figure 6.1: Marina distribution along the coast of Argentina

In terms of registered vessels, which exclude canoes, kayaks, inflatable boats, and all one-design sailboats, there is a significant upward trend in Argentina. In 2016, a count by the Parque Náutico Nacional in Argentina estimated a total of 149,560 registered vessels, a number that soared to approximately 208.500 by 2021 D'Elia (2021). Important to note is that vessels are not registered centrally but by different organisations, therefore these are estimations. Country-wide, mostly small recreational motorboats are sold, as can be seen in Figure 6.2.

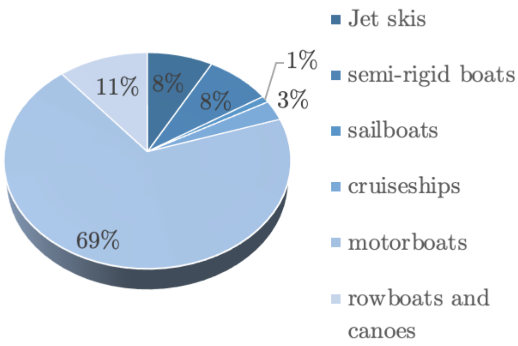


Figure 6.2: Various vessel types and their percentage of the market (D'Elia, 2021)

Country-wide, vessels primarily consist of motorboats, rowboats, and small boats with an average length not exceeding 6 metres and low horsepower (40/50 HP). This choice of vessels is common for navigating areas with minimal marina services like fueling stations and facilities like ramps and dry docks. In Buenos Aires, the statistics show a different distribution of vessel types: The numbers show mainly jet skis, semi-rigid boats, sailboats, cruisers, and many more vessels exceeding 6 metres in length, with a higher power. The reason for this might be: that it is the province with the highest percentage of construction and recreational activity in the country, with direct access to shipyards, a large service infrastructure, different types of navigation, etc.

(a) Sailboats during a sunny day along the coast of Buenos Aires (Own picture)

(b) Dry storage of motorboats in Tigre, a suburb of Buenos Aires (Own picture)

Figure 6.3: Around Buenos aires, generally speaking, larger types of vessels and more sailboats can be found.

6.1.2 San Antonio

Registrations and trend

In the San Antonio municipality, there are currently 93 vessels registered, which also consist of mainly motorboats, rowboats, and small boats with an average length not exceeding 6 metres and low horsepower (40/50 HP). However, as pointed out by Andrini et al. (2021), there is a downward trend in the number of registrations. This trend was attributed to the municipality's focus primarily on catering to tourist companies, inadvertently neglecting the needs of the local boating community. For example: the only possibility in the area for launching vessels is Bajada 3, a concrete ramp in Las Grutas. In Figure 6.7, it can be seen how crowded the beach is (where Bajada 3 is located) and it is not hard to imagine possible safety problems occurring when trying to launch vessels in such a crowded area.

Figure 6.4: High levels of tourism in high season cause difficulties for vessel owners to launch their vessels into the water

Vessel types

In the San Antonio municipality, various vessel types contribute to the market. To classify them systematically, the vessel types as identified by the PIANC guide will be used. An overview can be found in Figure 6.5. A distinction will also be made between residential and transient demand, which means the vessels that stay in the area and the vessels that visit throughout the year.

Vessel type	Typical characteristics [1]		
	Length Overall	Draft	Beam
Day boat (motor)	< 10 m	< 1 m	< 4 m
Day boat (sail)		< 2 m	< 4 m
Small cruising (motor)	10-15 m	< 1.5 m	< 5 m
Small cruising (sail)		< 3 m	< 5 m
Large cruising (motor)	15-20 m	< 2 m	< 6.5 m
Large cruising (sail)		< 3.5 m	< 6 m
Luxury (motor)	20-25 m	< 2 m	< 7 m
Luxury (sail)		< 4 m	< 7 m
Super-yacht [2]	> 25 m	See note 2	

[1] Typical characteristics apply to mono-hull vessels only.
[2] For specific guidance relating to superyacht, megayacht and gigayacht vessel characteristics the designer should refer to PIANC RecCom Report No. 134 – 'Design and Operational Guidelines for Superyacht Facilities' (2013).

Figure 6.5: Different vessel types and typical design dimensions according to PIANC

Residential demand
Day vessels (motor and sail) make up the vast majority of the registered vessels in the San Antonio municipality. These vessels consist of privately owned motorboats, rowboats, and small boats with an average length not exceeding 6 metres and low horsepower (40/50 HP), just like the rest of Argentina, because it is not possible to facilitate larger vessels in the area. Important to note is the contribution of tourist companies, mainly situated in Las Grutas. These companies own several vessels that are used for diving, whale watching, swimming with sea lions, or other touristic activities. Parador Rupeste, the whale-watching tour operator, owns 3 vessels.

Residential small cruising vessels are the largest vessel types present in the area (although very little), because of the lack of facilities in the area. The only people owning vessels more than 10 metres are the touristic operators. For example, the whale-watching vessels of Parador Rupeste, are 10 to 12 metres in length. One of them is thus considered a day vessel and the other a small cruising vessel. Because of the large stream of tourists during the summer, Parador Rupeste is seeking to expand the amount of vessels owned.

Transient demand
The transient demand for a marina consists of visitor vessels and passing-by vessels. In Las Grutas, several sailing regattas have been previously organised. In 2018 and 2019, the city hosted the Copa Golfo Azul, a regatta with approximately 30 sailing vessels (Pamperas and Lasers), and in 2019, it hosted the Pampero Grand Prix with approximately 40 vessels. The regattas attract many spectators and visitors and thereby contribute to the tourism industry in the area (?, ?).

In addition to the regattas, it is known that each year approximately eight vessels (consisting of small and large cruising vessels of 9 to 17 metres long, with 1.8 to 2.5 metres draught and even some luxury sail yachts above 20-25 metres) sail along the coast of Argentina from North to South. These trip ships are mainly owned by European and American tourists, according to stakeholder interviews. However, they currently do not stop at San Antonio Este or Las Grutas, as there are no facilities or berths for this kind of vessel in the area. Therefore these are not seen as part of the current market.

(a) One of the vessels of Parador Rupeste (residential demand)

(b) A small motorboat at high tide in Las Grutas (residential demand)

(c) The Pampero Grand Prix taking place in Las Grutas (transient demand)

(d) The 'Caoba – Rumbo Sur' project organises oceanic navigation from Buenos Aires to Ushuaia, but it currently does not stop at the Bahia San Antonio (transient demand).

Figure 6.6: Several vessel types that make up the market in San Antonio.

Based on the information above, an estimation of the current market in terms of the number of vessels could be made. It can be found in the table below.

2023

Market San antonio este	Residential	Transient
day boat (motor)	92	40
day boat (sail)	1	0
small cruising vessel (motor)	0	0
small cruising vessel (sail)	0	5
luxury (motor)	0	0
luxury (sail)	0	3
super-yacht	0	0
TOTAL	93	88

Table 6.1: Estimation of market size in terms of number of vessels in the municipality of Las Grutas

6.2 Market projection

6.2.1 Market drivers

Market drivers are factors that affect the supply and demand of the subject commodity. Marina market drivers typically include growth in the local population, changes in population demographics (age, wealth), and projected changes in tourism.

- In the area, tourism has been continuously increasing and currently 410.000 people visit the area each year. This increase in tourism brings people from all over the country, including people from Buenos Aires, who are buying vacation homes in the area. The increase in tourism could also boost the amount of vessels owned in the area, especially if a marina with various facilities would be built.
- The marina in San Antonio Este could be an extension to the marinas in Viedma (storage of +/- 55 vessels) and Bahia Blanca. The construction of a marina could therefore create more possibilities for vessel owners in the vicinity and in the San Antonio municipality to launch their vessels, but also store their vessels, which could eradicate the problem causing the decline in vessel ownership in the area.
- The marina could respond to the demand for residential berths for larger vessels (with a length higher than 6 metres) and small cruising vessels (length of 10-15 metres) in the area, by offering berthing places in water and on-land facilities for maintenance and storage.
- A marina in San Antonio Este could be beneficial in drawing in the tourist that is doing sailing trips along the coast in Argentina each year, by offering facilities for recharging, cleaning, and maintenance, which is nowhere else offered in the area between Buenos Aires and Ushuaia.
- A marina in San Antonio Este could provide an area to store vessels and organise regattas, therefore attracting participants and spectators and at the same time making people enthusiastic about vessel ownership in the area. In Bahia Blanca, many more regattas are organised and serve as an example for San Antonio.
- The marina could be used for touristic companies to place their daily used vessels. Currently, Parador Rupeste is the only tourist operator in the area with 3 vessels, but it expressed it might want to expand to 6 vessels in the future. In addition, other touristic operators might also be interested.

6.2.2 Prediction of market growth

Based on these predictions, the market in the future until 2038 was estimated, to translate this market to an appropriate slip-mix for the marina. During the first five years (till 2028):

- The total amount of registered vessels is assumed to increase by 40% (which is equal to the nationwide growth in Argentina between 2016 and 2021).
- The percentage of small sailboats is assumed to grow to 5 % of the total local market, which is a little more than the percentage in the whole country because there will be appropriate facilities. The small cruising vessels (sail) will grow to 3 % of the total market, which is the percentage of sailboats in the country.
- The percentage of small cruising vessels (motor) is assumed to grow to 5 % of the total local market.
- The vessels from Europeans that pass by the coast normally will now stop at SAE, therefore the number of transient vessels is assumed to be 6 large cruising vessels (sail) and 2 luxury vessels (sail) in addition to the 40 vessels from the regattas.

After 2028, it is assumed that the market will grow as a whole with a constant growth percentage. This percentage will be impacted by various factors, particularly by the economy of Argentina, which is currently under pressure. Therefore, 3 scenarios have been investigated: a small growth of 10% per 5 years, a medium growth of 20%, or a large growth of 40% per 5 years. This results in a range of approximately 100 vessels.

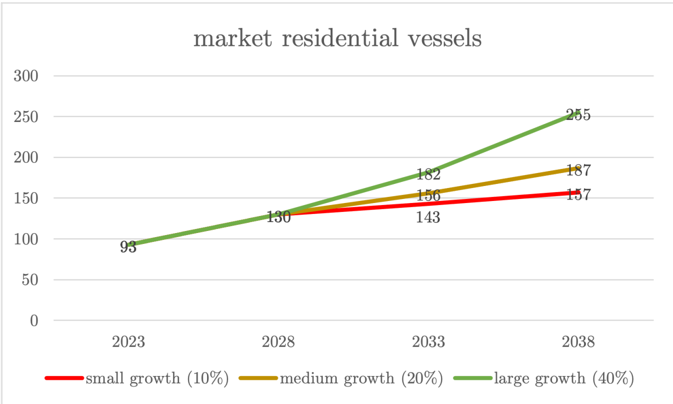
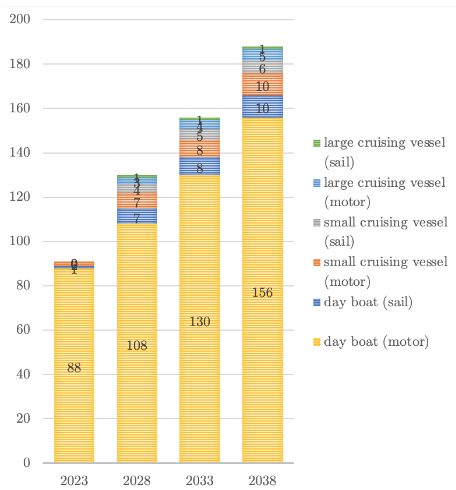
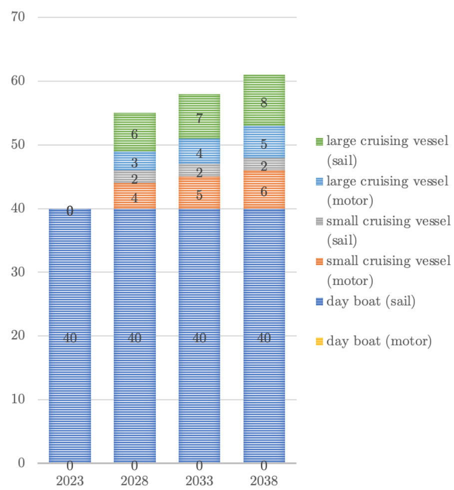


Figure 6.7: Three scenarios for the growth of the market in the San Antonio municipality

Finally, we opted to plan the marina for the moderate growth scenario. We anticipate continued market expansion driven by tourism potential, although the country's economic challenges might curtail growth compared to the most optimistic projections. The market's projected development is illustrated in Figure 6.8.



(a) Estimated development of residential vessel market



(b) Estimated development of transient vessel market

Figure 6.8: Around Buenos aires, generally speaking, larger types of vessels and more sailboats can be found.

6.3 Conclusion

Despite having limited quantitative data, this study provides valuable insights into the current market and its potential growth.

In Argentina, the majority of marinas are concentrated in Buenos Aires and the Litoral area, with few options further south. In the San Antonio municipality, 93 vessels are registered, with a declining trend.

The market projection shows various drivers that could shape the future market, including the growth in tourism, the need for extra facilities for vessel owners, and the potential to attract transient vessels. The construction of a marina in San Antonio Este is expected to cater these needs in the area. The study predicts market growth until 2038 and is done under three scenarios: small, medium, and large growth percentages, with the moderate growth scenario chosen for marina planning.

7 | Requirements and Constraints

This chapter will explain the different functional requirements that should be met in the preliminary design in order to guarantee proper functioning and sufficient attractiveness of the marina. The information provided in the previous chapters (area study, stakeholder analysis, philosophy and market study) will first be translated towards specific requirements. In the end of the chapter, a conclusion with a list of the requirements will be given.

7.1 Requirements from the stakeholder analysis

Due to the need for a connection with a high frequency between SAE and SAO, a water bus will be required. Because of the tidal character, high water and low water times differ every day, making it very inefficient to have a daily schedule to only navigate during high tide. This results in a requirement to have a water bus service that can provide service also during low tide. The solution for getting the vessels in and out of the water will be in the form of a ramp or a crane. The marina will educate visitors about the environment and the influence of garbage on it, to make them more aware. The desires of the private investors will be taken into account during the design, considering them as important stakeholders for the feasibility.

7.2 Requirements from the process analysis

A process analysis investigates possible activities that the future marina will facilitate in the future. These activities result in requirements for the design. The processes are described in E from the perspective of the different users of the marina. These users have been identified in the stakeholder analysis and consist of water bus users, recreational tourists, tourist companies, residential vessel users, passing-by vessel users and regatta sailors. Every step of the process is coupled to a corresponding requirement using a number E.7. These requirements will be elaborated in Section 7.5.

7.3 Requirements from philosophy

In order to create a design that can be considered sustainable, several recommendations have been made in the philosophy chapter. Each of these recommendations should be taken into account. Regarding functional requirements, some of these could be obtained directly from the chapter. Some of them overlap with requirements from the process analysis.

7.4 Requirements from market study

Based on the observations and assumptions of the market study, the design fleet and number of slips can be estimated. There are a few assumptions guiding this estimation. First, it is assumed 50% of the residential small boats will have a place in the marina, because people may choose to keep their vessel at home in order to save costs or because they can perform maintenance at home. For vessels larger than 8 metres, it is assumed they will be stored on the water, because it is very hard to transport these vessels or store them at home.

Regarding the transient demand, it is important to keep the seasonality of the different activities in mind, because they impact what the availability of flexible berths should be. In Figure 7.1, an overview is given for these activities and what kind of vessels they consist of.

During the high season, which spans three months, most vessels visit the marina simultaneously. If these visits are evenly distributed over the three months, approximately 33% of the vessels visit in one specific month and stay for a few days. Most likely, these visits do not occur exactly at the same time, so to account for variations, it was assumed that 20% of the residential demand would

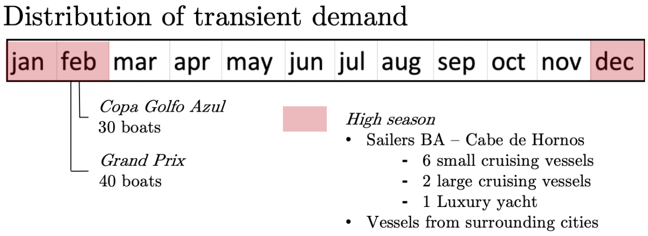


Figure 7.1: The distribution of the transient demand throughout the year.

berth at the same time in the peak periods. Consequently, the design fleet and number of slips was determined.

Vessel type	**Length (m)**	**Number of slips**	**Transient**	**Residential**	**Wet slips**	**Wet slips (%)**
Day boat (motor)	<10	79	0	79	4	5%
Day boat (sail)		5	0	5	1	10%
Small cruising vessel (motor)	10-15	11	1	10	11	100%
Small cruising vessel (sail)		8	2	6	8	100%
Large cruising vessel (motor)	15-20	2	1	1	2	100%
Large cruising vessel (sail)		2	1	1	2	100%
Luxury (motor)	20-25	0	0	0	0	0%
Luxury (sail)		1	1	0	1	100%
Super-yacht	>25	0	0	0	0	0%
Total		**108**	**6**	**102**	**29**	**27%**

Table 7.1: Numbers following from the market study

7.5 List of functional requirements

- Requirements regarding the wet surface area of the marina
  - The marina should offer wet berths for at least 5 day boats of less than 10 metres, 19 small cruising vessels of 10 to 15 metres and 4 berths for vessels of 15 to 20 metres. For more background, see Section 7.4.
  - There should be at least one berthing space for the water bus, accommodating 50 people. The length of the water bus is 15 metres, the width is 4 metres, and the draught is 1.2 metres.
  - There should be at least three berthing spaces for the company vessels.
  - 40 berths should be flexible, i.e. it should be possible to add them during regatta's for example.
  - There should be a small boat (for transporting people from vessels at buoys).
  - There should be at least one option for getting vessels in/out of the water in the form of a ramp or crane.
  - There should be one dock with facilities for waste, charging and sewage dump.
  - There should be enough lighting (potentially solar-powered)

  - A water bus that can provide a high frequency service during high tide and low tide.

- Requirements regarding the dry surface area of the marina.
  - There should be a terminal and a ticket office for the water bus connection between San Antonio Este and Oeste.
  - There should be an area with 79 dry berthing places for day boats of less than 10 metres, vessel maintenance and storage for temporary mooring and tools.
  - There should be a general information desk.
  - An interpretation center should be present , which is focused on educating the visitors of the area on the ecological value of the environment.
  - Various facilities should be established for tourist companies hosting marine activities, including the provision of space for at least three offices along with storage capacity for equipment.
  - Waiting areas should be allocated for people waiting for a tour (150 people), ferry services (100 people) and other services (50 people). The waiting areas should be logically placed, clearly indicated and a pleasant to stay.
  - There should be space for at least 50 people to relax, enjoy the view, eat something etc. including seating areas with benches.
  - There should be enough space for retail and food and beverage industry. Important is that these facilities should not do harm to the small-scale and natural feeling of the area. The design should at least contain 1 shop for daily needs (small supermarket or kiosk), a shop for boating materials and appliances.
  - Enough facilities should be present to ensure safety and security. Therefore, the access to private berthing, the docks for the touristic companies and the terminal should be separated and only accessible through (locked) fences or access points. In addition, there should be an area to store materials in order to provide first aid in case of emergencies.
  - There should be an office for the harbor master, that receives vessels and manages the storage departments and berthing places.
  - There should be a space for educational purposes regarding navigating and for organisational purposes, including at least a boat club and a sailing school.
  - There should be sanitary facilities such as toilets (8x men, 8x women, 3x handicapped) and changing rooms with showers (1x men, 1x women).
  - There should be a parking lot with sufficient amount of parking lots (2x bus, 4x camper, 50x regular cars.)

7.6 Constraints

7.6.1 Constraints for hydrometeorological conditions

The recommended maximum significant wave height criteria in small craft harbours is set 0.3 metres (Maritime Structures Standards Australia Committee, 2001) This limit fulfills the comfort requirements but the upper limit to serve the safety requirements is higher. This upper limit is 0.4 m for moorings on rigid berths with permanent contact between vessel and berth and 0.6 metres for a flexible mooring systems.(PIANC, 2016) It can be observed from the area study that these wave heights can be exceeded during extreme conditions at San Antonio Este. The corresponding percentages can be found in F.6. Adding these percentages gives a chance of 7.7% for exceeding a significant wave height of 0.3 metres. This implies that the significant wave height is approximately 676 hours per year higher than 0.3 metres. The chance of exceeding 0.6 metres is 0.9%, which implies 80 hours per year. The probability of exceeding these wave heights is in reality smaller, like it is explained in the area study. It is on the other hand expected to observe wave heights higher than 0.3 metres and 0.6 metres at the given location of the marina. These conditions need to be taken into account during the design and measures might need to be taken.

7.6.2 Constraints for design area

Two constraints limiting the design area were identified. Due to the requirement that the water bus must be operational 24/7, there are constraints on the location of the marina in the water. The water bus has a draft of 1.2 metres. This implies that, according to Appendix F.1.1, a consistent water depth of at least 1.5 metres is necessary to enable 24/7 operational capability. With Equation (3.1) it can be calculated that the bathymetric level needs to be 6.1 metres. In Figure 7.2 the 6 metre line from the (Navionics, 2023) chart is the red line. The marina should be built within this red area. The water level shown here corresponds to low tide, and the building adjacent to the road is Rupestre Experiencia Patagónica.
Finally, there is a fising area in the vicinity that should not be disturbed.

In Section 3.1, the onshore borders were discussed. These borders in relation to the constraints in the water can be seen in Figure 7.2.

Figure 7.2: Constraints for design area

8 | Layout alternatives

8.1 Design choices

To develop an alternative layout to the established requirements, research has been conducted into various marina systems. This research can be found in Appendix D. The marina systems from this research that are suitable within the area of this study to meet the requirements will be discussed below.

For the marina systems on water, several systems are possible. To access vessels from the land, there are two options: a fixed pier with a floating pontoon connected by a gangway or an entirely floating pontoon. In areas with a significant tidal range, it's important to construct the pontoons in both cases with piles for stability (Appendix D.2.3). The innovative concepts (Appendix D.2.6) are well-suited for this area and meet the requirements. However, given the small size of the marina, with relatively low flow velocities and consequently lower forces, the use of piles becomes an even more cost-effective option for securing the pontoons.

It is important that when choosing to have vessels permanently docked at a pontoon, wave action needs to be reduced to keep the wave height in the marina lower than the constraint of 0.3 metres mentioned in paragraph (Section 7.6.1). As described in section Appendix D.4.2, wave reduction in this area can be achieved in two ways. Either a floating breakwater or a wave screen can be utilized. In the case of flexible mooring, wave reduction is only needed 0.9% of the time (Section 7.6.1). In Section 3.2.4 is discussed that there are several reasons to assume that this 0.9% value can be reduced. Therefore, in this study, it is also assumed that no wave reduction is necessary for flexible mooring. For flexible mooring both buoys and piles, in combination with a floating ring, are suitable in the area of this study (Appendix D.2). An attention point for the use of buoys is the big swing radius during low tide.
For marina systems on land within the area of this study, the only two viable options are the use of a crane or a ramp. This is because the terrain in this area is hilly, making the other options discussed in Appendix D.3 not feasible.

To estimate the layout dimensions of the marina systems for the layout alternatives, the guidelines in Appendix F were used.

8.1.1 Alternative 1

Alternative 1 includes a pontoon type of floating walkway with at the end a large floating pontoon where passengers can board the water bus, the commercial vessels (vessels used by tourist companies) and the private vessels. Additionally, buoys are placed in the water to moor vessels larger than 8 metres. This design includes an environmentally friendly ramp to launch and retrieve vessels from the water.

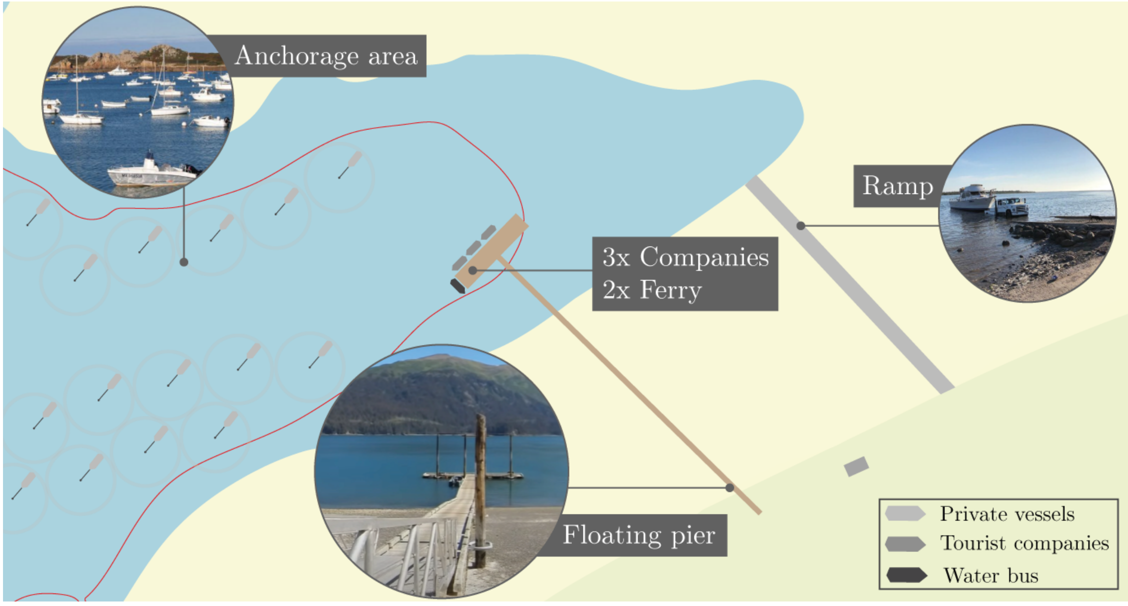


Figure 8.1: Alternative 1

8.1.2 Alternative 2

Alternative 2 includes a fixed pier with at the end two ramps to access the floating docks, including on the left a pontoon type of floating breakwater to reduce the wave height below 0.3 metre. The left ramp goes to the private part of the marina, where the residential vessels above 8 metres have their berths. The right ramp goes to the commercial part of the marina, where the vessels of tourist companies and the water bus can remain at finger piers. This design also includes an environmentally friendly ramp to launch and retrieve vessels from the water.

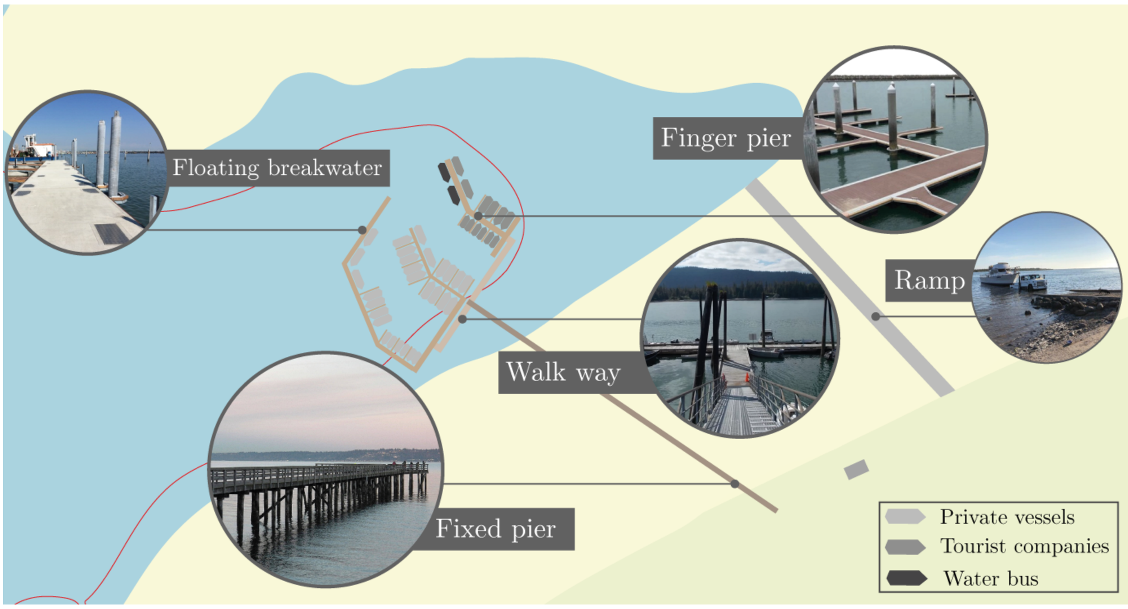


Figure 8.2: Alternative 2

8.1.3 Alternative 3

Alternative 3 includes a fixed pier with wavescreens underneath to lower the wave height in the marina and at its end a crane to launch and retrieve vessels in and out of the water. This design includes two ramps to separate the private and commercial part of the marina. The ramp below leads to the private vessels and the ramp above leads to the commercial vessels, like the water bus and the vessels of tourist companies.

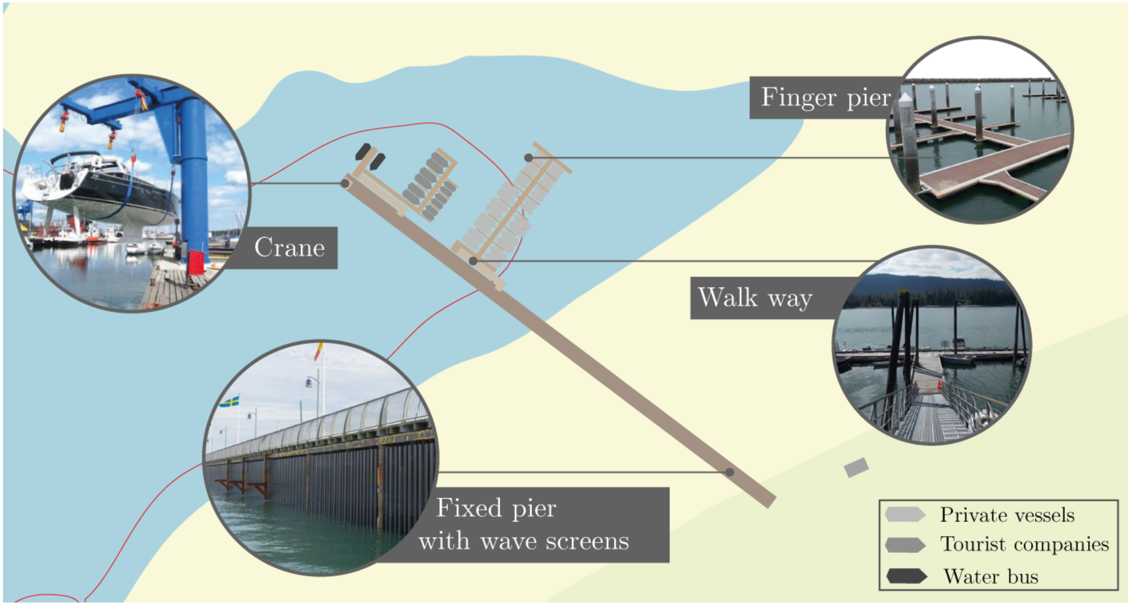


Figure 8.3: Alternative 3

8.2 Multi-criteria analysis

The multi-criteria analysis (MCA) compares the different alternatives, based on criteria. First, the most important criteria to consider will be elaborated. Then, a sensitivity analysis will be performed. This analysis sets weights on the criteria, based on their importance in the decision. After the sensitivity analysis, each alternative gets a weight for the amount it suits the criteria.

8.2.1 Criteria

In a MCA, various criteria are used to evaluate and compare the alternatives. The criteria chosen for evaluation are given below.

1. **Nautical accessibility** This criterion refers to the ease with which vessels can navigate to their berths and can be launched and retrieved from the water.
2. **Flexibility for marina development** Possibilities for further expansion and ease of phase development refer to the potential for extending the marina's services in the future and the ease of construction of the current design in phases.
3. **Hydrometeorological and environmental conditions** This criterion is about the protection and conservation of the environment of Bahía San Antonio. The creation of the new marina must not disturb the nature reserve.

4. **Aesthetic appeal** Aesthetic appeal refers to the look and feel of the marina. In this case, an important aspect is that the marina blocks the view as little as possible, so it blends in within the environment and people can enjoy the view.

5. **User comfort** This criterion refers to the travel time of tourists and private users at the marina from the moment they arrive until they board the water bus, a commercial vessel, or their vessel. It also includes facilities such as water supply and electricity available to the private users at their berths. Sewage pump-out facilities and fuel supply will be centralized for all alternatives. Furthermore, comfort is seen in how much the commercial part of the marina is separated from the private part. The "commercial part" of the marina refers to the area where the water bus and vessels operated by tourist companies can dock. The "private part" of the marina designates the section where vessels owned by residents or transient vessels have their berths.

6. **Construction and material costs** With this criterion, the three alternatives are evaluated based on their respective construction costs and material costs.

8.2.2 Performance of the multi-criteria analysis

To perform the MCA, weights need to be added to the different criteria. These weights indicate the level of importance. Weights can be added, ranging from 1 to 5 to all criteria:

1. Negligible
2. Low
3. Moderate
4. Significant
5. Critical

After the ranking is given to the criteria, the alternatives will be ranked per the criteria. This ranking also goes from 1 to 5 with a different meaning. 1 means the alternative doesn't apply to the criteria and 5 means it applies completely. After these weights are given, each design will get a score. The design with the highest score comes out as the best alternative in the MCA. It is also important to pay attention to the scores for every different criterion for each alternative. In this way, a combination can be made of the best features of each alternative. The result of our MCA, based on our knowledge, is given in Figure 8.4.

Criteria	Weight	Alternative 1	Score	Alternative 2	Score	Alternative 3	Score
1. Nautical accesibility	3	4	12	3	9	2	6
2. Flexibility for Marina development	3	3	9	4	12	2	6
3. Hydrometeo and environmental conditions	5	4	20	3	15	2	10
4. Aesthetic appeal	2	4	8	3	6	1	2
5. User comfort	3	2	6	5	15	3	9
6. Construction and material costs	5	5	25	3	15	2	10
	Total		80		72		43

Figure 8.4: Multi-criteria analysis

A survey is made and sent to the stakeholders and the experts. This is done to involve them as much as possible. They were also allowed to give comments on their choices, so their argumentation is clear and can be taken into account when choosing a preliminary design. The results and comments can be found in Appendix G. All comments are valuable to take into account when making final decisions. A couple of things can be noticed when observing and comparing the outcomes. Alternative 1 results as the best general alternative from the survey and the team. This result will be seen in the preliminary design, but components of the other alternatives will also be taken into account. The biggest advantages of alternative 1 according to the comments are the lowest initial costs, lowest environmental impact, and easy accessibility. Also, the floating pier is seen as a component with lots of advantages.

8.3 Conclusion

In the search for marina layout alternatives, three options were explored. The first one including a floating walkway and a boat ramp, the second featuring a fixed pier and a boat ramp and the final one combining a fixed pier with wave screens to reduce wave height, while using a crane for launching and retrieval.
To determine the best choice, a multi-criteria analysis was conducted, considering criteria like nautical accessibility, flexibility for development, environmental conditions, aesthetic appeal, user comfort, and construction costs. Alternative 1 ranked the highest, mainly due to lower costs, minimal environmental impact, and easy accessibility.

9 | Location of water bus stop in San Antonio Oeste

In this section, a brief explanation will be given of the location choice of the water bus stop on the west side of the bay, in San Antonio Oeste. The main criterion for this choice is the ability of the location to be serviceable even in low tide, something that is quite challenging, as the tidal differences are large. When choosing this location, three possible locations were considered: Punta Delgado (next to the ALPAT plant), Muelle de San Antonio Oeste (a small fishing dock in the north of San Antonio Oeste), and Punta Verde. They can be seen in figure 9.1. A nautical chart picturing the fairway along the three locations can be seen in figure 9.9.
The water bus needs to transport 50 passengers at a time. Vessels this size have a length of approximately 15 metres. From Maritime Structures Standards Australia Committee (2001) follows that the required water depth corresponding to this vessel type needs to be a minimum of 1,0 + 0,3 = 1,5 m. The wish is for the water bus to be operable 24/7.

Figure 9.1: Possible locations San Antonio Oeste

9.1 ALPAT (Punta Delgado)

ALPAT is short for Álcalis de la Patagonia, a factory producing natrium carbonate, the only one of its kind in South America. Next to the factory a pier was built, originally constructed to serve as a terminal for limestone transport. In its 20 years of existence, it has never been used, however, as cheaper options arose. Pictures of the pier can be seen in figure 9.2.

(a) The pier, facing the ALPAT plant

(b) Facing the sea, right side of the pier

(c) The driveway, facing the sea

(d) The pier during low tide, picture taken from a boat

Figure 9.2: The pier near the ALPAT factory (pictures taken by Femke Middeldorp, Coen Rijna and Jip Nooy van der Kolff)

Figure 9.3: Low tide at Punta Delgado, picture from February 2016 (*Google Earth*, 2023)

This pier could be used as a boarding location for the water bus, as it reaches far into the water, bridging a big area that runs dry during low tide. Important to note is the willingness of the owners of ALPAT to put the pier in use as a water bus stop. What also should be taken into

consideration is the fact that, when this location is picked, the local bus company will still be operational, as people need to be transported from Punta Delgado to the city (and the other way around). Right now, buses drive from San Antonio Oeste to San Antonio Este. This is a line that probably will disappear when the water bus gets realized. Therefore, this location might result in a win-win situation.
From Navionics (2023) and Servicio de Hidrografía Naval (n.d.) it can be seen that at this location, the seabed is located between 0 and 0,5 metres below MSL.

9.2 Muelle de San Antonio Oeste

On the north side of San Antonio Oeste lies a small fishing dock. Nowhere else the big tidal difference can be observed better than here, as can be seen in figure 9.4. Pictures were taken during low tide (9.4a and 9.4b) and during high tide (9.4c and 9.4d).

(a) Fishing dock during low tide (1)

(b) Fishing dock during low tide (2)

(c) Fishing dock during high tide (1)

(d) Fishing dock during high tide (2)

Figure 9.4: Muelle de San Antonio Oeste (pictures taken by Femke Middeldorp and Jip Nooy van der Kolff)

Visible is the impossibility of vessels to enter or leave the small harbour in low tide. About 70 metres from the dock, a small fairway is present during low tide. This might be the only possibility for the water bus to navigate, but whether this fairway is deep enough for this, is highly doubtful. See figure 9.5. Because Google Earth might not show the tide at its lowest point, it is unsure whether this fairway will dry up even more.

Figure 9.5: Low tide at the fishing dock, with the fairway visible, picture from February 2016 (*Google Earth*, 2023)

9.3 Punta Verde

Punta Verde is a small seaward strip of land, three kilometres north of the ALPAT factory. It is a quiet place with a nice beach. Pictures can be seen in figure 9.6. This location, as well, is hard to reach over sea during low tide. The seabed

(a) (b) (c) (d)

Figure 9.6: Punta Verde (pictures taken by Femke Middeldorp and Coen Rijna)

In figure 9.7 Punta Verde can be seen. As mentioned before, Google Earth might not show the tide at its lowest point, so it is hard to tell if this picture shows the worst possible conditions.

Figure 9.7: Low tide at Punta Verde, picture from February 2016 (*Google Earth*, 2023)

9.4 Conclusion and recommendations

9.4.1 Conclusions

After visiting the three locations and conducting online research, the best option for the water bus stop in San Antonio Oeste seems to be Punta Delgado, next to the ALPAT plant. This has several reasons:

- The other two options, Muelle de San Antonio Oeste and Punta Verde are very hard, if not impossible to reach during low tide. Although it is not yet clear how long an extended walkway needs to be to reach water deep enough to navigate in, Punta Delgado is closest to water this deep.
- The pier at Punta Delgado lies closest to the proposed location of the marina, where the other stop will be. The water bus would have to navigate approximately 10,000 metres from the fishing dock to the marina, 8,000 metres from Punta Verde, and only 4,000 metres from Punta Delgado.
- During the site visit, ALPAT executives expressed their sincere willingness to host the water bus stop. They consider it as an investment and a solution to an issue they have with trespassers using the pier illegally.
- When realizing the water connection from San Antonio Este to San Antonio Oeste, the local bus company will lose an important line. Because ALPAT is a ten-minute drive from the San Antonio Oeste center, it would not have to lose its customers altogether.

This being said, several comments have to be mentioned as well:

- The fact that ALPAT is not located a walking distance from San Antonio Oeste might be favorable for the bus company, but not as pleasant for the traveler. From their point of view, the fishing dock might be the optimal location.
- Although the pier reaches approximately 200 metres into the water, this is not enough to bridge the complete distance needed for the water to be deep enough. A walkway or bridge leading up to a floating pontoon will be needed to solve this.

- Because a water depth of 1.5 metres is required for a 15-metre-long water bus to navigate, a water level of 5,75 metres (concerning the historical minimum) is needed at Punta Delgado. This is based on the level of the seabed at this location. As pictured in figure 9.8, this happens less than 50% of the time. This is not in accordance with the wish for the bus to be operable 24/7. A solution could be to reduce the number of passengers and the required draught of the vessel.

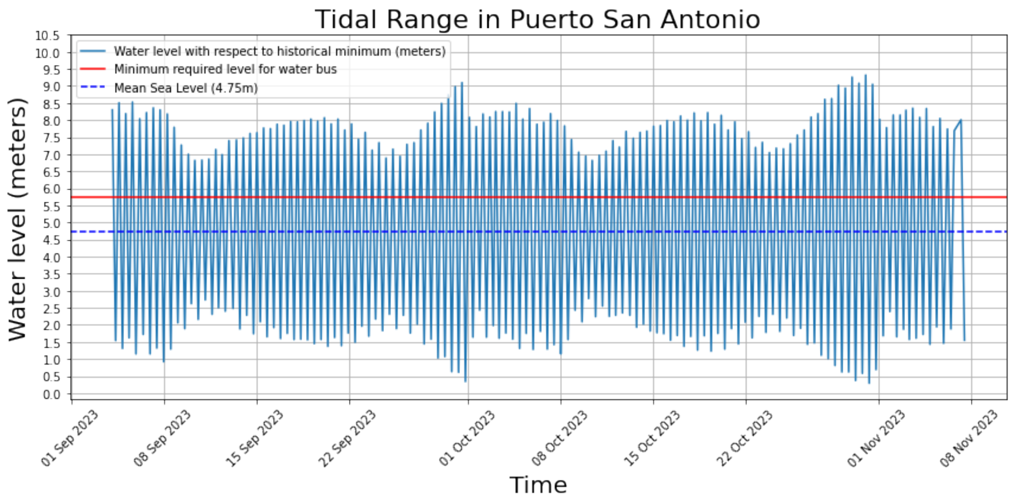


Figure 9.8: Required water level for the water bus (red line)

9.4.2 Recommendations

Although it now is assumed that the pier at Punta Delgado seems the best option, further research needs to be conducted to confirm this. When the assumption is right about Punta Delgado, the needed length of the walkway (from the water bus stop to the ALPAT-pier) needs to be figured out. A decision has to be made on whether this length is realistic. Finally, it has to be investigated whether the wish to operate the water bus 24/7 is a possibility. If not, based on the tidal heights, an overview is needed with moments when the water bus can not be in operation.

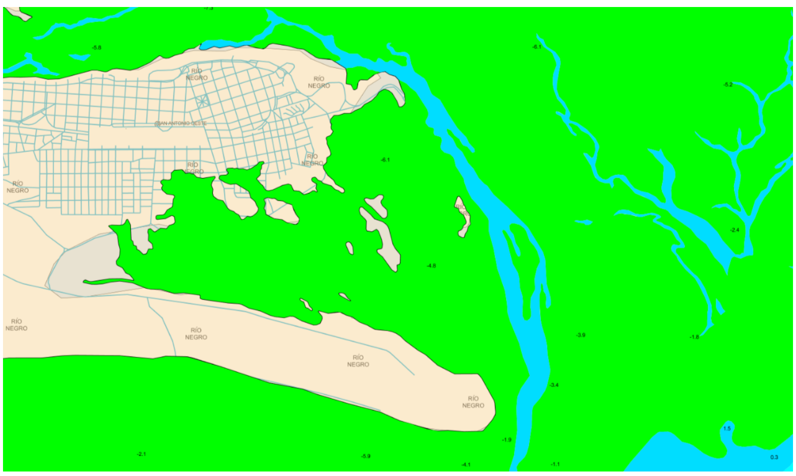


Figure 9.9: Nautical chart of the possible locations in San Antonio Oeste (Servicio de Hidrografía Naval, n.d.)

10 | Preliminary Design

From the multi-criteria analysis, the first alternative scored highest and was therefore chosen. However, some changes have been made to the design as more research was performed to make educated design choices. In this chapter, the preliminary design of the several components of the marina will be presented. These components consist of the boat ramp, the fixed pier, the mooring piles, and the pontoons. For each of the components, a detailed description will be provided, as well as some initial drawings and calculations to support the design decisions and dimensions. For the dry area, including the on-shore facilities, the design will be on a conceptual level.

10.1 Layout of the marina

First, the preliminary layout plan that was adopted will be discussed. This layout can be seen in Figure 10.1

Figure 10.1: The preliminary design of the marina during low tide

In this layout, some changes can be observed compared to the layout from the multi-criteria analysis: a fixed pier now forms the connection to the floating pontoons at the end of the pier, instead of the floating pier in the initial design. This choice will be explained in Section 10.2.1. Next to the fixed pier, it was decided that mooring piles would be used instead of mooring buoys, as the swing length was found to be too large due to the large tidal range in the bay. The calculation of this can be found in Appendix H.1.

For the dry area of the design, only a conceptual design with a layout structure is provide. First, a parking area was added for 50 cars, 2 busses and 4 campers, answering to the requirements of enough parking spots. It was decided to make the parking area in the shape of a long rectangle and use permeable concrete, to prevent the dune landscape from becoming one large block of concrete. When coming from the parking area, people walk directly into the central, round building with several desks for information, companies offices, an interpretation center and restrooms. This building should be the eye catcher of the area and blend in with the environment.

Figure 10.2: Impression of the central building. The picture is an existing building in Holkham, United Kingdom

Figure 10.3: Impression of the inside of the building. The picture is an existing building in Holkham, United Kingdom

From this building, of which an impression can be seen in Figure 10.3, several paths leave. One of these paths, which is covered with timber planks, goes along the coastline. Because this is a very frequently visited area in summer, there should be no fences placed in order to allow for unrestricted access and view. Along the route, information signs could be placed that inform people about the area and its ecologic beauty.

Figure 10.4: An impression of the route along the coast with information sign (own picture)

In order to create enough economic possibilities, several small houses/huts can be found in the area, with souvenir shops, places to eat, places to buy boat accessories and other facilities such as a boat club and sailing school. There, it will feel like a small scale 'boulevard' is created. The fact that these houses are small, make them financially feasible and make that they blend in with the environment. An example of what these houses could possibly be is found in Figure 10.5.

Figure 10.5: An impression of small shops along the coast in Hastings England. Advisable would be to go for a less colourful design in order to blend well into the natural environment.

10.2 Preliminary design of the Pier

In this section, the choice of material as well as some initial dimensions of the fixed pier will be discussed. The dimensions will be approximated using rules of thumb and available guidelines. Additionally, some initial checks are performed on strength and stiffness. Note that a thorough structural calculation still needs to be done to ensure these values satisfy the ultimate and serviceability limit states. Note that only vertical loads were considered. Horizontal loads from vessels, waves, currents, and wind were left out of the analysis, due to lack of time.

10.2.1 Comparison with floating pier

In the design of the multi-criteria analysis, a floating pier was presented. However, after discussion with the team, the choice was made to include a fixed pier instead of a floating pier. In Appendix G.4, an overview was made on the advantages and disadvantages. Although the floating pier had advantages such as better visibility and fewer piles, it posed issues like stability, accessibility, and higher maintenance costs. Additionally, it produced more sound, had a shorter lifespan, and required ground interventions, which were not ideal.

10.2.2 Material

Generally fixed piers are constructed with timber, concrete, or steel (PIANC, 2017). The oldest and most affordable pile options are timber piles (HMP Marine, n.d.). Additionally, timber has a natural aesthetic and the lowest environmental footprint. The drawback of timber piles is that they are more likely to corrode compared to concrete, which has a very good corrosion resistance. Therefore the type of timber and its protection layer should be carefully chosen when timber is used. The maximum available length of timber piles is approximately 20 metres (TimberPilingCouncil, n.d.). According to Section 10.2.3 the length of the required pile does fit within the available range. When longer piles are required and large forces are exerted on the piles, typically concrete or steel is chosen (HMP Marine, n.d.). The new marina is located in a protected bay, so the assumption is made that steel or concrete is not necessary for the construction of the pier. Hence the choice is made to use timber with a protective layer for the design of the pier.

10.2.3 Structural components and dimensions

Lay-out of the pier

As explained in Section 7.6.2, there is a specific design area for the marina, which is limited by the draught of certain vessels. The pier needs to end in this specific design area, resulting in a pier of 240 metres in length. The minimum width of walkways, with a length of 200 metres, is 2.4 metres, as explained in Appendix F.1.1. For the preliminary design, the choice is made to widen the pier up to 3 metres in width. This increases the accessibility and comfort of the users. Another reason is the consideration of the potential expansion of the marina.

Vertical loads

The dimensions of the components of the pier need to be based on the loads the pier has to be able to withstand. The uniformly distributed load for public "unrestricted areas" of a marina is determined as 5 kN per metre squared (PIANC, 2017). The permanent loads exist out of the self-weight of the different components. The pier exists out of piles, beams, purlins, a deck, and on both sides a handrail. The build-up of the construction is drawn in Figure 10.6 and Figure 10.9. The weight of the timber depends on the type of timber used. A common type in Argentina is Eucalyptus or Pine according to an Argentine lumber company Aserrado Silvio (Aserradero Silvio, 2008). Impregnated Eucalyptus is used for the pier since it's the most affordable option. The material properties of Eucalyptus with a strength class of D40 can be found in Appendix I.2 (Soons & van Raaij, 2014) (World Forest Group, 2021). Together with formulas and partial factors from the Eurocode the design values of the load in ULS and SLS are calculated. The calculations can be found in Appendix I.

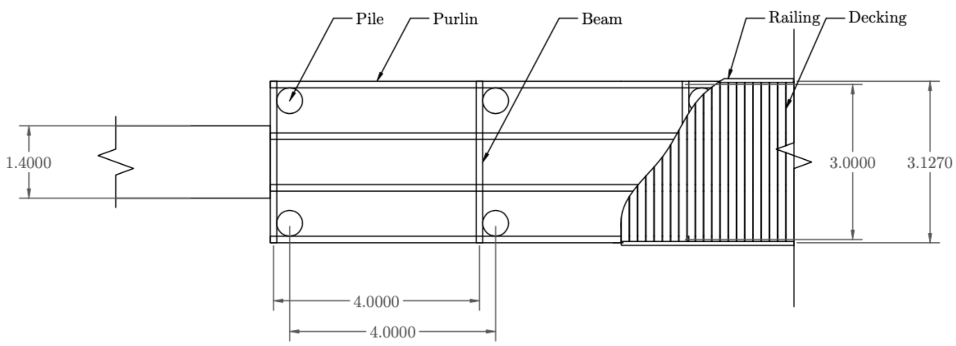


Figure 10.6: Upper view

Beams, purlins, and handrails

The dimensions of the components of the handrail are based on information from the Marine Construction magazine (2020) and the Southern Forest Products Association (2014). The chosen sizes originate from the available sizes provided by Aserrado Silvio, which can be found in Appendix I.2. Resulting in posts of 101.6 by 152.4 millimetres, rails of 38.1 by 152.4 millimetres, and rail caps of 76.2 by 203.2 millimetres. An example of how the handrail looks like can be found in Appendix I.1. The handrails should be strong enough to keep people safe on the pier. No calculations have been done yet, but this is required in the next step of the design. The required thickness of the deck comes from the Southern Forest Products Association (2014) and together with available sizes from Aserradero Silvio, stated in Figure I.2, timber planks of 38.1 millimetres by 152.4 millimetres were selected. The Quick Reference provides a first estimation of the dimensions of the beams and purlins (Soons & van Raaij, 2014). Consequently, with formulas from the Dutch Eurocode, the dimensions are checked on their moment and shear force capacity (Technische Commissie CEN/TC 250, 2019). Additionally, the maximum deflection is calculated and verified. The calculations can be found in Appendix I.2. From the available sizes of Asserradero Silvio, stated in Figure I.2, the dimensions of the timber components are chosen. As shown in Figure 10.7, all beams and purlins have the same dimensions of 355.6 millimetres by 127 millimetres. The bending of the decking was not yet calculated.

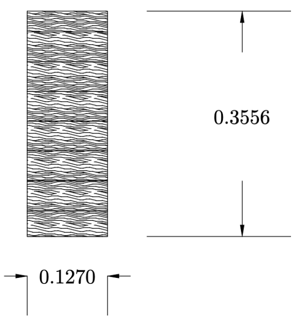


Figure 10.7: Cross-section of the glulam timber beams and purlins used for the pier

Piles

The length of the timber piles depends on the load on the piles and the bearing capacity of the soil. On the exact location of the pier, no soil studies have been performed. However, a soil study close to the existing harbour of San Antonio Este has been done. Therefore, these studies were used to approximate the geotechnical parametres of the soil at the location of the marina. However, they do not suffice for detailed design calculations as they were taken from a different location, and therefore a detailed soil investigation should be made before a final design could be made. To make a first estimation of the embedded length (i.e. the depth of the pile underneath the seabed), a guideline written by Southern Forest Products Association (2014) was used. This guideline prescribed certain depths of timber piles based on the soil density, as can be seen in Figure 10.8:

PILE EMBEDMENT CHART			
PILE SIZE CURCUMFERENCE (TIP DIAMETER)	25" (8" tip)	31" (10" tip)	8"x8" Square Sawn
Soil Type	Embedment Depth (Feet)		
Medium Dense Sand	8	8	8
Loose Sand	12	9	10
Medium Stiff Clay	8	8	8
Soft Clay	8	8	8

Figure 10.8: Embedment depth of the piles (Southern Forest Products Association, 2014)

According to the soil studies by Vazquez (2005) of the Puerto San Antonio Este, the upper 5 metres of the soil consist mainly of medium dense to dense sand. In these soil studies the Unified Soil Classification System was used, which can be found in Figure B.1. According to Figure 10.8, a minimum embedment depth of 8 feet is required and to be on the safe side we assume to have loose sand, which guides us towards the 12 feet (approximately 4 metres). The corresponding diameter according to the guideline will be approximately 10", which corresponds to 250 millimetres in the metric system. This diameter is for a pier in a residential area, hence lower horizontal forces. Since the piles of the new marina will be located in an area where they can catch wind and with no breakwater present, a larger pile diameter is chosen. Looking at available diameters, a pile diameter of 500 millimetres is selected (Van Biezen Houtimport, n.d.).

To verify the assumptions of the guideline with the situation at San Antonio Este, a quick calculation was made. This can be found in Appendix I.3. First, the design value for the vertical loads per pile was calculated, which consists of self weight of the pier and loads from people on the pier according to (PIANC, 2017). Then, the bearing capacity and skin friction were calculated using the same procedure that was used for the original calculations of Puerto San Antonio Este. This showed that piles with a diameter of 500 millimetres and an embedment depth of 4 metres were sufficiently large. Therefore, the assumed embedment depth seems like a good first estimation. Again, this is based on soil studies of a different location using only vertical loading and neglecting horizontal loads like waves, currents, and wind. Additional calculations research should be applied to come up with an accurate embedment strength.

Currently, the length of the piles embedded in the ground has been established. Consequently, the length of the piles above ground needs to be determined. The maximum water level above ground according to Figure A.2 and Equation (3.1) in the specific design area described in Section 7.6.2 is 10.78 metres. The fixed pier should be 1 metre above the highest water level according to Department of Transport (2013). For sea level rise another 0.4 metre is recommended for the design life of 50 years. This gives a required pile length of 16.18 metres. Piles with a length of 17 metres and a diameter of 500 millimetres are chosen for the design of the pier. Finally, the normal force and the buckling capacity of the piles were checked using the Dutch Eurocode and showed sufficient results (Technische Commissie CEN/TC 250, 2019). These verifications can be found in Appendix I.3. Figure 10.9 and Figure 10.10 show the preliminary design of the pier in high and low tide. In Figure 10.9 cross bracings are added to resist the horizontal loads. As the horizontal loads are not calculated yet, the cross bracings aren't either. This should be done in the next design step.

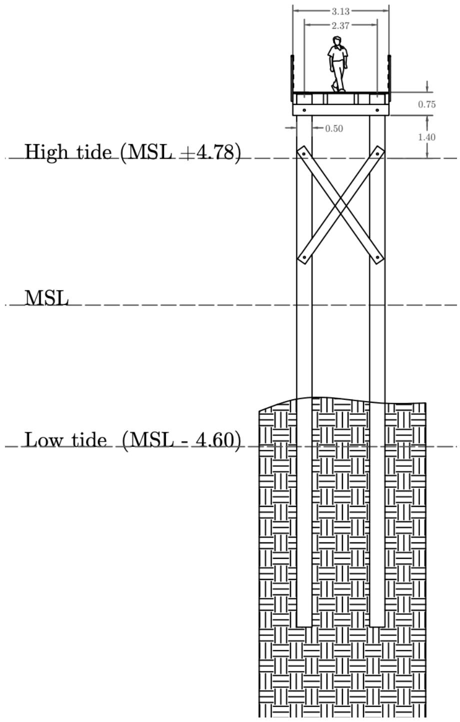


Figure 10.9: Front view

10.3 Preliminary design of the floating structure

To embark on vessels from the fixed pier, which in low tide conditions will be approximately 10 metres above the water table, a floating structure in the form of pontoons is used, accessed by a gangway.

10.3.1 Dimensions

The pontoon square is designed to be 15 metres in size, allowing the water bus to temporarily dock, and passengers to board or disembark. Also, the pontoon is made large enough for passengers to have a waiting space. The gangway is put in the middle of the pontoon square, so the large force from the gangway can spread more easily and the pontoon is more balanced. The pontoon is divided into three separate parts with each a width of 5 metres and three mooring piles to keep the pontoon in place.

As stated in Appendix F.1.1, the minimum width of walkways is 1.5 metres. The choice was made to enlarge the walkway to 3 metres in width since it is used by people who are en route to board a vessel for a tourist activity and by people who temporarily need to berth to for example use the sewage dump or board their vessel. Hence potentially two-way traffic. The attached fingers have the required uniform width of 0.9 metre according to Appendix F.1.1. The length also fulfills the requirements of 0.8 times the length of the largest berthing vessel, so no mooring pile at the end of the finger is needed. Resulting in a finger length of 9.6 metres. The final design of the pontoon and its dimensions are shown in Figure 10.10.

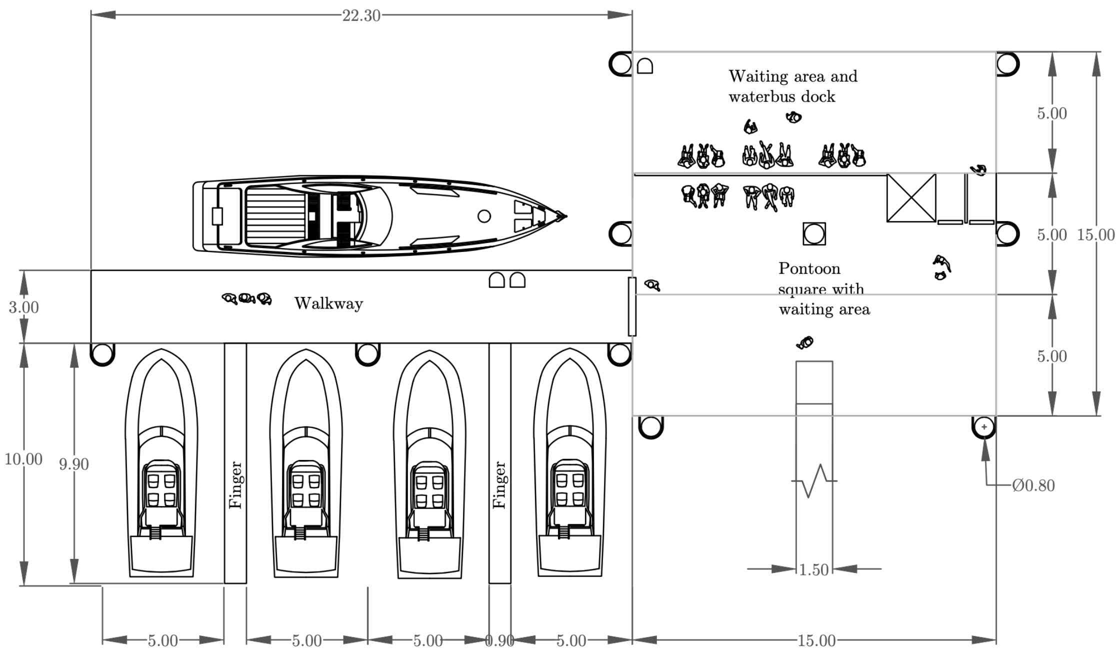


Figure 10.10: Top view of the floating structure

10.3.2 Material

In marina design, floating structures are typically constructed as concrete or aluminum pontoons (Department of Transport, 2013). The advantage of the concrete pontoon is its weight. It lowers the centre of gravity of the pontoon, hence increasing its stability. Especially for small-width installations with specific buoyancy requirements, the concrete pontoon can serve as a solution (Poralu Marine, 2018a). Furthermore, because of their additional weight, they can be installed in high tidal zones with areas that require additional protection against waves. Concrete pontoons have a lifespan of more than 20 years and require minimal maintenance since they won't rust or corrode (HSB Marine Construction, 2023).

The advantage of the aluminium pontoon is the fact that they are lightweight (Poralu Marine, 2018b). This contributes greatly to the flexibility of the marina and it makes the marina easy to construct. Different from concrete pontoons, aluminium ones are endlessly customizable (*TJS Marine - Floating Pontoons*, n.d.). Moreover, aluminium pontoons have high stability as well (Department of Transport, 2013). Additionally, aluminium pontoons have a lifespan of more than fifty years and require no maintenance. Even in salt water the aluminium pontoons do not corrode, because "the metal natural oxide film neutralizes the effect of corrosion" (Structurmarine, 2023). The material aluminium can be fully recycled, which contributes to lowering the environmental footprint of the design (Poralu Marine, 2018b). The costs of the aluminium pontoons are generally lower than the ones made of concrete (*Aluminium pontoons in your marina*, n.d.). Also, the construction and transportation costs are lower as a result of the lightweight material (Poralu Marine, 2018b).

The main differences between the aluminium and concrete pontoons are the flexibility, the costs, and the environmental footprint. Aluminium is superior in all of those aspects, but the most important aspect of the pontoons is that they should be able to carry the design load of 5 kN per square metre, as described in Section 10.2.3. The maximum design load of aluminium pontoons is 3,5 kN per square metre. For concrete pontoons, the design load can go up to 5,6 kN per square metre. Meaning that concrete pontoons have to be used for the design. Lengths of concrete pontoons can go up to 25 metres and the standard widths have a limit of 5 metres (SF Marina, n.d.). The freeboard of these concrete pontoons is approximately 0.5 metres and the total height of the pontoons is 1 metre.

The deck of concrete pontoons is often the concrete dry brushed surface or a wood layer is added (tmmarinas.com, 2023). Both options require little but regular maintenance. Wood is durable when protected properly, but maintenance is required regularly to prevent rotting and decay over time (JetDock, 2023). A type of wood decking with minimal required maintenance is pressure-treated wood decking. Furthermore, wood provides a natural aesthetic. Combining maintenance with the aesthetic leads to the use of pressure-treated wood decking for the new marina design.

10.3.3 Mooring piles of floating structure

The floating pontoons are kept in place with mooring piles. The embedment length of the piles is based on the piles used for the harbour of San Antonio Este (Vazquez, 2005), since there is no information about the soil at the location of the new marina. For the design of the new marina soil studies are necessary, but to still provide an estimation of the piles the soil studies of the close by harbour are used. The assumption is made that the horizontal forces on the mooring piles of the floating structure are significantly larger than the horizontal forces on the piles of the pier. This can be explained by the fact that the mooring piles have to keep the floating pontoon in place, which is a big load that is subjected to currents. Also, vessels are attached to the floating pontoons with mooring lines, which add another horizontal force to the mooring piles. As a result of the horizontal forces, an overturning moment arises at the ground level of the pile. The soil strength and the embedment length of the pile are two parameters that are important in resisting this overturning moment. The soil is not very strong (Vazquez, 2005) and can not be changed, however, the embedment length of the pile is something that can be chosen. As explained in Section 10.2, due to lack of time are the horizontal loads left out of the analysis, therefore the minimal embedment length of the piles from the harbour of San Antonio Este will be used for the mooring piles as a first estimation to ensure sufficient overturning moment. Therefore, the embedment length of the mooring piles of the floating structure becomes 21 metres.

According to Department of Transport (2013), the length of the mooring piles should extend 1.2 metres above the highest water level with the additional height accounting for the freeboard of the pontoon. The additional 0.4 metre for the sea level rise should be added here as well. Similar to the calculation done in Section 10.2.3, the required pile length comes down to 33.38 metres. For the design, a pile length is chosen of 34 metres. As described in Section 10.2.2, the maximum length of timber piles is approximately 20 metres, so timber is not an option. Steel is a very expensive material in Argentina according to an expert from Besna. Hence the choice is made to use a steel casing that can be filled with concrete and re-used for all piles, called Fundex piles (Doornbos, 1986). The diameters of these piles, for this purpose, are usually between 500 millimetres to 800 millimetres here in Argentina, according to an expert from Besna. Since little is known about the soil and the horizontal forces, the largest diameter of 800 mm is chosen to be on the safe side.

10.4 Preliminary design of the gangway

10.4.1 Dimensions

In this section, some initial dimensions as well as the choice of material of the gangway will be discussed. As seen in Figure 10.11 and Figure 10.9, the gangway must be able to cover a height of 11.53 metres, which is the distance from the fixed pier to the floating pontoon during low tide.

In Appendix F.1.1, it is stated that the slope of a gangway should not exceed 1:3. As a result, the length of the gangway will be 34.75 metres. For the width of the gangway, 1.5 metres is maintained, as visible in Figure 10.6. In (Department of Transport, 2013), it is stated that a 1.5 metres minimum passage should be provided for two-way pedestrian traffic for people carrying small loads. Since this serves as access to the water bus and tourist activities, this minimum width is adopted in this preliminary design.

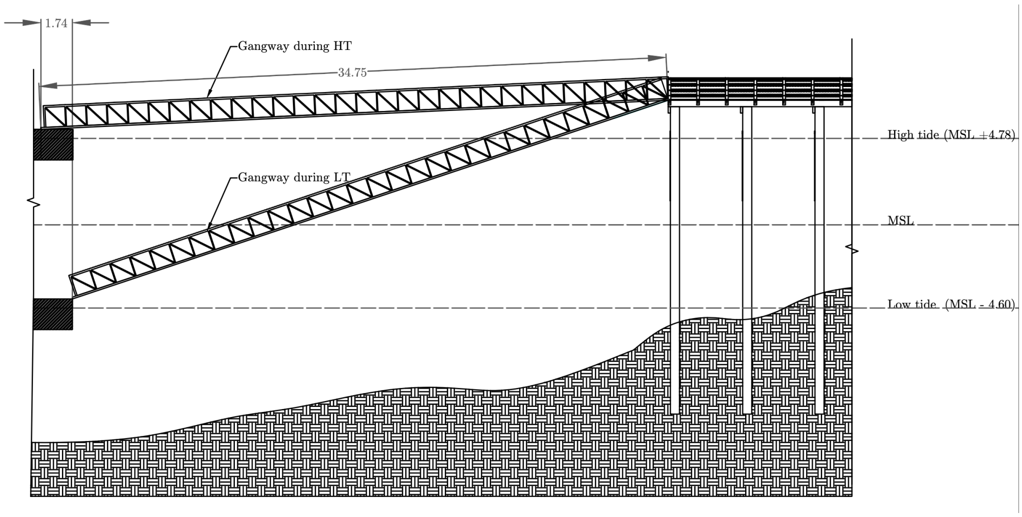


Figure 10.11: Side view

10.4.2 Material

The gangway is made of aluminum due to several advantages it offers. It is lightweight, durable, and easy to construct (Poralu Marine, 2023). Aluminium gangways can come in any length, spanning up to 36.6 metres before requiring. The gangway features railings with a truss structure measuring 1.2 metres in height (Wahoo Docks, 2023). This implies that covering the 34.75 metres required in this preliminary design is feasible. To ensure safety regardless of the bridge's incline when following the water levels, the aluminium non-slip grating is screwed onto the deck, adding extra non-slip protection (Poralu Marine, 2023).

10.5 Mooring field

The principle of pile mooring is explained in Appendix D.2.2. No specific requirements of distances between the mooring piles are found, but Appendix F.1.1 discusses the required distance between vessels for alongside berthing. Since this is a similar maneuver, but without a dock, half of the distance is assumed appropriate between the vessel and the mooring pile. Resulting in a distance of 1.5 metres, which is illustrated in Figure 10.12.

The embedment depth is estimated the same as the embedment depth of the mooring piles of the floating structure, described in Section 10.3.3. In a similar fashion as for the mooring piles of the floating structure, done in Figure H.1, the total pile length can be calculated. The difference is that the draught of the vessels that need to be able to moor the piles at all times can go up to 2.5 metres, as is written in Section 6.1.2. Meaning that the maximum water depth in this area is 1 metre more than the water depth of the area of the floating structure. Hence this 1 extra metre shouldn't be forgotten. From this calculation follows a required total pile length of 34,38 metre. The mooring piles used for the design have a pile length of 35 metres.

As explained in Section 10.3.3, the size of the horizontal forces influences the chosen diameter of the piles. The horizontal forces of the mooring piles for the mooring field are considered to be lower since no floating pontoon with vessels attached exerts forces onto the piles. Only mooring lines with vessels and the current exert forces onto the pile. Hence a smaller diameter of 600 millimetres is chosen, which can be recognized in Figure 10.12.

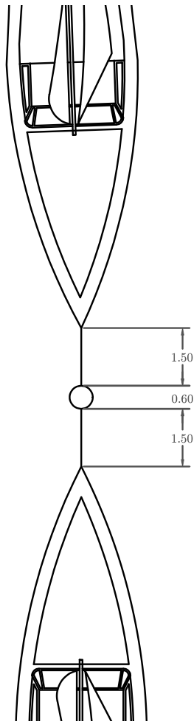


Figure 10.12: Top view of pile mooring

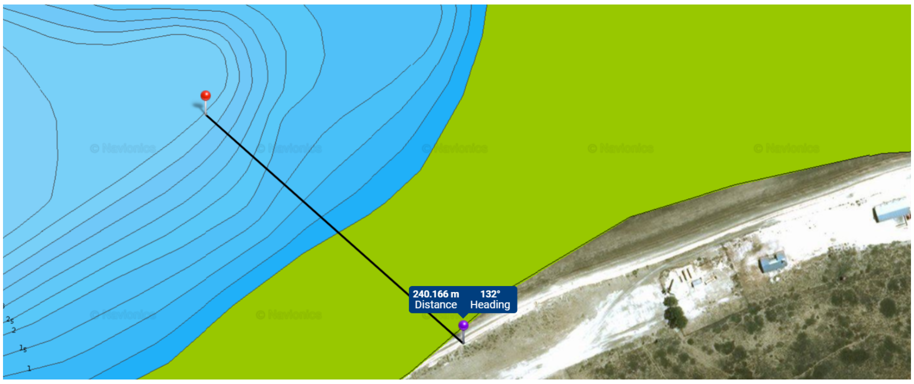
10.6 Boat ramp

The boat ramp is a structure that facilitates the launching of vessels into and out of the water. Vessels on trailers will be driven into the water until they can float.

10.6.1 Location

The location of the ramp was determined by the required water depth at the lowest point of the ramp. According to the Maritime Structures Standards Australia Committee (2001), the minimal draught of the largest vessel that will be launched on the ramp (length of 12 metres) is 1,0 m (Appendix F.1). A minimum of 300mm (under keel clearance) needs to be added to this. This results in a required water depth of 1,3 m.
The average low tide level is -3,09 m +MSL, therefore we need the seabed to lie $3,09 + 1,3 = 4,39$ m below MSL.
When considering the direction of the ramp, it should be aligned with the dominant wave direction (Maritime Structures Standards Australia Committee, 2001), following from figure A.7. The final proposed location of the ramp can be seen in figure 10.13.

(a) The location of the ramp in *Google Earth* (2023)



(b) The location of the ramp in Navionics (2023)

Figure 10.13

10.6.2 Dimensions

The dimensions of the ramp follow from several factors. First of all, the horizontal distance results from the location of the ramp described above. It is 240 m (see figure 10.13b). This is an exceptionally long ramp, a result of the very large tidal difference in the area.
The vertical distance to be bridged was chosen to be the difference between -4.39 m +MSL and +6 m +MSL (so 10,39 m). This choice was based on the resulting slope of the ramp, aligning nicely with the bathymetry of the existing ground (the orange line in figure 10.14).
Because after economic considerations it was chosen to design only one lane, the prescribed minimum width is 4 metres. In figures 10.14 and 10.17 the dimensions as well as the materials (clarified in the next section) of the ramp are described. Figure 10.14 shows a longitudinal section of the ramp, including the average low tide and average high tide according to Servicio de Hidrografía Naval (2023) and the required water depth of 1,3 m at the end of the ramp.

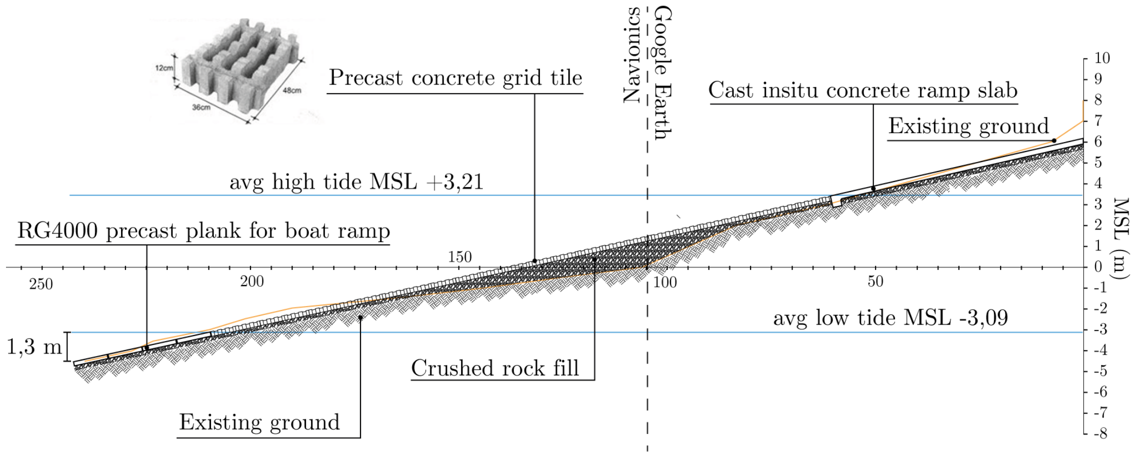


Figure 10.14: Longitudinal section of the ramp

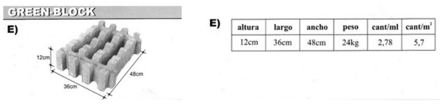
The slope resulting from the horizontal and vertical distance of the ramp is 10,39:240 = 1:23,1. It is acknowledged that this slope is by far not steep enough to meet the guidelines (minimum slope of 1:9). This minimum was set because low slopes will lead to cars driving too far into the water when launching their vessels. Therefore it needs to be noted that this ramp will not be accessible for regular passenger vehicles. It can only be used by a high enough tractor (see figure 10.15).

Figure 10.15: Tractor driving into the water to retrieve the vessel

10.6.3 Material

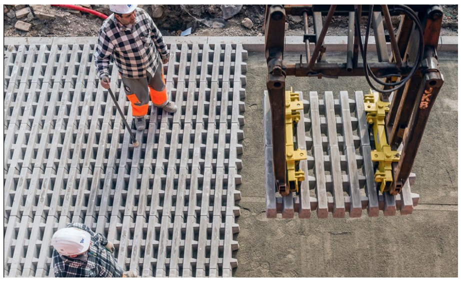
In figures 10.14 and 10.17 the proposed materials are described. When below the ramp filling is needed, a crushed rock fill is used. Underneath and above this fill, geotextile is applied. Another base of crushed rock is applied for the foundation, followed by a strong top layer. The top layer depends on the location in the longitudinal direction of the ramp. When above the average high tide level, a cast in-situ concrete slab is used. Between average high tide level and average low tide level, concrete grid pavers are applied. This kind of concrete tile offers many advantages compared to precast concrete planks, which are generally used in the design of ramps. For San Antonio Este, we consider the aesthetic and environmental value of the concrete grid tiles most important. We believe it will increase the feasibility of the project because of its environmental advantages, despite being a more expensive option. In the past, a design for a concrete ramp in Las Grutas was not realised because of concerns by environmental groups (Andrini et al., 2021).

According to Beeldens (n.d.), the thickness of a concrete grid element should be larger than 116 mm for occasionally heavy traffic (which is the case for a boat ramp). A manufacturer of concrete grid tiles ('bloques verdes') that satisfied the requirements was found in Uruguay and this design was chosen as the top layer. A visualisation of the design can be seen in Section 10.6.3. The gaps between the blocks would be filled with material that was excavated to construct the ramp.



altura	largo	ancho	peso	cant/ml	cant/m^2
12cm	36cm	48cm	24kg	2,78	5,7

(a) Technical specifications of the green block (Hopresa, n.d.)



(b) Placement of precast concrete grid tiles in Belgium (note: this block has different dimensions than the one chosen for SAE) (Beeldens, n.d.)

Figure 10.16: The type of concrete grid tiles chosen and an impression of the placement of the tiles

When below the average low tide level, precast concrete planks are applied to save money (this area is seldom above the water, so the advantages of concrete grid pavers are minimal).

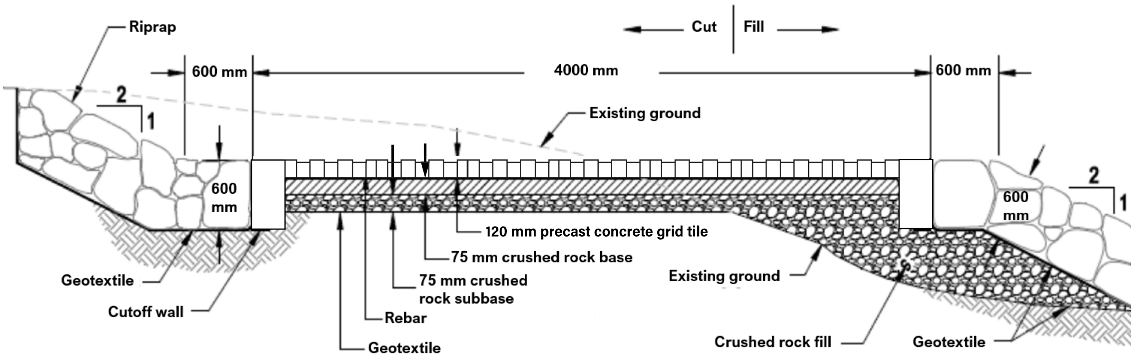


Figure 10.17: Cross section of the ramp

On the sides of the ramp, again geotextile is applied, followed by a deposit of riprap. See again figure 10.17. This figure shows on the left what the cross-section looks like when excavation is needed and on the right side what the cross-section looks like when filling is needed.

10.7 3D visual

This section includes 3D visuals that illustrate the design's response to both high and low tides. The design choices, dimensions, and materials detailed in the preceding sections are visually represented.

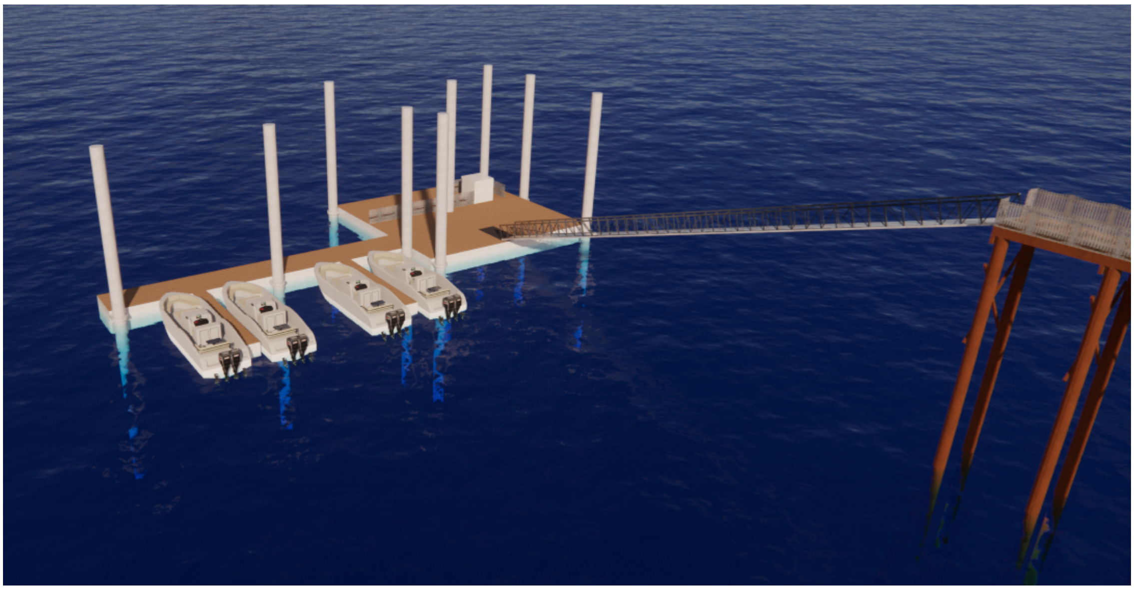


Figure 10.18: 3D visual during low tide

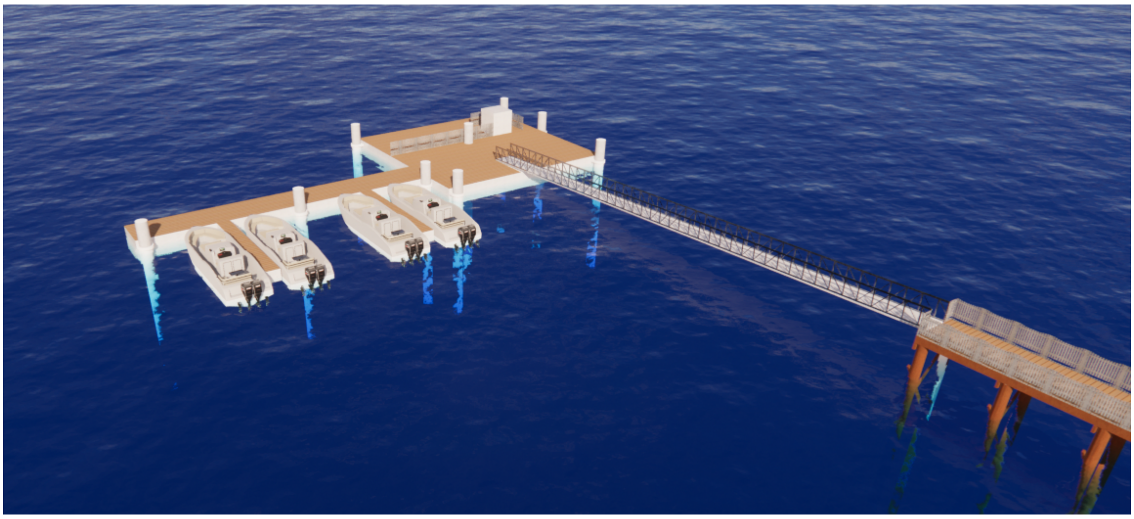


Figure 10.19: 3D visual during high tide

10.8 Cost Estimation of the preliminary design

In this paragraph, a Class 5 cost estimation will be done according to the AACE cost estimate classification system. Meaning it is the cost estimation with the largest range in accuracy. Typical ranges for the class 5 accuracy are on the low side -20% to -50% and +30% to +100% on the high side (Christensen & Dysert, 2005). Note that the calculations have only been performed on the structural parts. Not included are the installations pipelines, electricity, lights, fences and the facilities on the pontoons.

10.8.1 Cost estimation of the pier

The cost of the different timber components of the pier needs to be estimated. The cost estimation of the superstructure of the pier is based on information from Aserradero Silvio (2008). For the timber piles a foundation company from the Netherlands, Vanthek Projects (n.d.), is asked for advice. First the total length of the different components of the pier are calculated in Table J.1. Consequently the cost estimation of the pier is concluded in Table 10.1. The prices per metre of the timber components, which are used in Table 10.1, are including construction costs.

Component	**Cross section (mm)**	**Cost per unit ($/m)**	**Length (m)**	**Cost ($)**
Posts	101.6 x 152.4	18.2	290.4	5,285.3
Rails	38.1 x 152.4	3.1	1920	5,952
Railcaps	76.2 x 203.2	8.7	480	4,176
Deck	38.1 x 152.4	3.1	4800	14,880
Purlins	127 x 355.6	53.1	960	50,976
Beams	127 x 355.6	53.1	183	9,717.3
Piles	500	30	984	29,520
TOTAL				120,507

Table 10.1: Cost estimation of the pier

10.8.2 Cost estimation of the floating structure

In this section, the costs of the floating structure, including mooring piles, are calculated. The costs of the concrete pontoons are estimated using information from the supplier SF Marina. The result of the cost estimation of the concrete pontoons can be found in Table 10.2. The prices of the pontoons are including the costs for placement, but excluding the costs for the transportation of the floating working platform. This platform is needed for all construction in water and its costs will be added to the end summation.

Part	**Cost per unit ($/m^2)**	**Area (m^2)**	**Cost ($)**
Pontoon square	309.3	225	73,766.4
Walkway	309.3	66.9	21,933.2
Fingers	373.2	17.28	6,836.6
TOTAL			102,536

Table 10.2: Cost estimation of the floating structure

The cost estimation of the mooring piles of the floating structure is based on information from an expert of the company Besna. According to this expert, a percentage of 1% of the pile area is assumed for the reinforcement of the mooring piles. The weight of steel is taken as 78.5 kN/m^3 (PIANC, 2017). First, the amount of concrete and steel in cubic metre and kilograms is calculated, which can be found in table Table J.2. Consequently, the cost estimation of the mooring piles of the floating structure is done in table Table 10.3.

Component	**Cost per unit ($)**	**Unit**	**Quantity**	**Cost ($)**
Concrete piles	500	m^3	171	85,451
Reinforcement	0.85	kg	1342	1,140
Steel casing	400	kg	3995	1,597,829
TOTAL				1,684,420

Table 10.3: Cost estimation of the mooring piles of the floating structure

10.8.3 Cost estimation of the gangway

The cost of the gangway is based on information from a manufacturer from Florida. (Dock Builders, 2023) is a manufacturer of aluminum gangways with truss construction in Florida. For a gangway that is 1 metre wide and 5 metres long, they charge 5,852 $. When converted to a gangway that is 1.5 metres wide and 35 metres long, the estimated price becomes 61,000 $ for the gangway used in this preliminary design.

10.8.4 Cost estimation of the Mooring field

The cost estimation of the mooring field is similar to the cost estimation of the mooring piles needed for the floating structure. Hence an expert from the company Besna provided information for this estimation. The calculation of the required amount of steel and concrete can be found in table Table J.3. The cost estimation of the piles of mooring field can be found in table 10.4.

Component	**Cost per unit ($)**	**Unit**	**Quantity**	**Cost ($)**
Concrete piles	500	m^3	336	168,232
Reinforcement	0.85	kg	776.8	660.3
Steel casing	400	kg	3076	1,230,510
TOTAL				1,399,403

Table 10.4: Cost estimation of the mooring piles of the mooring field

10.8.5 Cost estimation of the boat ramp

The construction cost of the boat ramp consists of several components: mobilization of, excavation, fill material, geotextile, riprap, signage, and concrete, divided into precast concrete planks and in situ cast concrete. The costs per unit were estimated based on two reference projects from the USA (California (California Natural Resources Agency, 2019) and Oregon (Oregon State Marine Board, 2017)). In table 10.5 an estimation of the total construction costs of the ramp is depicted. The calculation of the cost estimation of the boat ramp is described in appendix J.0.4.

Element	**Cost per unit ($)**	**Unit**	**Quantity**	**Cost ($)**
Mobilization	50,000.00	LS	1	50,000.00
Excavation	17.66	m^3	63	1,112.41
Fill material	22.89	m^3	373	8,537.65
Geotextile	5.38	m^2	1536	8,266.69
Riprap	104.64	m^3	692	72,408.13
Signage	500.00	LS	1	500.00
Precast concrete planks	40.00	m^2	140	5,600.00
Precast concrete grid tiles	60.00	m^2	564	33,840.00
Insitu cast concrete	455.17	m^3	90	40,965.01
TOTAL				221,229.88

Table 10.5: Cost estimation of the boat ramp

10.8.6 Total estimated costs

The costs of the different sections of the design have been added together in an end summation, stated in table Table 10.6. The cost of the mobilization of the construction pontoon is provided by an expert from Besna. Resulting in a total estimated cost of the marina construction in water of 3,659,096.

Section	**Cost ($)**
Pier	120,507
Floating pontoon	102,536
Mooring piles of floating pontoon	1,684,420
Gangway	61,000
Mooring piles of mooring field	1,399,403
Boat ramp	221,230
Mobilization of the construction pontoon	70,000
TOTAL	3,659,096

Table 10.6: Total estimated costs

11 | Conclusion and recommendations

11.1 Conclusion

This paper discussed the development of a preliminary design for a marina in San Antonio Este. It was produced by 5 students from the TU Delft as part of their masters in civil engineering, in collaboration with Port consultants Rotterdam, Besna consultants and the university of Buenos Aires.

The research was divided into two stages: the research stage and the design stage. In the research stage, the needs and wishes of the several people involved were mapped and the technical feasibility of the project was investigated, through a detailed area study (including a project visit), a stakeholder analysis and a market study. In the area study, it was concluded that building a marina in the area is challenging, due to the large tidal difference (reaching amplitudes higher than 9 metres). During low tide, the wet area with large enough draught is limited, causing difficulties in spatial planning. In addition, hydrometeorological conditions create the need for active wave attenuation if permanent berthing on floating pontoons is desired. In addition, caution is required as the area is an important ecosystem due to its tidal character. In the stakeholder analysis, the need for facilities for vessel storage, launching and maintenance was identified, and the the management model of the marina was chosen to be fully private. Finally, the results of the market study show the potential for a marina, based on the current market and projections for the future: even in a bad scenario, the market in San Antonio Este will grow. The market study was used to create an ideal slip-mix, making sure the design played into the demand of today and also of the future. After these analyses, a literature review was done on how to incorporate a sustainable vision into the design.

From all the investigations in the research stage, requirements came forth, that had to be incorporated in the design. When the research stage was finished, the design stage started with the composition of three design alternatives. Two of these alternatives contained permanent berthing on floating pontoons and therefore needed wave attenuation. The other alternative had only several mooring buoys on the water. From the three layout alternatives, the alternative with the lowest initial costs, lowest environmental impact, and easiest accessibility was chosen. The analysis showed this was the first alternative, and this one was elaborated further. In the preliminary design, the pier, floating pontoon, gangway, mooring field, and boat ramp were designed in detail. The final costs were expected to amount to $3,659,096 USD.

The preliminary design given in previous Chapter 10 is the recommended design coming from this research. It should cater to the needs of the stakeholders, providing storage for their vessels. Also, it should support tourist companies by offering space for their offices and vessels. In addition, it should offer a place for the water bus, creating a long-needed connection between San Antonio Este and San Antonio Oeste.

11.2 Recommendations

Before you lies a preliminary design. In order to progress it to a final design, several steps need to be taken. This chapter will elaborate on which steps these are, but will also cover which parts of the design need further development in order to improve it. It is important to note that this report was produced in eight weeks and due to the time constrains, some parts need more data or in-depth calculations to draw valid conclusions.

The design could also be more precise and worked out in more detail if there was more relevant data available. Also, keep in mind the design alternatives when looking for future development of the marina. There might also be useful components in these alternatives that were not chosen in this preliminary design.

Regarding the area study, more data and measurements are needed to draw conclusions. This mainly applies to the hydrometeorological and geotechnical conditions. More accurate data on wave height or current speed at the design location are needed to determine accurate loads on the structure. These accurate estimations are needed to improve safety and structural stability. Measuring the wave heights can be done for example by placing a pressure box on the bottom of the water throughout the year. This box converts pressures to wave heights. Secondly, a more accurate bathymetry is needed, to know what the exact offshore limits are for building the marina.

The last soil study performed in the area is from 1978. To improve the geotechnical data, a soil investigation needs to be done at the correct location. Thus, more accurate pile bearing capacity calculations can be performed. This will make clear if the piles should be placed deeper or shallower into the soil, which will lead to more structural safety and a more accurate cost estimation. An environmental assessment is vital to be able to satisfy the environmental restrictions. It is recommended to investigate the impact of the piles on the soil and the environment, or the impact of the structure on marine migration. Another thing that could cause issues is the increased traffic by marine vessels due to the construction of the marina and its effects on the environment.

When considering the preliminary design, the dimensions of the piles of the pier and pontoons are now only based on vertical forces, due to time constraints when making this study. It was chosen to leave calculations including horizontal forces for a later stage, to make sure they are of high quality. For the next steps of the design, the horizontal forces should be calculated and the proper checks should be done on all components of (pier, mooring piles and piles for the floating pontoons). Concerning the mooring piles used to moor vessels, it is recommended to look for alternative options. Piling can be quite disruptive for the environment, and solutions involving buoys will be beneficial. However, due to the large tidal differences, normal buoys are not sufficient. Therefore, one should look for buoys that can adapt to the tidal differences. Another option that can be considered is to place only a few buoys on the water in the first stage of construction, and next to that, solely store vessels on land. Later, if the demand is going up, the mooring field using the piles can be placed. Finally, the cost estimations were difficult to perform, due to the unstable financial situation in Argentina. For example, the ramp turned out to be quite expensive considering American prices, this might be cheaper in Argentina.

Further steps, in order to make the design realized, are to speak to different parties that could be interested. Then, several elements in the design can be changed to make them more suitable for the different investors. In addition, the design of the dry area should be taken from conceptual to preliminary level. This can be done, for example by (land) architects that design the spatial planning and the central building. In order to do so, an accurate topographic map should be created first to gain insight in the height differences in the area, as google earth data is not accurate enough for designing. Then, higher level cost analyses can be done for the pier and pontoons as well as the design of the land area.

References

Administración general de puertos. (n.d.). Retrieved from https://www.argentina.gob.ar/transporte/administracion-general-puertos-se (Accessed on 20-10-23)

Aluminium pontoons in your marina. (n.d.). Retrieved from https://aister.com/en/blog-en/adventages-aluminium-pontoons/ (Accessed on October 11, 2023)

Amarres - sotamar. (n.d.). Retrieved from https://www.sotamar.com/es/AMARRES-94134 (Accessed on 27-09-23)

Andrini, J. C., Arecco, P., Cucci, A., & Veleda, V. (2021, September 10). *Diagnóstico de la situación actual. desarrollo integral puerto de san antonio este - componente desarrollo de un "polo logístico pesquero y náutico deportivo".* (Tech. Rep.).

Arecco, P., Zivojnovic, P., & Veleda, V. (2019). *Curso de planificación portuaria.* (191205 Curso BC Curso Planificación Portuaria (día 2).PDF)

Arena Solutions. (n.d.). *Sustainable development.* Retrieved from https://www.arenasolutions.com/resources/glossary/sustainable-development/ (Accessed: 06-10-2023)

Argentina - Ministerio de Ambiente y Desarrollo Sostenible. (2023). *¿qué hacemos en el ministerio de ambiente y desarrollo sostenible?* Retrieved from https://www.argentina.gob.ar/ambiente/institucional/que-hacemos

Aserradero Silvio. (2008). Retrieved from https://aserraderosilvio.com.ar/indexSF.html (Accessed on October 26, 2023)

ASTM. (2017). *Standard practice for classification of soils for engineering purposes (unified soil classification system).* ASTM Standard D2487-17E01. Retrieved 2023-09-20, from https://www.astm.org/Standards/D2487.htm

Beeldens, A. (n.d.). *Presentation: Prefab beton voor openbare ruimte, water en groen.* PDF document. Retrieved from https://www.febelcem.be/fileadmin/user_upload/agenda/journees-info/20170601/Pres_Berchem_010617_-_ABeeldens.pdf (Accessed on 2023-10-30)

Besna. (n.d.). *InnovaciÓn en ingenierÍa.* Retrieved from https://www.besna.com.ar/ (Accessed on October 31, 2023)

Blue Flag. (2023). *Blue Flag.* Retrieved 22-09-2023, from https://www.blueflag.global/

California Natural Resources Agency. (2019, November). *Summary of bids lake oroville* (Tech. Rep.). California Natural Resources Agency - Department of Water Resources Division of Engineering. Bid Date: November 6, 2019. (Title: Loafer Point Boat Ramp Facility - Stage I (Site 3B) Lake Oroville)

Candock. (n.d.). *Candock - floating dock system.* Retrieved from https://candock.se/floating-dock-system (Accessed on 22-09-23)

Christensen, P., & Dysert, L. R. (2005). *Cost estimate classification system – as applied in engineering, procurement, and construction for the process industries* (Tech. Rep.). The Association for the Advancement of Cost Engineering.

Clerico, L. D. (2023, September 11). *Visitalpat.* San Antonio Oeste.

Dai, J., Wang, C. M., Utsunomiya, T., & Duan, W. (2018). Review of recent research and developments on floating breakwaters. *Ocean Engineering*, *158*, 132-151. Retrieved from https://www.sciencedirect.com/science/article/pii/S0029801818303652 doi: https://doi.org/10.1016/j.oceaneng.2018.03.083

Dangen S.A. (2023). *Linea mobiliario exterior.* Retrieved from https://www.dangen.com.ar/productos/3/Linea-Mobiliario-Exterior (Accessed on 30 oktober 2023)

de la Provincia de Río Negro, L. (1990). *Ley provincial nº2353.* Retrieved from https://web.legisrn.gov.ar/digesto/normas/documento?id=1990010039&e=DEFINITIVO ([Online; accessed September 15, 2023])

D'Elia, M. (2021). *Cuantas embarcaciones hay en la argentina.* Retrieved from https://weekend-perfil-com.translate.goog/noticias/nautica/cuantas-embarcaciones-hay-en-la-argentina.phtml?_x_tr_sl=es&_x_tr_tl=nl&_x_tr_hl=nl&_x_tr_pto=wapp

Deltares. (2023). *Energy Transition: Responsible Choices and Sustainable Use.* Retrieved

2023-09-25, from https://www.deltares.nl/en/expertise/areas-of-expertise/energy-transition-responsible-choices-and-sustainable-use
den Brave, R., van Doormaal, T., Kuster, T., Termote, D., Veen, C. T., & Westerink, D. (2022). *Redevelopment of the riverfront of rosario* (Tech. Rep.). Delft University of Technology.
Department of Transport. (2013, July). *Design code for maritime infrastructure* (Tech. Rep.). Department of Transport, Maritime Division.
Dock Builders. (2023). *Aluminum gangway 3' x 16'.* Retrieved from https://www.dockbuilders.com/aluminum-gangway-3-x-16.html (20-10-2023)
Doornbos, S. (1986, March). *Fundex techniques for forming in-situ reinforced concrete piles* (Tech. Rep.). Fundenngstechnieken Verstraeten B.V.
ESPO. (2022). *Valencia's Port Authority and City Council to Install A Device Generating Energy From Waves.* Retrieved 2023-09-25, from https://www.espo.be/practices/valencias-port-authority-and-city-council-to-insta
FEE. (2019). *The sdgs and blue flag.* Retrieved from https://static1.squarespace.com/static/55371ebde4b0e49a1e2ee9f6/t/5d8b1b960603222cff9d6f27/1569397789915/Blue+Flag+and+the+SDGs.pdf
Gabinete municipal - san antonio oeste. (n.d.). Retrieved from https://sanantoniooeste.gob.ar/gabinete-municipal/ (Accessed on 20-10-23)
Gobierno de la Provincia de Río Negro. (2013). *PLAN DE MANEJO ÁREA NATURAL PROTEGIDA BAHÍA DE SAN ANTONIO, RÍO NEGRO.* (PROGRAMA DE APOYO A LA MODERNIZACIÓN PRODUCTIVA DE LA PROVINCIA DE RIO NEGRO. PRÉSTAMO BID 1463/1464 OC-AR)
Gobierno de Río Negro. (2019). *Ambiente recuerda restricciones de usos en el Área natural protegida bahía de san antonio anpbsa.* https://ambiente.rionegro.gov.ar/?contID=50273. (Accessed 07-08-202)
Gobierno de Río Negro. (2023). *Autoridades.* Retrieved from https://rionegro.gov.ar/autoridades ([Accessed on September 21, 2023])
Google Earth. (2023). Software. Retrieved from https://www.google.com/earth/
Hagadone Marine Group. (2022). *Dry stack boat storage explained.* Retrieved from https://hagadonemarine.com/dry-stack-boat-storage-explained/#:~:text=Dry%20stack%20storage%20is%20a,on%20top%20of%20each%20other. (Accessed on [insert the date you accessed the website here])
HMP Marine. (n.d.). *Materials most commonly used in marine construction.* Retrieved from https://www.hmpmarine.net/materials-most-commonly-used-in-marine-construction/
Hopresa. (n.d.). *Adoquín green block.* Retrieved from http://www.hopresa.com.uy/?portfolio=adoquin-green-block (Retrieved on 2023-10-30)
HSB Marine Construction. (2023). *Floating Concrete Pontoons and Docks.* Retrieved from https://www.hsbmarine.com/blog/floating-concrete-pontoons-and-docks (Accessed on October 11, 2023)
ITtoolkit.com. (2023). *The project stakeholder analysis: Roles, interests and influence.* Retrieved from https://www.ittoolkit.com/articles/stakeholder-analysis (Accessed on October 16th 2023)
JetDock. (2023). *Types of docks.* Retrieved from https://www.jetdock.com/knowledge-center/types-of-docks.asp
Jonkers, H., & Ottelé, M. (2022). *Sustainability in the built environment.* TU Delft Faculty of Civil Engineering & Geosciences. (Reader)
Kendrick Equipment. (2023). *Kendrick equipment - marine travelift.* https://www.kendrickequipment.com/marine-travelift/. (25-10-2023)
Lucy, J. A. (1977). Dry stack storage: A promising marina alternative. *WM ScholarWorks*. doi: 10.21220/M2-TC9F-PE14
Manuel, B. (1995). Response of a pile restrained floating breakwater.. Retrieved from https://api.semanticscholar.org/CorpusID:89614615
Marine piling for floating pontoons: Everything you need to know. (2020). Retrieved

from https://www.micksmarinemaintenance.com.au/marine-piling-for-floating-pontoons-everything-you-need-to-know/ (Accessed on 26-09-2023)

Marine Travelift, I. (n.d.). *Marine travelift project.* Retrieved from https://trends.nauticexpo.com/marine-travelift-inc/project-25733-317267.html (Accessed on 27-09-23)

Maritime Structures Standards Australia Committee. (2001). *Standards australia, guidelines for design of marinas.* Retrieved from https://hamiltonislandproperty.files.wordpress.com/2012/06/as_3962-2001_guidelines_for_design_of_marinas.pdf (Accessed on 03-10-23)

Martín, R., & Yepes, V. (2023). Landscape values in a marina in granada (spain): Enhancing landscape management through public participation. *Land*, *12*(2). Retrieved from https://www.mdpi.com/2073-445X/12/2/492 doi: 10.3390/land12020492

McCartney, B. L. (1985). Floating breakwater design. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, *111*(2), 304-318. Retrieved from https://ascelibrary.org/doi/abs/10.1061/%28ASCE%290733-950X%281985%29111%3A2%28304%29 doi: 10.1061/(ASCE)0733-950X(1985)111:2(304)

MCMag. (2020, September 30). *Suggested marina walkway handrail requirements.* Retrieved from https://marineconstructionmagazine.com/blog/suggested-marina-walkway-handrail-requirements/ (Accessed on October 27, 2023)

M. Elizabeth Carbone, W. D. M. y. M. C. P. (2014). *Procesos ambientales que afectan la bahía san antonio y su área de adyacencia (prov. de rio negro)* (Tech. Rep.).

MeteoBlue. (2023). *Climate Data for Puerto San Antonio Este, Argentina.* Retrieved 2023-09-25, from https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/puerto-san-antonio-este_argentina_3840083

MeteoBlue. (2023). *Datos climáticos y meteorológicos históricos simulados para puerto san antonio este.* Retrieved from https://www.meteoblue.com/es/tiempo/historyclimate/climatemodelled/puerto-san-antonio-este_argentina_3840083

Ministerio de turismo y deportes de argentina. (n.d.). Retrieved from https://www.argentina.gob.ar/turismoydeportes (Accessed on 20-10-23)

Nautical Insurance. (2023). *Mooring types.* https://www.nautical-insurance.co.uk/customer-information/mooring-types. (24-10-2023)

NauticExpo. (2023). *Product Listing on NauticExpo.* Website. Retrieved from https://www.nauticexpo.com/prod/ypmarinas/product-44674-460562.html

Navionics. (2023). *Bathymetry map of bahía san antonio.* Retrieved from https://webapp.navionics.com/?lang=es#boating@8&key=bpzwFty%7CjK

Nisa Syahidah, I. D. K. (2015). *Mooring buoy installation.* https://d2d2tb15kqhejt.cloudfront.net/downloads/BEEP_mooring_buoy.pdf. (Accessed on 27-09-023)

NOAA. (2015). *Understanding Living Shorelines.* Retrieved 21-09-2023, from https://www.fisheries.noaa.gov/insight/understanding-living-shorelines#what-is-a-living-shoreline?

Oechsner Boats. (n.d.). *Requirements for trailering trailerable boats.* Retrieved from https://oechsner-boats.de/allgemein/trailerable-boats-requirements-for-trailering/?lang=en (Accessed: October 25th, 2023)

Oregon State Marine Board. (2017, February 14). *Dayton boat ramp, yamhill river mile 4.9 for yamhill county parks - conceptual cost estimate* (Tech. Rep.). Oregon State Marine Board, Facilities Department.

Overton, M. (2018). *Wave screens protect basins when long fetch attenuators fall short.* Retrieved from https://www.marinadockage.com/wave-screens-protect-basins-long-fetch-attenuators-fall-short/

Paula Nogueira Machado Schffer, J. C. R. N. C. F. F. P. L.-F. c. S. A. E. P. J. A. d. R. J. E. F. O., Elírio E. Toldo Junior. (2023). *Architecture of shelly beach ridges in a sheltered beach environment in punta perdices beach, san antonio bay, argentina* (Tech. Rep.).

PIANC. (2014). *PIANC Report No. 150: 'Sustainable Ports' A Guide for Port Authorities* (Tech. Rep.). PIANC. (Report n° 150)

PIANC. (2016). *PIANC Report No. 149, Part II: Guidelines for Marina Design* (Tech. Rep.). PIANC. (Report n° 149, Part II)

PIANC. (2017). *PIANC Report No. 149, Part IV: Guidelines for Marina Design* (Tech. Rep.). PIANC. (RecCom WG Report n° 149, Part IV)

PIANC. (2020). *PIANC Report No. 168, 2020: Single point yacht moorings* (Tech. Rep.). PIANC. (Report n° 168)

Poralu Marine. (2018a). *Concrete Dock Floats.* Retrieved from https://www.poralu.com/en/products/concrete-floats/ (Accessed on October 11, 2023)

Poralu Marine. (2018b). *Floating Docks.* Retrieved from https://www.poralu.com/en/products/floating-docks/ (Accessed on October 11, 2023)

Poralu Marine. (2023). *Poralu marine - gangways.* Retrieved from https://www.poralu.com/en/products/gangways/ (20-10-2023)

Prefectura naval argentina. (n.d.). Retrieved from https://www.argentina.gob.ar/prefecturanaval (Accessed on 20-10-23)

ProductPlan. (2023). *Stakeholder analysis.* Retrieved from https://www.productplan.com/glossary/stakeholder-analysis/

Puertos, vías navegables y marina mercante. (n.d.). Retrieved from https://www.argentina.gob.ar/transporte/puertos-vias-navegables-y-marina-mercante (Accessed on 20-10-23)

Redacción. (2023). *Control comercial bajo la órbita de mario hernández «el municipio estará para acompañar al comerciante».* Retrieved from https://informativohoy.com.ar/control-comercial-bajo-la-orbita-de-mario-hernandez-el-municipio-estara-para-acompanar-al-comerciante/ (Accessed October 16th 2023)

Ricardou, F.-X. (2020). *Deviation radius: How do you manage your anchorage?* Retrieved from https://www.boatsnews.com/story/33886/deviation-radius-how-do-you-manage-your-anchorage (Accessed on 27-09-2023)

Scarborough Marina. (n.d.). *Brisbane's newest undercover drystack.* https://www.scarbmarina.com.au/drystack. (Accessed October 20, 2023)

Sea-Help. (2023). *Sea-help - winter storage for yacht and boat work.* https://www.sea-help.eu/en/guide/winter-storage-yacht-boat-work/. (25-10-2023)

Seaflex. (2023). *Seaflex mooring system.* https://www.seaflex.com/products/seaflex-mooring-system/. (25-9-2023)

Seafloatech. (2022). *Seafloatech.* Retrieved from https://www.seafloatech.com/en-gb/home (Accessed on 27-09-23)

Segemar. (1999). *Carta geologica de la republica argentina - san antonio oeste.* Map. Instituto de Geologica y Recursos Minerales. (1:250.000)

Servicio de Hidrografía Naval. (n.d.). *Geoportal.* Retrieved 2023-10-24, from http://geoportal.ddns.net/#/geoportal

Servicio de Hidrografía Naval. (2023). *Tablas de marea.* Retrieved from http://www.hidro.gov.ar/oceanografia/Tmareas/RE_Mareas.asp

SF Marina. (n.d.). *Concrete pontoon.* Retrieved from https://www.sfmarina.com/wp-content/uploads/2021/01/SF_Pontoon1000_2021.pdf (Accessed on October 30, 2023)

Snowden, R. (2007). *Managing successful programmes.* London: The Stationery Office.

Soons, F., & van Raaij, B. (2014). *Quick reference* (Tech. Rep.). Section Structural and Building Engineering, TU Delft.

South Australian Department for Infrastructure and Transport. (2022). *West Beach Boat Ramp.* Retrieved from https://dit.sa.gov.au/infrastructure/completed_projects/westbeachboatramp

Southern Forest Products Association. (2014). *Marine construction guide.* Metairie, Louisiana: Southern Forest Products Association.

Stichting Nederland Schoon and ANWB. (2006). *Measuring system for beach litter.* Stichting Nederland Schoon.

Structurmarine. (2023). *Structurmarine Benefits.* Retrieved from https://www.structurmarine.com/benefits/ (Accessed on October 11, 2023)

Symes, M. (2023). *Introduction to sustainability in marinas.* Innovamarina.

Sánchez, A., & Giordano, L. (2023, September 12). *Site visit.* San Antonio Este.

Technische Commissie CEN/TC 250. (2019). *Nen-en 1990+a1+a1/c2:2019 nl* (Dutch Version ed.).

The Coca-Cola Company. (2021). *Coca-Cola Australia Teams Up with Seabin Project.* Retrieved from https://www.coca-colacompany.com/au/media-centre/media-releases/coca-cola-australia-teams-up-with-seabin-project

Thomson, G. G. (2000). *Wave transmission through multi-layered wave screens* (Master's thesis). Kingston, Ontario, Canada.

TimberPilingCouncil. (n.d.). *Timber piling council availability.* Retrieved from https://www.timberpilingcouncil.com/availability

Tjs marine - floating pontoons. (n.d.). Retrieved from https://tjsmarine.com.au/commercial/floating-pontoons/ (Accessed on 26-09-23)

tmmarinas.com. (2023). *Heavy-duty pontoons.* Retrieved from https://tmmarinas.com/floating-pontoons/heavy-duty-pontoons/

The ultimate floating pontoon checklist. (2020). Retrieved from https://www.micksmarinemaintenance.com.au/the-ultimate-floating-pontoon-checklist/ (Accessed on 26-09-23])

Van Biezen Houtimport. (n.d.). *Ronde palen - houten heipalen.* Retrieved from https://www.vanbiezenhoutimport.nl/ronde-palen/houten-heipalen/ (Accessed: 27-10-2023)

Vanthek Projects. (n.d.). *Vanthek projects.* Retrieved from https://www.vanthek.com/ (Accessed on October 31, 2023)

Vazquez, R. H. R. (2005). *Estudio de suelos, puerto san antonio este.* Technical report. (Estudio No. 1101)

Velzen, E. v., Beyer, D., Berger, H., Greese, C., & Schelfhout, H. (2007, July). *Technisch rapport: Ontwerpbelastingen voor het rivierengebied (tror)* (Tech. Rep.). Rijkswaterstaat – Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling. Retrieved from URL_OF_THE_PDF_FILE

Verheul, W., & Heurkens, E. (2021). Meervoudige waardecreatie van publieke en private projecten in stedelijke ontwikkeling. *Grondzaken en gebiedsontwikkeling*, *16*(2), 12–17.

Verruijt, A. (2001). *Grondmechanica.* Technische Universiteit Delft.

Wahoo Docks. (2023). *Wahoo docks - gangway.* Retrieved from https://www.wahoodocks.com/gangway/ (20-10-2023)

Warren, C. (2020). *Cowes harbour handbook.* Style of Wight Magazine.

Waterdoorlatende modu tegel (grijs). (n.d.). https://www.betondingen.nl/waterdoorlatende-modu-tegel-grijs.html. (Accessed on October 27, 2023)

Weykamp, G. (2020). *Sustainable Design Strategies and Cost Savings.* Retrieved 22-09-2023, from https://www.marinadockage.com/sustainable-design-strategies-and-cost-savings/

Wickens Engineering Ltd. (n.d.). *Benefits of dry stack boat storage.* Retrieved from https://www.wickens.co.uk/products/dry-stack-boat-storage/benefits (Accessed on 27-09-23)

Wikipedia contributors. (2023). *San antonio oeste — wikipedia, la enciclopedia libre.* Retrieved from https://es.wikipedia.org/wiki/San_Antonio_Oeste (Accessed: August 6, 2023)

World Forest Group. (2021). *Taking the measure of wood: How to determine who's the strongest?* Retrieved from https://www.worldforestgroup.com/measuring-species-strength-why-should-i-care/ (Accessed on October 30, 2023)

A | Hydrometeo Conditions

A.1 Tidal conditions

Las alturas están referidas al plano de reducción que pasa 4,75 m debajo del nivel medio

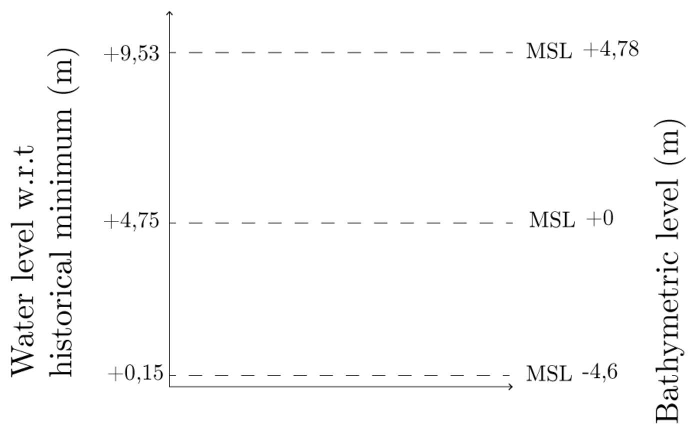
Alturas en metros sobre el plano de reducción, correspondientes a la predicción **2022**				Amplitud	
Pleamar		Bajamar			
Máxima	Media	Más baja	Media	Máxima	Media
9,27	8,00	0,21	1,62	8,96	6,38

Figure A.1: Tidal conditions in the year 2022 (Servicio de Hidrografía Naval, 2023)

Las alturas están referidas al plano de reducción que pasa 4,75 m debajo del nivel medio

Alturas en metros sobre el plano de reducción, correspondientes a la predicción **2023**				Amplitud	
Pleamar		Bajamar			
Máxima	Media	Más baja	Media	Máxima	Media
9,53	7,96	0,15	1,66	9,26	6,30

Figure A.2: Tidal conditions in the year 2023 (Servicio de Hidrografía Naval, 2023)



Water depth = bathymetric level - 4,75 + tide level

Figure A.3: Calculate the consistent water depth

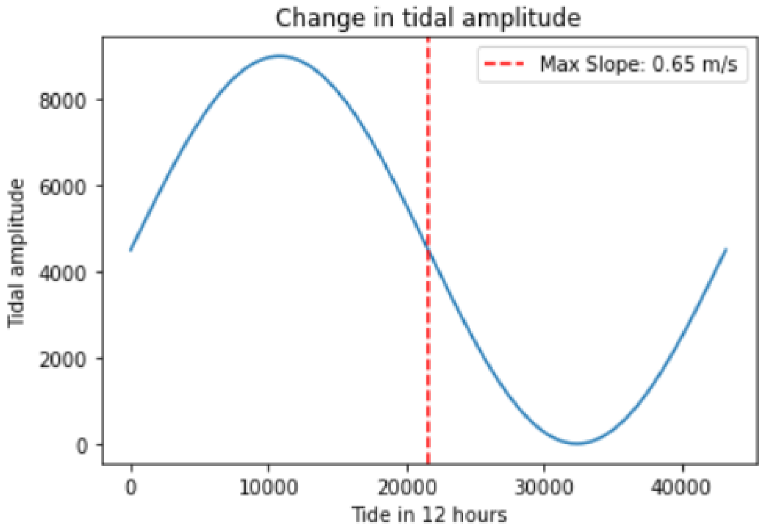


Figure A.4: Estimation of the maximum current speed

A.2 Bathymetry

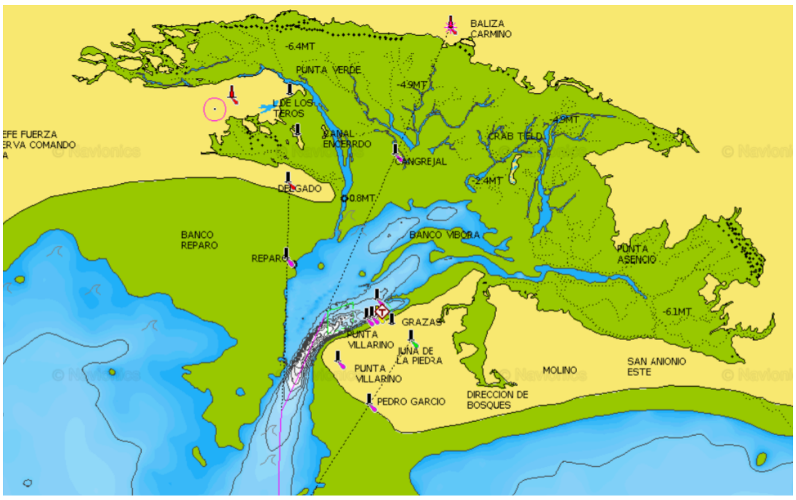
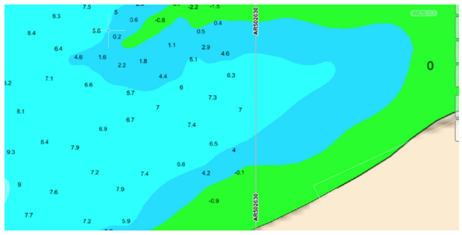
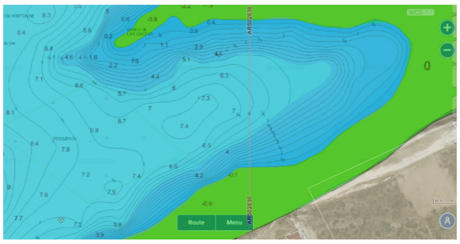


Figure A.5: Bathymetry Bahía San Antonio (Navionics, 2023)



(a) Bathymetry from Navionics (Navionics, 2023)

(b) Bathymetry from Official Nautical Chart (Servicio de Hidrografía Naval, n.d.)



(c) Navionics and Official Nautical Chart on top of each other

Figure A.6: Comparison of the bathymetry obtained from Navionics and the Official Nautical Chart

A.3 Wind conditions

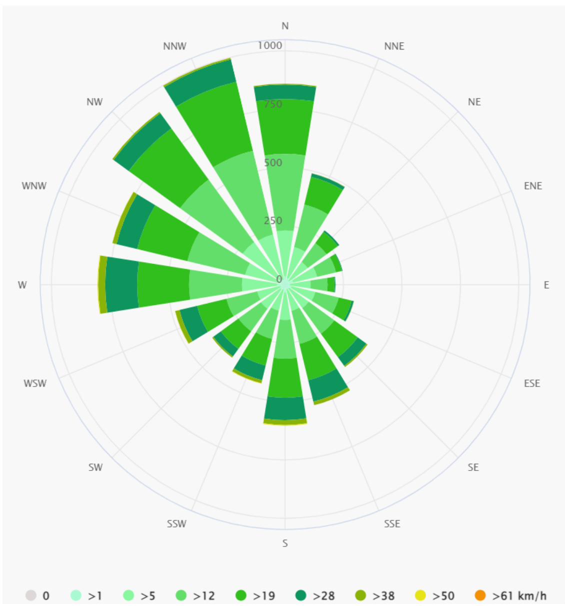


Figure A.7: Wind rose at Puerto San Antonio Este (MeteoBlue, 2023)

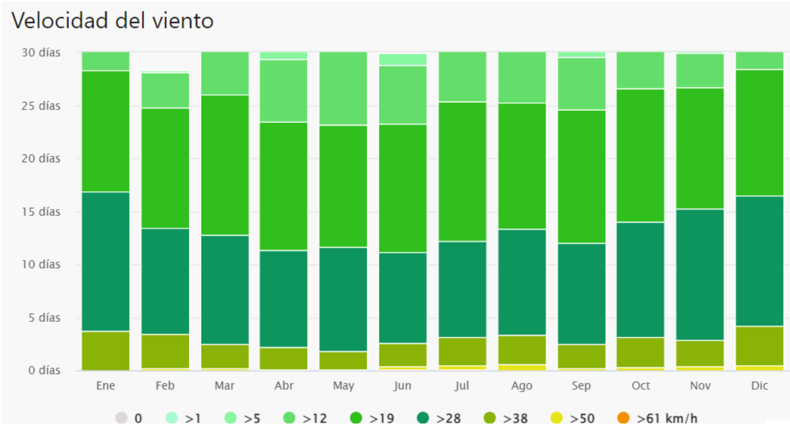


Figure A.8: Monthly wind conditions at Puerto San Antonio Este (MeteoBlue, 2023)

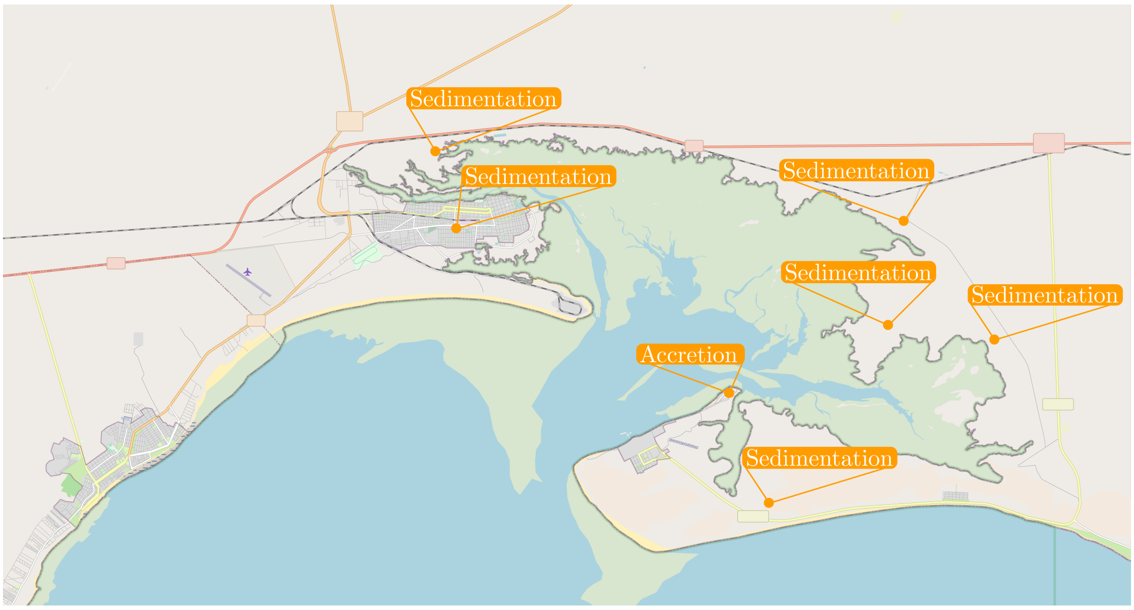


Figure A.9: Occurance of sedimentation and accretion (M. Elizabeth Carbone, 2014)

A.4 Wave conditions

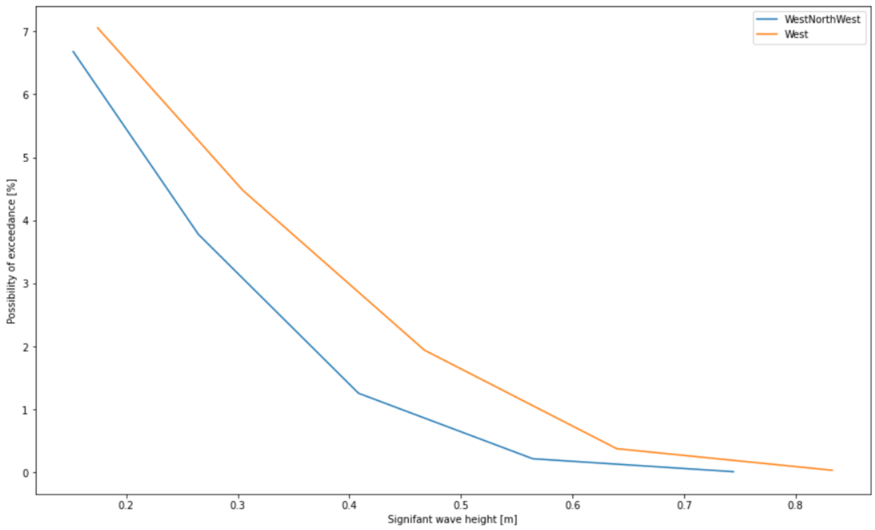


Figure A.10: Exceedance probability of significant wave heights

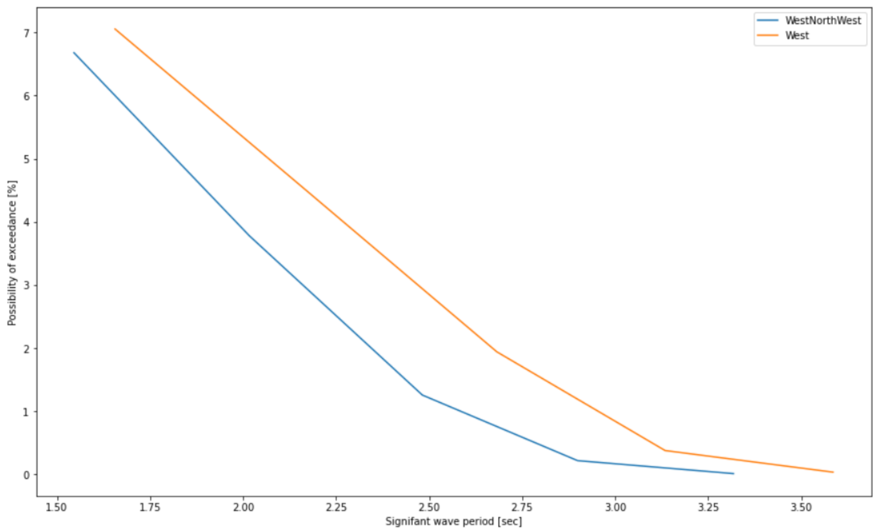


Figure A.11: Exceedance probability of significant wave period

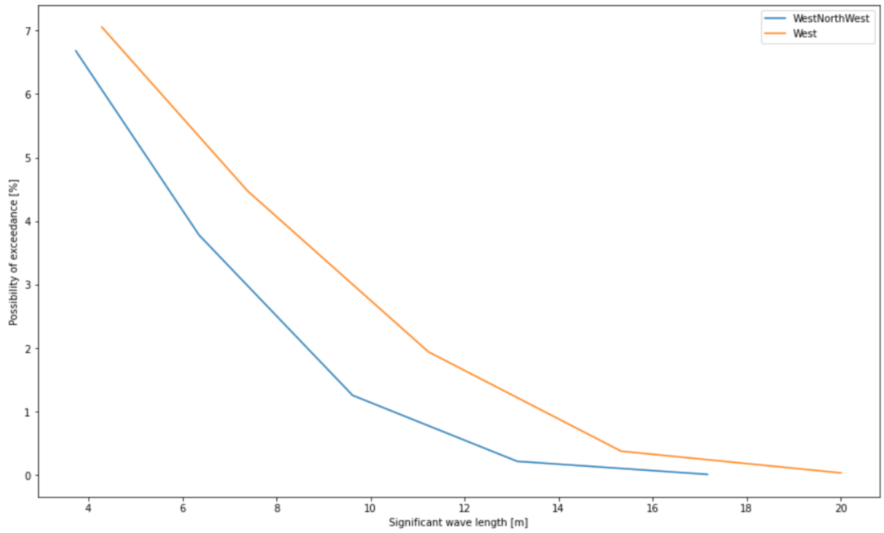


Figure A.12: Exceedance probability of significant wavelengths

A.5 Python scripts

In [1]:
```
import matplotlib.pyplot as plt
import numpy as np
from scipy.optimize import newton
```

In [2]:
```
def did(d,v,g):
    di = (d*g) / (v**2)
    return di

def diF(F,v,g):
    iF = (F*g) / (v**2)
    return iF

def Hs(dd,dF,g,v):
    a = 0.283 * np.tanh(0.35 * (dd**0.75))
    b = np.tanh( (0.0125* (dF**0.42)) / (np.tanh(0.35*(dd**0.75))) )
    dH = a*b
    HS = (dH*(v**2))/g
    return HS

def Ts(dd,dF,g,v):
    c = 2.4 * np.pi * np.tanh(0.833 * (dd**0.375))
    d = np.tanh( (0.077* (dF**0.25)) / (np.tanh(0.833*(dd**0.375))) )
    dT = c*d
    TS = (dT*v)/g
    return TS
```

In [3]:
```
g = 9.81
d = 7-4.75+8
#West North West = 292.5 degrees
#West = 270 degrees
print(d)
```

```
10.25
```

In [4]:
```
# Effective fetch

plusmin = 90/4/2

dN = [(292.5-plusmin), (292.5- 0.5*plusmin), 292.5, (292.5+ 0.5*plusmin), (292.5+pl
aN = np.zeros(len(dN))
lN = [7700, 9100, 10600, 12300, 13500]

dW = [(270-plusmin), (270- 0.5*plusmin), 270, (270+ 0.5*plusmin), (270+plusmin)]
aW = np.zeros(len(dN))
lW = [13500, 14700, 15400, 17800, 20200]

for i in range(len(dN)):
    aN[i] = dN[i]-292.5
    aW[i] = dW[i]-270
```

In [5]:
```
def effF(R,a):
    boven = np.zeros(len(R))
    cos = np.zeros(len(R))
    for i in range(len(R)):
        boven[i] = R[i] * (np.cos(a[i])**2)
        cos[i] = np.cos(a[i])
    F = np.sum(boven)/np.sum(cos)
    return round(F, 2)

FN = effF(lN, aN)
FW = effF(lW, aW)
```

```
print('The effective fetch of direction West North West is:', FN/1000, 'km')
print('The effective fetch of direction West is:', FW/1000, 'km')
```

```
The effective fetch of direction West North West is: 8.2111 km
The effective fetch of direction West is: 12.27474 km
```

In [6]:
```
kmh = [12,19,28,38,50]
u = np.zeros(len(kmh))
for i in range(len(kmh)):
    u[i] = kmh[i]*1000/3600
```

In [7]:
```
dimFN = np.zeros(len(u))
dimFW = np.zeros(len(u))
dimd = np.zeros(len(u))

for i in range(len(u)):
    dimFN[i] = diF(FN,u[i],g)
    dimFW[i] = diF(FW,u[i],g)
    dimd[i] = did(d,u[i],g)
```

In [8]:
```
HsN = np.zeros(len(u))
HsW = np.zeros(len(u))
TsN = np.zeros(len(u))
TsW = np.zeros(len(u))

for i in range(len(HsN)):
    HsN[i] = Hs(dimd[i],dimFN[i],g,u[i])
    HsW[i] = Hs(dimd[i],dimFW[i],g,u[i])
    TsN[i] = Ts(dimd[i],dimFN[i],g,u[i])
    TsW[i] = Ts(dimd[i],dimFW[i],g,u[i])

print(HsN)
print(TsN)
print(HsW)
print(TsW)
```

```
[0.15244163 0.26461613 0.40822152 0.56437604 0.74418327]
[1.54588008 2.01709963 2.4818788  2.89888268 3.31767891]
[0.17434309 0.304535   0.46720865 0.63959269 0.83278006]
[1.65606722 2.17445452 2.68200364 3.13413441 3.5854209 ]
```

In [9]:
```
#Width of floating breakwater

kN = np.zeros(len(TsN))
kW = np.zeros(len(TsW))

def equation(k, ω, g, d):
    return ω**2 - g * k * np.tanh(k * d)

initial_guess_k = 1.0

for i in range(len(kN)):
    ω = (2*np.pi)/ TsN[i]
    kN[i] = newton(equation, initial_guess_k, args=(ω, g, d))

for i in range(len(kN)):
    ω = (2*np.pi)/ TsW[i]
    kW[i] = newton(equation, initial_guess_k, args=(ω, g, d))

print("Solution for kN:", kN)
print("Solution for kW:", kW)


def calculate_B(Kt, ki, h, draft):
```

```
    expression_squared = (1 / Kt**2) - 1
    B = 2 * np.cosh(ki * h - ki * draft) * np.sqrt(expression_squared) / (ki * np.s
    return B

# Example usage:
ki = kW[3]
h = d
draft = 2.0
Kt_value = 0.5

# Calculate B using the known Kt
B_value = calculate_B(Kt_value, ki, h, draft)
print(f"Calculated B: {B_value}")
```

```
Solution for kN: [1.68398853 0.9890905  0.65332746 0.47893519 0.36601664]
Solution for kW: [1.46735369 0.85111863 0.55947551 0.40987397 0.31405071]
Calculated B: 3.7284420669525513
```

In [10]:

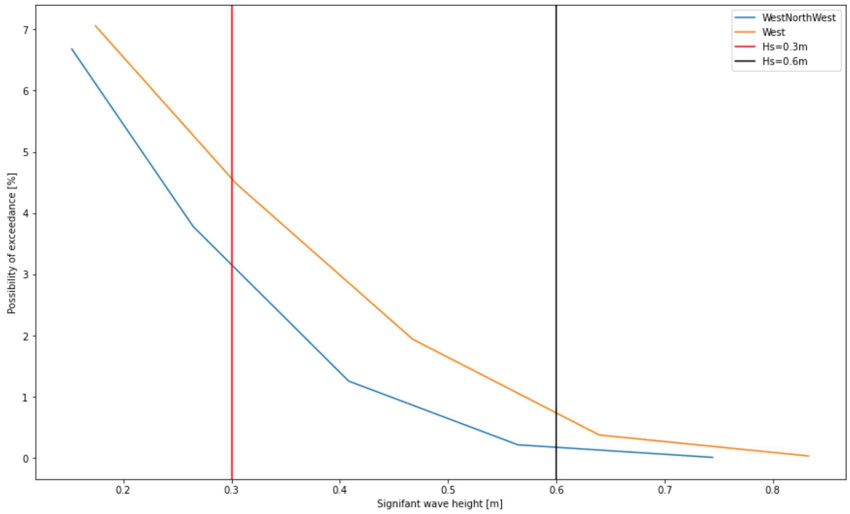
```
#hours/year
# a = >12 km/h
# b = >19 km/h
# c = >28 km/h
# d = >38 km/h
# e = >50 km/h

#WNW
aN = 254
bN = 221
cN = 91
dN = 18
eN = 1

#West
aW = 226
bW = 222
cW = 137
dW = 30
eW = 3

def perc(hrs):
    tot = 365*24
    p = (hrs/tot) *100
    return p

#WNW
N50 = perc(eN)
N38 = N50 + perc(dN)
N28 = N38 + perc(cN)
N19 = N28 + perc(bN)
N12 = N19 + perc(aN)

#West
W50 = perc(eW)
W38 = W50 + perc(dW)
W28 = W38 + perc(cW)
W19 = W28 + perc(bW)
W12 = W19 + perc(aW)

pN = [N12, N19, N28, N38, N50]
pW = [W12, W19, W28, W38, W50]
```

In [11]:

```
#Plot

plt.figure(figsize = (15,9))
```

```
plt.plot(HsN, pN, label='WestNorthWest')
plt.plot(HsW, pW, label='West')

vertical_x1 = 0.3
plt.axvline(x=vertical_x1, c='r', label = 'Hs=0.3m')
mN = (N28 - N19) / (HsN[2] - HsN[1])
bN = N19 - mN * HsN[1]
intersection_yN = mN * vertical_x1 + bN
#plt.plot(vertical_x1, intersection_yN, 'ro', label=f'{intersection_yN:.2f} %')
mW = (W19 - W12) / (HsW[1] - HsW[0])
bW = W12 - mW * HsW[0]
intersection_yW = mW * vertical_x1 + bW
#plt.plot(vertical_x1, intersection_yW, 'go', label=f'{intersection_yW:.2f} %')
limit1 = round(intersection_yN+intersection_yW,2)

vertical_x2 = 0.6
plt.axvline(x=vertical_x2, c='k', label = 'Hs=0.6m')
mN = (N50 - N38) / (HsN[4] - HsN[3])
bN = N38 - mN * HsN[3]
intersection_yN = mN * vertical_x2 + bN
#plt.plot(vertical_x, intersection_yN, 'ro', label=f'{intersection_yN:.2f} %')
mW = (W38 - W28) / (HsW[3] - HsW[2])
bW = W28 - mW * HsW[2]
intersection_yW = mW * vertical_x2 + bW
#plt.plot(vertical_x, intersection_yW, 'go', label=f'{intersection_yW:.2f} %')
limit2 = round(intersection_yN+intersection_yW,2)

print('The probability of the occurence of a wave height higher than', vertical_x1,
print('The probability of the occurence of a wave height higher than', vertical_x2,

plt.xlabel('Signifant wave height [m]')
plt.ylabel('Possibility of exceedance [%]')
plt.legend();
```

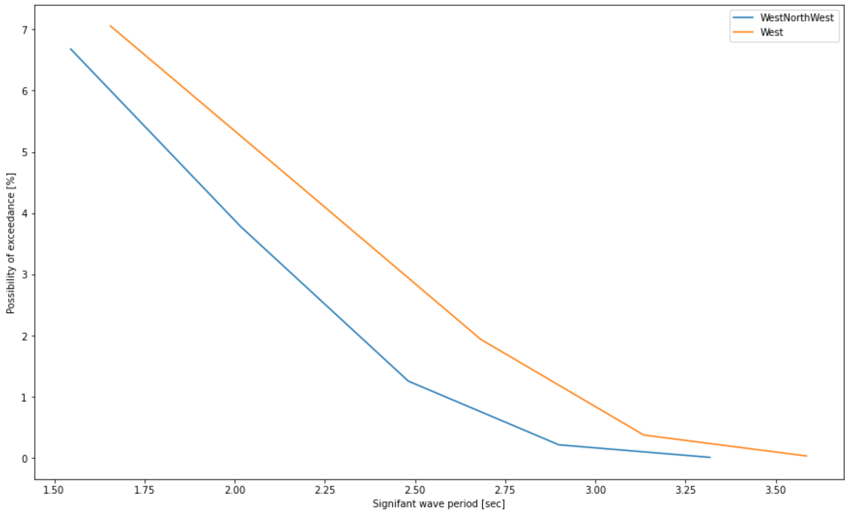
```
The probability of the occurence of a wave height higher than 0.3 is 7.72 %. This
is 676 hours per year.
The probability of the occurence of a wave height higher than 0.6 is 0.91 %. This
is 80 hours per year.
```



In [12]:
```
#Plot

plt.figure(figsize = (15,9))
```

```
plt.plot(TsN, pN, label='WestNorthWest')
plt.plot(TsW, pW, label='West')
plt.xlabel('Signifant wave period [sec]')
plt.ylabel('Possibility of exceedance [%]')
plt.legend()
print('TsN:', TsN)
print('TsW:', TsW);
```

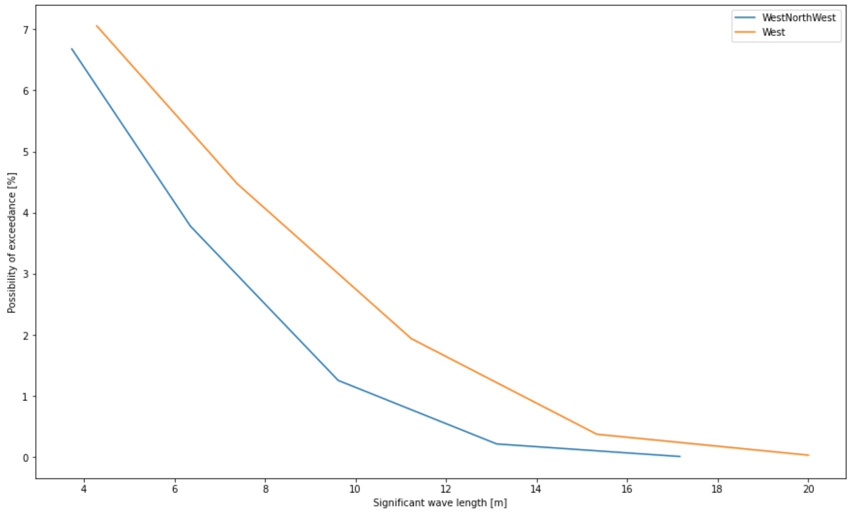
```
TsN: [1.54588008 2.01709963 2.4818788  2.89888268 3.31767891]
TsW: [1.65606722 2.17445452 2.68200364 3.13413441 3.5854209 ]
```



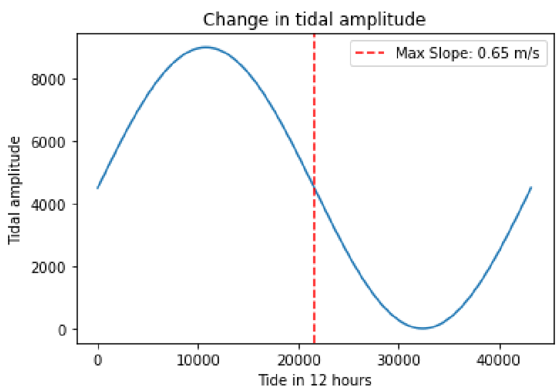
In [13]:

```
#Wave Length

LN = np.zeros(len(TsN))
LW = np.zeros(len(TsW))

for i in range(len(TsN)):
    def WaveLength(L):
        return L - (g * TsN[i]**2 / (2 * np.pi)) * np.tanh(2 * np.pi * d / L)
    LN[i] = newton(WaveLength, x0=8)
print("Solution for LN:", LN)

for i in range(len(TsW)):
    def WaveLength(L):
        return L - (g * TsW[i]**2 / (2 * np.pi)) * np.tanh(2 * np.pi * d / L)
    LW[i] = newton(WaveLength, x0=8)
print("Solution for LW:", LW)

plt.figure(figsize = (15,9))
plt.plot(LN, pN, label='WestNorthWest')
plt.plot(LW, pW, label='West')
plt.xlabel('Significant wave length [m]')
plt.ylabel('Possibility of exceedance [%]')
plt.legend();
```

```
Solution for LN: [ 3.73113308  6.35248777  9.61720676 13.11907216 17.1663927 ]
Solution for LW: [ 4.2819842   7.3822674  11.23049218 15.32955435 20.0069131 ]
```


WestNorthWest
West
Possibility of exceedance [%]
Significant wave length [m]
0
1
2
3
4
5
6
7
4
6
8
10
12
14
16
18
20

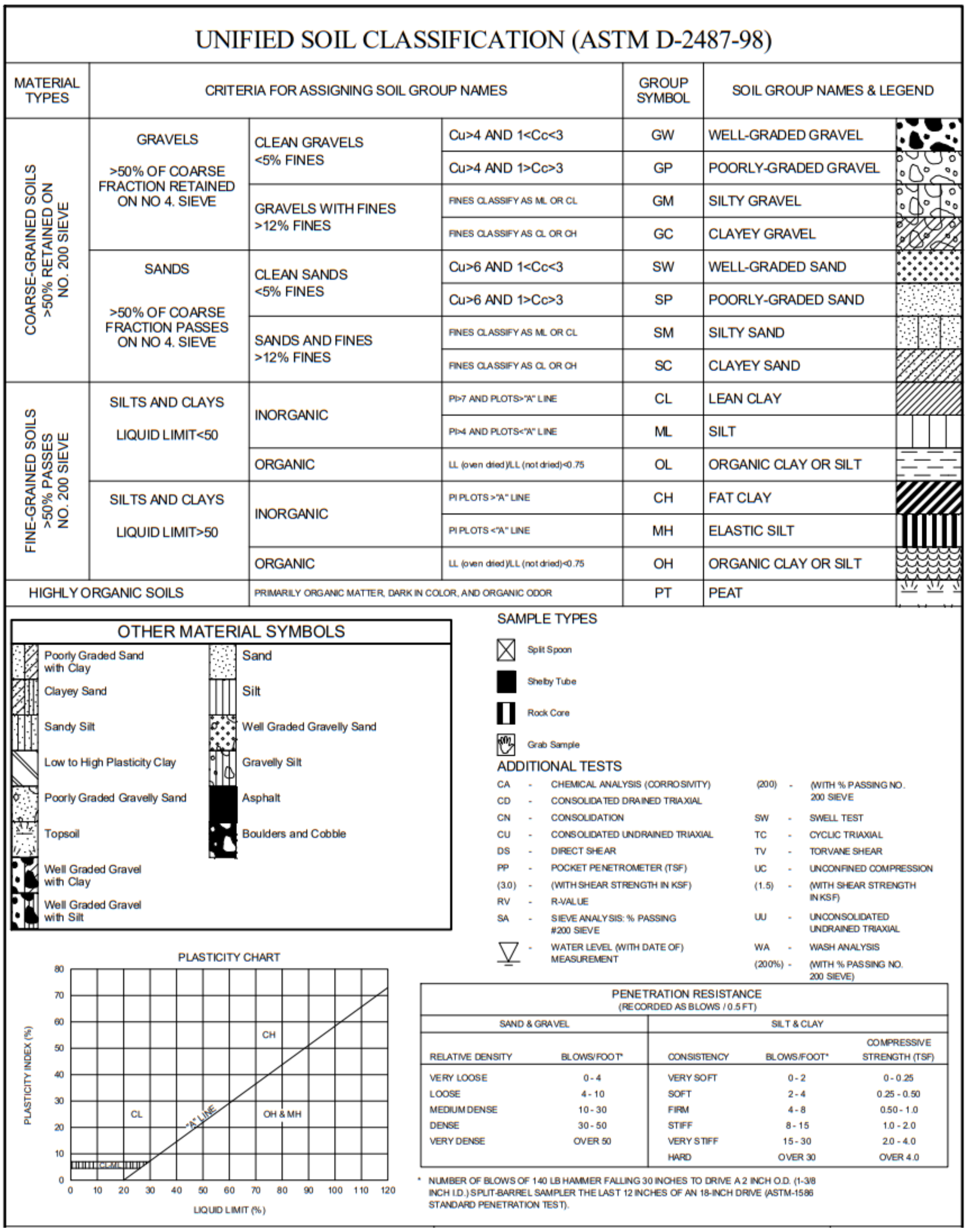
In [1]:
```
import numpy as np
import matplotlib.pyplot as plt

def sine_wave(amplitude, frequency, time):
    return amplitude * np.sin(2 * np.pi * frequency * time)

# Generate a time array
t = np.linspace(0, 12*3600, 1000)

amplitude = 4500
frequency = 1/(12*3600)

# Evaluate the sine wave for the entire time array
y = sine_wave(amplitude, frequency, t)

# Calculate the derivative (slope)
dy_dt = np.gradient(y, t)

# Find the maximum slope (maximum absolute value of the derivative)
max_slope = np.max(np.abs(dy_dt))

# Plot the sine wave
plt.plot(t, y+4500)
plt.xlabel("Tide in 12 hours")
plt.ylabel("Tidal amplitude")
plt.title("Change in tidal amplitude")

# Annotate the maximum slope on the graph
plt.axvline(x=t[np.argmax(np.abs(dy_dt))]+21600, color='r', linestyle='--', label=f
plt.legend()

plt.show()

print("Maximum current speed:", max_slope, 'm/s')
```




```
Maximum current speed: 0.6544941544533003 m/s
```

B | Geotechnical data

B.1 Unified Soil Classification System



UNIFIED SOIL CLASSIFICATION (ASTM D-2487-98)

MATERIAL TYPES	CRITERIA FOR ASSIGNING SOIL GROUP NAMES			GROUP SYMBOL	SOIL GROUP NAMES & LEGEND
COARSE-GRAINED SOILS >50% RETAINED ON NO. 200 SIEVE	GRAVELS >50% OF COARSE FRACTION RETAINED ON NO 4. SIEVE	CLEAN GRAVELS <5% FINES	Cu>4 AND 1<Cc<3	GW	WELL-GRADED GRAVEL
			Cu>4 AND 1>Cc>3	GP	POORLY-GRADED GRAVEL
		GRAVELS WITH FINES >12% FINES	FINES CLASSIFY AS ML OR CL	GM	SILTY GRAVEL
			FINES CLASSIFY AS CL OR CH	GC	CLAYEY GRAVEL
	SANDS >50% OF COARSE FRACTION PASSES ON NO 4. SIEVE	CLEAN SANDS <5% FINES	Cu>6 AND 1<Cc<3	SW	WELL-GRADED SAND
			Cu>6 AND 1>Cc>3	SP	POORLY-GRADED SAND
		SANDS AND FINES >12% FINES	FINES CLASSIFY AS ML OR CL	SM	SILTY SAND
			FINES CLASSIFY AS CL OR CH	SC	CLAYEY SAND
FINE-GRAINED SOILS >50% PASSES NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT<50	INORGANIC	PI>7 AND PLOTS>"A" LINE	CL	LEAN CLAY
			PI>4 AND PLOTS<"A" LINE	ML	SILT
		ORGANIC	LL (oven dried)/LL (not dried)<0.75	OL	ORGANIC CLAY OR SILT
	SILTS AND CLAYS LIQUID LIMIT>50	INORGANIC	PI PLOTS >"A" LINE	CH	FAT CLAY
			PI PLOTS <"A" LINE	MH	ELASTIC SILT
		ORGANIC	LL (oven dried)/LL (not dried)<0.75	OH	ORGANIC CLAY OR SILT
HIGHLY ORGANIC SOILS		PRIMARILY ORGANIC MATTER, DARK IN COLOR, AND ORGANIC ODOR		PT	PEAT

OTHER MATERIAL SYMBOLS

Poorly Graded Sand with Clay	Sand
Clayey Sand	Silt
Sandy Silt	Well Graded Gravelly Sand
Low to High Plasticity Clay	Gravelly Silt
Poorly Graded Gravelly Sand	Asphalt
Topsoil	Boulders and Cobble
Well Graded Gravel with Clay	
Well Graded Gravel with Silt	

SAMPLE TYPES

Split Spoon
Shelby Tube
Rock Core
Grab Sample

ADDITIONAL TESTS

CA	-	CHEMICAL ANALYSIS (CORROSIVITY)	(200)	-	(WITH % PASSING NO. 200 SIEVE
CD	-	CONSOLIDATED DRAINED TRIAXIAL			
CN	-	CONSOLIDATION	SW	-	SWELL TEST
CU	-	CONSOLIDATED UNDRAINED TRIAXIAL	TC	-	CYCLIC TRIAXIAL
DS	-	DIRECT SHEAR	TV	-	TORVANE SHEAR
PP	-	POCKET PENETROMETER (TSF)	UC	-	UNCONFINED COMPRESSION
(3.0)	-	(WITH SHEAR STRENGTH IN KSF)	(1.5)	-	(WITH SHEAR STRENGTH IN KSF)
RV	-	R-VALUE			
SA	-	SIEVE ANALYSIS: % PASSING #200 SIEVE	UU	-	UNCONSOLIDATED UNDRAINED TRIAXIAL
▽	-	WATER LEVEL (WITH DATE OF) MEASUREMENT	WA	-	WASH ANALYSIS
			(200%)	-	(WITH % PASSING NO. 200 SIEVE)

PLASTICITY CHART

PENETRATION RESISTANCE (RECORDED AS BLOWS / 0.5 FT)

SAND & GRAVEL		SILT & CLAY		
RELATIVE DENSITY	BLOWS/FOOT*	CONSISTENCY	BLOWS/FOOT*	COMPRESSIVE STRENGTH (TSF)
VERY LOOSE	0 - 4	VERY SOFT	0 - 2	0 - 0.25
LOOSE	4 - 10	SOFT	2 - 4	0.25 - 0.50
MEDIUM DENSE	10 - 30	FIRM	4 - 8	0.50 - 1.0
DENSE	30 - 50	STIFF	8 - 15	1.0 - 2.0
VERY DENSE	OVER 50	VERY STIFF	15 - 30	2.0 - 4.0
		HARD	OVER 30	OVER 4.0

* NUMBER OF BLOWS OF 140 LB HAMMER FALLING 30 INCHES TO DRIVE A 2 INCH O.D. (1-3/8 INCH I.D.) SPLIT-BARREL SAMPLER THE LAST 12 INCHES OF AN 18-INCH DRIVE (ASTM-1586 STANDARD PENETRATION TEST).

Figure B.1: Unified Soil Classification System (ASTM, 2017)

C | Stakeholder analysis

Stakeholder	Primary goal	Stance towards project	Influence	Interest
1. National Ports Directorate	To ensure high quality ports and waterways (den Brave et al., 2022).	The project will result in a new high quality marina, which helps improving the bahía San Antonio and the waterfront. Resulting in the National Ports Directorate to have a general positive stance against the project.	May cause interference by not issuing the permit to construct the marina design due to overarching spatial plan or interference with the waterway.	The National Ports Directorate has medium interest, because the new marina will result in little impact on their work, but there is some level of accountability, since they issue the permit.
2. Prefectura Naval Argentina	Responsible for tasks related to maritime safety	It needs to approve the safety of the vessels that will be used for the water bus. As long as they are safe, they should have a positive stance.	May interfere by not approving the vessels used for the water bus.	They have medium interest in the marina, since they are only concerned with maritime safety.
3. Ministry of Tourism and Sports of Río Negro	To foster growth in the province by enhancing tourism.	The new marina design can potentially provide places for tourists on boats to stay the night at this beautiful location. Moreover it will become easier for tourists staying in Las Grutas or San Antonio Oeste to cross the bahía San Antonio and enjoy the nature reserve there. Overall a positive stance.	The ministry can influence the project impact since it has to approve the plans regarding the touristic activities in the area.	The new marina design will have a positive impact on tourism in the area, resulting in medium interest.
4. Secretary of Environment and Climate Change of Río Negro	To supervise the province's environmental policy and advance sustainable development.	The secretary is reluctant against a new marina in a nature reserve owned by the province.	The secretary has to make sure the environmental laws are obeyed. It will oversee this for all projects. In addition it has to approve the construction and the following activities in their nature reserve.	The secretary has interest in the project relating the protection of the environment. On the other side, the current situation means a lot of shells are crushed daily by cars that are used to put boats in the water. This could be an opportunity to

				regulate the boat usage around bahía San Antonio and educate tourists as well.
5. Secretary of State of Planning of Río Negro	In charge of the urban development of Río Negro.	The water bus over the bahía San Antonio improves the connectivity between the two cities, which leads to a positive result regarding urban development. The stance depends on whether the new marina fits within the current development plans of the area of the Nation.	According to Rocio Fernandez from the municipality of San Antonio Oeste the lands of the location of the marina design belong to the province of Río Negro. They may cause interference by not issuing the permit to construct the marina design due to an overarching development plan of the area.	This entity has medium interest, since the new marina will influence their development plans, so it will impact their work. Additionally they will have a level of accountability, since they issue the permit.
6. Corredor Bioceanico Norpatagónico	The development of the Bioceanic Corridor Norpatagónico infrastructure by projects with sustainable development and environmental conservation as a premise.	A marina that boosts the economy, provides jobs, enhances the bahía San Antonio would fit their goal, hence a positive stance towards the project.	The entity has a large influence on the project, since it has provincial delegates on their board and are the only entity on provincial level that concerns themselves with the waterways and marinas. Additionally, they can be an investor for the project.	Medium interest, since this marina is just a small part of their large overarching goal, so the marina will have a small impact on their work. If they invest, their accountability grows and a successful outcome will be very important to them.
7. Undersecretary of Commercial control, traffic and transport of San Antonio Oeste	In charge of the public transport, managing traffic and providing transportation infrastructure. (Reddacción, 2023)	The water bus provides a faster connection between San Antonio Oeste and San Antonio Este. This results in a positive stance towards the project.	The undersecretary will have to provide a license for the water bus connecting the two cities.	This entity has medium interest, since the project will have an impact on their work, but their level of accountability is not very large.
8. Tourism and Culture Agency of San Antonio Oeste	Improving the quality of the tourism services in San Antonio, but with their best	Tourism is an important business for the community of San Antonio, hence the directorate has a	The ministry can influence the project impact since it has to approve the plans regarding the	This entity has medium interest, since the project will have an impact on their work, but their level of

	interests at heart for the residents of San Antonio.	positive stance towards a project that boosts tourism in the area.	touristic activities in the area.	accountability is not very large.
9. Agencia de protección ambiental bahía San Antonio	Protect and conserve the environment of the bahía San Antonio.	The agency feels reluctant towards a new marina in a nature reserve.	The agency can influence the project impact. Alone they don't have a lot of power, but together with local residents or other environmental organizations their influence grows.	This entity has a medium interest in the new marina, since it will be build in the area they protect, so the outcome is important to them.
10. Terminal de Servicios Portuarios Patagonia Norte S.A.	Exploit business of transporting fruit from Argentina over the ocean.	The marina and it's connection will provide an easier way for their employees to cross the bahía San Antonio, hence a positive stance towards the project.	The company has very little influence, since the new marina is very different from their port and so there is no interference.	Low interest, since the marina won't interfere with their business and their employees still make it to work every day, so the marina will not have an direct impact on their business.
11. Local residents	Relating the marina, their goals are: working at the Puerto San Antonio Este, enjoying and protecting the beautiful surroundings at San Antonio Este and or sailing in the bahía San Antonio.	They have a positive stance towards the project, since it will shorten the travel time between San Antonio Este and San Antonio Oeste and it will be made possible for them to put their boats easily in the water at the marina. They can be afraid of the increase in tourists damaging the area, but this problem is acknowledged and something that the design needs to prevent.	The locals have medium power as well, because they are one of the reasons this design is made and together their power can increase.	This marina will have a large impact on their daily life. Resulting in a large interest, because they will benefit from the marina becoming a success.
12. Tourists	Enjoy the surroundings of San Antotonio and do touristic activities there.	A positive stance towards the project, since the new marina provides an easier and faster way to travel to San Antonio Este	The tourists have very little influence on the project, because they don't have an actual voice in the	The tourists have medium interest, since they will be one of the main users of the marina. Meaning that they benefit

		from San Antonio Oeste or Las Grutas to enjoy the touristic activities there.	discussion regarding the design.	from the marina becoming a success.
13. Parador Rupestre	Providing services and experiences to tourists.	Agustín is very interested in the new marina design, resulting in a positive stance.	Agustín has medium influence on the project, since he doesn't have the means to invest much, but he is one of the big players regarding tourist companies in the area. Meaning he would love to make us of it, resulting in paying rent, which gives him influence as a future investor.	Agustín has large interest in the success of the project. It will give him a chance to expand his business.
14. Tourist companies from Las Grutas	Providing services and experiences to tourists.	A new marina provides possibilities for these companies to grow their businesses, which results in a positive stance towards the project.	These companies have medium influence, because they are one of the reasons this design is made and they could possibly be the investors for this marina. Together their power can increase.	This marina can provide berths for their boats, which has a big influence in their business, hence a large interest.
15. Transporte Las Grutas S.A.	Transportation company based in San Antonio Oeste. Regarding this project: the company organizes the current transportation between San Antonio Oeste and San Antonio Este.	The company has a negative stance towards the project, since their transportation between San Antonio Oeste and San Antonio Este will become practically redundant. Alternative routes can become interesting, like a bus service from Las Grutas and the center of San Antonio Oeste to the terminal for the water bus in San Antonio Oeste.	This company has little influence on the design, since they have no voice in the decision process.	Little interest, since they will be interested in the outcome and the new bus service possibilities for them, but they don't care about the marina itself.

16. ALPAT	Building a successful business by producing sodium carbonate.	The company has a positive stance towards the project, but especially if their pier will be used for the connection over water between San Antonio Este and San Antonio Oeste.	ALPAT doesn't have much influence in the decision making process, but they could become a possible investor to increase their influence. This will increase the likelihood of the project being realized.	If ALPAT invests in the project, their interest grows, because they become more interested in making the project a success.
17. Private investors	Generating revenue.	The stance towards the project depends on how strong the business case will be. The complete business case is outside of the scope for this research.	Investors can influence the project, since they will make it happen.	Since they invest, they definitely are interested in the outcome of the project. They can enjoy great financial benefits when the project becomes a success.
18. Fundación Inalafquen	Environmental management and ecotourism.	The foundation feels reluctant towards a new marina in a nature reserve.	Alone they don't have a lot of power, but together with local residents or other environmental organizations, for example the department of the municipality regarding environmental protection, their influence grows.	They have medium interest in the new marina, since the marina will be build in a nature reserve, which is what they try to protect and preserve.

D | Additional research

D.1 Philosophy: a sustainable development

The philosophy that was guiding during the design process is a sustainable development. Below, a research into the different options is presented, per pillar of sustainability (1. Environmental protection and enhancement, 2. Social progress, and 3. Economic development (Jonkers & Ottelé, 2022) according to the Brundtland Commission)

D.1.1 Environmental protection and enhancement

Environmental protection and enhancement focuses on preserving and enhancing the health of the planet. The marina will be located in a sensitive coastal ecosystem. It is important that the design minimizes the negative impact on this ecosystem. The following themes discussed are relevant to this study to minimize this impact.

Construction

Construction always has a big impact on the environment, as well as financial consequences. A lot can be gained when taking these upcoming ideas into consideration.

Nature-based features and solutions: These are proactive ecological enhancements, that use the power of nature to address various environmental challenges (Symes, 2023). Examples are designing artificial reefs and using ecosystem functions in the landscape, storm water management, and infrastructure design. Also living shorelines can be included in the design, enhancing aquatic habitats. These are protected, stabilized coastal edges made of natural materials such as plants, sand, or rocks (NOAA, 2015).

Materials: The use of appropriate building materials can make a difference in the environmental footprint. An example is Kebony, "a modified pine product that utilizes a byproduct of the sugar industry to stabilize the cellular structure of the wood. The result is a real wood product with no chemical additives that looks and lasts over 30 years, at low cost and without impacting rainforests." (Weykamp, 2020).

Location: When constructing a sensitive ecosystem, choosing the right location can lower the impact on this ecosystem substantially. Here, environmental reports can be taken into account. Also, choosing a location where wave height (and with that, the need for wave protection) is minimal, can lower costs on maintenance and materials (Weykamp, 2020).

Renewable energy

Using renewable and natural energy sources is critical in an environmentally friendly design. There are several options, like wind and solar energy. Also, the sea can play a big role in this context.

Wind energy: Wind energy should never be ignored as a possible source of energy. In figure A.3, in the appendix, it can be seen that wind is present often, at reasonable velocities. A solution could be wind turbines incorporated into mooring buoys.

Solar energy: Figure D.1 shows there are between 9 and 17 sunny days in a month. Using solar energy as an alternative source of energy is therefore an option.

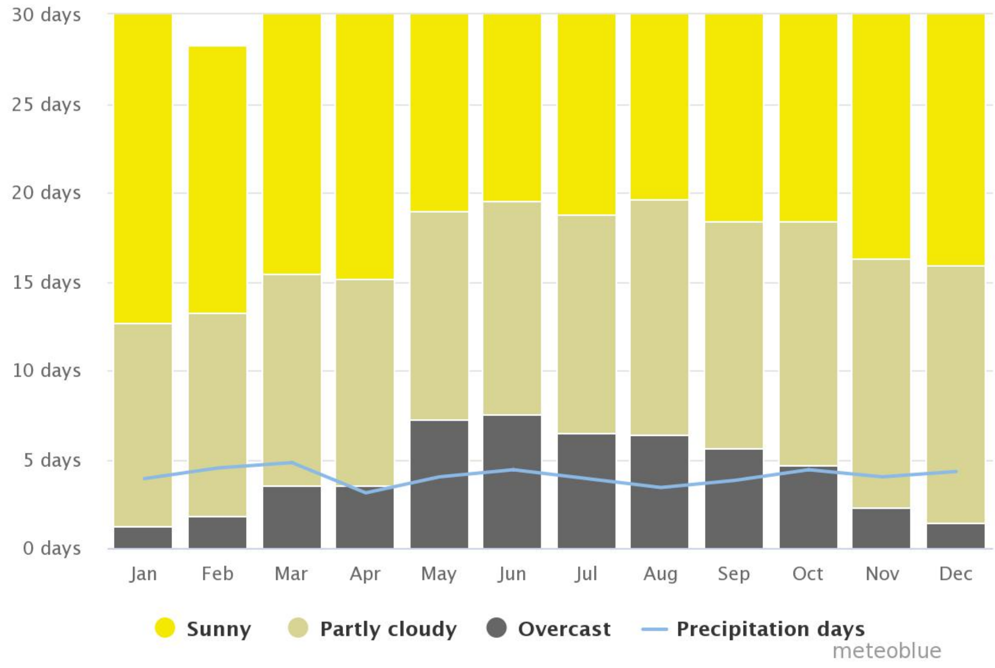


Figure D.1: Cloudy, sunny, and precipitation days in San Antonio Este (MeteoBlue, 2023)

Not only the common onshore solar panels can be an option for generating solar energy. Also offshore, floating solar panels are an increasingly common sight (Deltares, 2023). Although space-efficient, the effects on surrounding ecosystems are yet unknown. Another technology that generates energy from the sun is aqua thermal energy. Here, energy is extracted from surface water heat using a surface water heat pump (SWHP)(Deltares, 2023).

Hydraulic energy (waves and tides):

As the sea is close by, including waves and a large tidal difference, generating energy from this source is a logical option. For wave energy, Wave Energy Converters (WEC) are used, like in the Port of Valencia (ESPO, 2022). Another very interesting technology is tidal energy. Because the tidal difference in San Antonio can be as high as nine metres, this is an option that definitely should be considered. However, construction of such installations is very costly and could go into millions of US dollars, which makes this option not feasible in SAE.

Pollution reduction

To reduce the pollution created by the marina, several aspects and solutions can be taken into account when designing.

Sewage: Having a system for the collection, temporary storage, treatment, and proper disposal of sewage reduces contamination of sea water (Symes, 2023).

Water taps: Installing water taps with drinking water reduces plastic bottles being used, with that plastic pollution of the beaches (FEE, 2019).

Waste management: Managing waste in a proper way is vital to reducing pollution on beaches. Installing enough trash cans is a must. Another solution is the Seabin, to keep marinas clean and free of trash, both improving water quality and reducing maintenance time (Weykamp, 2020).

This is a bin connected to a water pump. This pump sucks in floating trash which then gets trapped inside a bag. See Figure D.2.

Figure D.2: The Seabin (The Coca-Cola Company, 2021)

Light pollution: Light pollution is a phenomenon occurring at night, caused by lighting. It happens when excessive or misdirected artificial light interferes with natural darkness in the night environment. Light pollution not only hinders astronomical observations but also disrupts the natural rhythms of animals, plants, and humans. A solution is the Dark Sky strategy. According to Weykamp, "Dark Sky lighting strategies aim to minimize light pollution and glare. The strategy is to use efficient light fixtures with shielded cut-off lenses, and strategically place light only in areas that need to be lit. Dark Sky lighting can help people see better at night, attract fewer insects, and reduce light pollution that can negatively impact migratory birds."

Noise pollution: To reduce noise pollution, one could think of using sound-absorbing materials during construction. Also, electric vehicles produce less noise than fuelled ones. A last option to consider is to begin slowly when driving piles, to give animals the chance to escape the site (PIANC, 2014).

Electric vessels/vehicles: The use of electric vessels and vehicles creates several solutions to minimize the environmental impact. Firstly, they produce zero emissions, reducing air pollution and greenhouse gas emissions. Secondly, electric motors are highly energy-efficient, converting a greater percentage of the energy stored in batteries into usable power, which minimizes energy waste. Also, as mentioned before, noise pollution is minimized.

Monitoring of emissions/pollution

Monitoring the ecological impact of the marina is essential because it helps understand the environmental consequences of the marina, allowing it to identify areas where improvements can be made to reduce harm to ecosystems, conserve resources, and minimize pollution. Monitoring can be done by installing gas analyzers at key emission sources, collecting water samples, and testing soil samples.

Beach litter: Stichting Nederland Schoon and ANWB (2006) created a system to measure beach litter. Measured in units per area, a beach can be described as very clean, clean, moderately clean, dirty, or very dirty. This is a system that could be considered to keep litter from the beach in San Antonio Este.

Phased development

Phased development is a project management approach that involves dividing a larger project into distinct phases. Each phase is designed to achieve specific objectives and milestones, building upon the progress of the previous phase. A phased approach can facilitate more effective environmental management of marina development. Environmental impacts can be assessed and mitigated during each phase, ensuring adherence to local regulatory requirements. To oversee the environmental effects during construction, monitoring is crucial.

D.1.2 Social progress

The social progress in sustainability development aims to improve the quality of life for all individuals and communities within the marina. The following themes discussed are relevant to this study to enhance this.

Education

Education is a crucial aspect of social progress, it gives individuals the opportunity to actively participate with knowledge and skills in improving the quality of life in the marina. Below are a few examples of how the design of the marina can make people more aware of sustainability.

Interpretation centre: First and foremost, an interpretation centre should be adopted in the design (FEE, 2019). This is the perfect solution for the education of visitors through interactive exhibits, displays, educational programs, and trained staff to help them better understand and appreciate the significance of the surrounding environment.

Sustainable products: By providing sustainable goods and incorporating recycled products in the marina, the promotion of environmentally friendly choices and the contribution to visitor education are accomplished.

Educational signs: The use of educational signs in the marina about the sustainable aspects educates the visitors. For example, when generating solar energy, a display could be placed showing the quantity of power generated.

Navigation safety: Providing lessons on navigation safety is crucial for the well-being of society. This can be accomplished by setting up a place specifically for boating or sailing schools.

Create marina community: Establishing a marina community involves creating spaces such as boat clubs where vessel owners can gather. This fosters a sense of community, encouraging participation in various activities within and around the marina. Furthermore, it provides an environment for the exchange of knowledge among members.

Handling peaks in demand

Effectively managing peaks in demand is crucial for social progress within sustainable development as it ensures equitable access to resources and services. This involves not only seasonal variations but also event-driven peaks. The design must be adaptable to accommodate these peaks. Here are some examples illustrating the features that can enhance the flexibility of a marina.

Cowes Harbour in the United Kingdom hosts a yearly regatta week. To increase the harbour's capacity, they utilize seasonal moorings consisting of buoys. To transport visitors from their vessels to the land, they deploy additional water taxis. The vessels using these seasonal moorings can access services such as fuel and electricity at the harbour itself, where temporary additional facilities have been set up (Warren, 2020).

Another example that could be used to make the marina more flexible is the use of modular floating cubes. Modular floating cubes are an innovative solution for expanding marina capacity during peak periods. These cubes can be seamlessly integrated with the existing marina infrastructure. They offer an adaptable and scalable solution and are very easy to install and remove. These modular floating cubes not only provide functionality but also contribute to the sustainability of marina expansions. They are often made from durable materials to minimize ecological impact and the cubes also require no maintenance. In summary, modular floating cubes offer significant adaptability, convenience, and sustainability (Candock, n.d.).

Social equity

By addressing inequalities and ensuring that every individual has access to the same resources, rights, and opportunities, social equality promotes a more inclusive and harmonious society.

Job creation: The marina can help create jobs by supporting employment opportunities, including marina staff, vessel maintenance and repair professionals, hospitality and tourism workers, and suppliers of goods and services.

Accessibility for disabled people: Creating infrastructure so people with disabilities can enter the beach and vessels is important because it promotes inclusivity (FEE, 2019).

Vessel sharing: vessel sharing can be a good option for people who do not often use vessels. It is a system that allows individuals or organizations to rent or share vessels with others for specific durations, making boating more affordable and accessible to a broader range of people (Weykamp, 2020).

Phased development

In addition to the fact that phased development helps with environmental protection as described earlier, it can also help to support social progress. Marina requirements and user needs may change over time. Phased development provides the flexibility to adjust to these changes and make improvements in the next phase.

Cultural and Recreational value

Spaces devoted to cultural events or recreational activities could contribute to a higher sense of community, contributing to a sense of ownership and higher participation and public support of the community. Spaces like this could include:

- Opportunities for residents to engage in recreational activities like boating, fishing, swimming, water sports, or wellness activities like waterfront yoga.
- Cultural events like markets, movie nights, workshops, races, art exhibitions, tours, etc.
- Well-designed public space where people engaging in the different marina activities can meet, wait, rest, or play, such as a park, viewpoint, or square.

D.1.3 Economical development

One of the primary objectives of this study is to create a feasible marina design with a strong likelihood of being realized in practice. The biggest challenge with respect to the feasibility is the financial viability. Therefore, it is vital to not only create a functional design but also to add value in order to attract investors who are willing to cooperate toward the realization of the project.

Verheul and Heurkens (2021) describe how the creation of value should be of high interest for both private and public investors, when it comes to urban development: not only do investments in common values and public functions yield benefits to private parties through increased real estate values and economic activity, they can also contribute to the health, well-being, and prosperity of the local user community. Thereby, they can reinforce the project's financial success. In the context of a marina, Martín and Yepes (2023) describes which values of a marina contribute to user satisfaction. As the project of designing a marina in San Antonio Este will be in the form of a PPP (public-private partnership), investments in the development and integration of societal and sustainable goals in order to create value are of high importance. The paper by Verheul and Heurkens and Martín and Yepes serve as a framework for value creation in the design of our marina. In addition to a short discussion on how these values can be added to the marina in San Antonio Este.

In order to achieve high return on investment rates, high commercial value should be added to the area. Money could be earned by directly providing services like restaurants, shops, or hotels, or by renting out real estate to business owners. In terms of our marina, commercial value could be added in the form of:

- Paid berthing spots for vessels, which could lead to either daily, monthly, or yearly income.
- Promoting A-use by adding places to eat (in the form of one or more restaurants, snack bars, food trucks, and coffee shops) and places to buy (souvenir shops, boat shops, kiosks, etc.) either owned or rented out by private investors. These will also create monthly or yearly income possibilities.
- Profiting from the organisation of events, such as hosting nautical sports events ...?. These events will enhance the marina's name recognition and attract more visitors, which leads to more income for local businesses.
- Creating space for businesses in the tourism sector to establish themselves and facilitate the provision of docking spaces (on land and on water), access areas, office space, and ticket sales facilities. This will create a vibrant marina with many possibilities to do business and will create higher user appreciation
- Create spaces for vessel maintenance, where vessel owners can let their vessel be repaired or washed, buy items and components

Blue Flag and the SDGs

Blue Flag is a certificate awarded to sustainable marinas, beaches, and vessels. Integrating their philosophy, mainly based on the Sustainable Development Goals, automatically contributes to the sustainability of the design.

> *"Blue Flag is a world-renowned ecolabel trusted by millions around the globe. The mission of Blue Flag is to promote sustainability in the tourism sector, through environmental education, environmental protection, and other sustainable development practices. Thanks to Blue Flag and its partnerships, more than 4,500 beaches, marinas, and eco-tourism vessels are concretely contributing to the sustainable development goals. Blue Flag also campaigns against disparity, inequality, unemployment, health threats, depletion of natural resources, environmental threats, pollution, and general environmental degradation."* (Blue Flag, 2023)

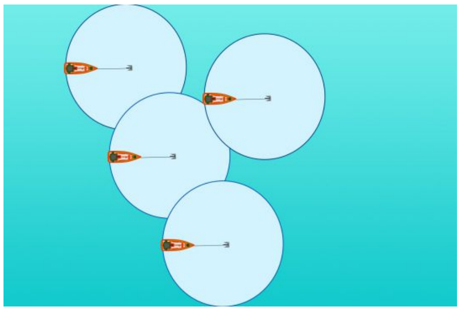
D.2 Marina systems on water

This section will discuss the various ways to store vessels in the water and how to access them. The system types will be elaborated and the advantages and disadvantages will be discussed.

D.2.1 Mooring buoys

A mooring buoy is a floating structure that is used to moor vessels in deep or shallow water. Its main components are a buoy, sinker or anchor, and chain or rope between the anchor and buoy (Nisa Syahidah, 2015). These mooring buoys offer a high degree of mooring flexibility due to simple installation procedures and high adaptability to diverse environmental conditions. Although mooring buoys respond well to changes in tides, it is important to ensure that the chain between the buoy and anchor is long enough to prevent the buoy from submerging when the water level is at its highest. In addition, it should be noted that at lower water levels, vessels that have a larger swing vessel anchored to the buoys may experience a larger turning radius at lower water levels. The vessel swing radius can be calculated using the procedure in Figure H.1. This is important for the marina in San Antonio Este because of the large tidal range.

(a) Mooring buoys (*Amarres - Sotamar*, n.d.)



(b) Radius plan view (Ricardou, 2020)

Figure D.3: Examples of mooring buoys

D.2.2 Pile moorings

Pile moorings consist of vertical piles that are embedded in the seabed. Their upper ends extend above the water surface (Nautical Insurance, 2023). Each vessel requires a front and rear pile to moor both the bow and stern. Pile diameters usually range from 300 to 500 mm and are selected based on water depth and bottom conditions. Due to the significant tidal range in the area of this study, they will need to attach the mooring lines to a floating ring around the pile as can been seen in Figure D.4b. This ring will move up and down as the water level changes (PIANC, 2020).

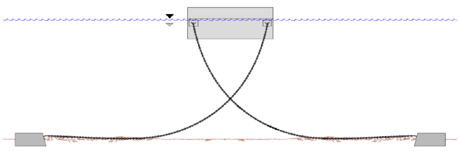
(a) Example of a mooring pile area (PIANC, 2020)

(b) A floating mooring ring (PIANC, 2020)

Figure D.4: Mooring pile system

D.2.3 Floating pontoons

Floating pontoons are marine structures designed to provide a platform on water and offer space for vessels to dock. They are mainly used in marinas with high tidal influence (PIANC, 2017). Floating pontoons come in various configurations to meet different requirements, including three common variants: piled pontoons, cabled pontoons, and strut pontoons(*The Ultimate Floating Pontoon Checklist*, 2020). Cabled and strut pontoons are suitable for more calm and sheltered waters. These pontoons use cables or struts to maintain stability. In turbulent or open water environments, the forces acting on these external components can cause unpredictable movements, making the pontoons unable to provide a stable platform (PIANC, 2017).



(a) Cabled pontoon

(b) Strut pontoon

Figure D.5: Examples of cabled and strut pontoons
(PIANC, 2017)

The third mentioned type of floating pontoon is the piled pontoon. In this type, the floating pontoon is guided by piles driven into the ground. This makes the pontoons more stable and most appropriate for more turbulent water conditions (*Marine Piling for Floating Pontoons: Everything You Need to Know*, 2020). The length of the guiding facilities must have a sufficient height so that the floating pontoon is not flooded at the maximum water level to be expected or shall be secured against floating away (PIANC, 2017).

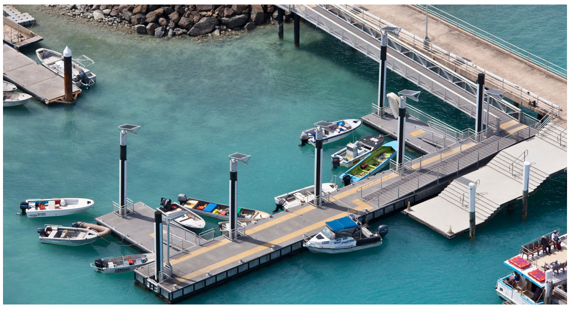


Figure D.6: Example of a piled pontoon marina (*TJS Marine - Floating Pontoons*, n.d.)

The use of pontoons is limited to wave heights of one metre and wave periods of five seconds. Based on the area study, we assume that the waves will remain below these limitations. Due to the high tidal range and strong winds in the area of this study, it would be advisable that if pontoons are chosen for the preliminary design, piled pontoons should be selected. These can effectively respond to the high tidal range and remain stable.

D.2.4 Fixed pier

A fixed pier basically consists of piles as the supporting foundation, extended beams between pairs of piles, and a decking structure. When waves cause uncomfortable motion, a fixed pier can provide a stable platform (PIANC, 2017). The area of this study experiences a significant tidal difference. The pier must be constructed with sufficient elevation to prevent submersion during high tide.

Figure D.7: Example of a fixed pier, Alpat pier

If the design of this study consists entirely of a fixed pier, it will not be possible to board the vessels during low tide. The height difference between the vessel and the deck becomes too great. In this study, it is desired to be able to access the vessels even during low tide. Therefore, the design cannot be entirely based on a fixed pier. A floating pontoon will need to be attached to the fixed pier using a gangway as seen in Figure D.8.

Figure D.8: Example of a combination of a fixed pier and a floating pontoon, SAE pier

D.2.5 Boat lifts

Boat lifts are mechanical devices designed to lift and lower small vessels in and out of the water. They are used to keep them out of the water when not in use, preventing issues related to constant water exposure, such as hull corrosion and fouling. They offer convenient and efficient access to vessels, especially in locations with tidal variations or in areas prone to adverse weather conditions. In figure D.9 how boat lifts ensure that it remains possible to board your vessel from a fixed pier during low tide.

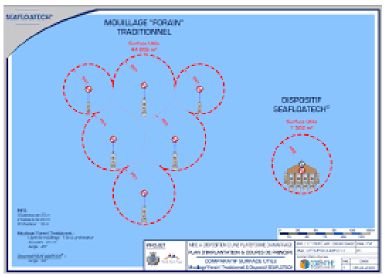
Figure D.9: Example a boatlift on a fixed pier

In the area of this study, the tidal range will be approximately 9 metres high. The boat lift will need to bridge this height in order to access the water during low tide.

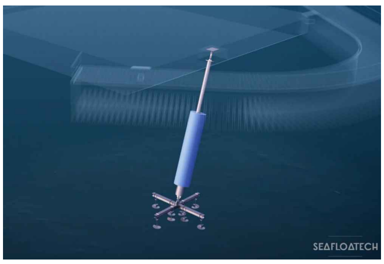
D.2.6 Innovative ideas

In the field of marina systems on water, new innovative ideas are also emerging. An example of a company is: Seafloatech. They has conceived and designed a concept that challenges traditional notions of coastal development. Seafloatech's innovative approach involves creating pontoon islands detached from the mainland. They make use of an innovative Pod, with virtually unlimited potential. It is a safe, environmentally friendly, and adaptable mooring system from the seabed to the surface (Seafloatech, 2022). In figure D.10, this pod can be seen. Another advantage of these pontoon islands is that they save space compared to mooring buoys (Seafloatech, 2022). This is clearly visible in figure D.10. This innovative idea can be a practical design solution in the layout of this study because the vessel berths are not connected to the mainland. They can be attached further out in the bay, allowing them to remain in the water even during low tide. Using a small taxi boat, passengers can be transported to the marina.

(a) Example of a pontoon island



(b) Pontoon island compared to mooring buoys



(c) Seafloatech Pod

Figure D.10: Seafloatech's innovative idea (Seafloatech, 2022)

Another example of a company with an innovative idea is: Seaflex. Seaflex specializes in innovative and environmentally friendly mooring solutions for marinas and other industries. They are known for their elastic mooring systems that provide flexibility and stability for floating structures, such as docks and pontoons. By using these elastic mooring systems (Figure D.11), the marina system becomes flexible with high tidal ranges. Seaflex can often be the most cost-effective mooring system over time, given its extended lifespan, straightforward inspection process, and minimal maintenance requirements (Seaflex, 2023).

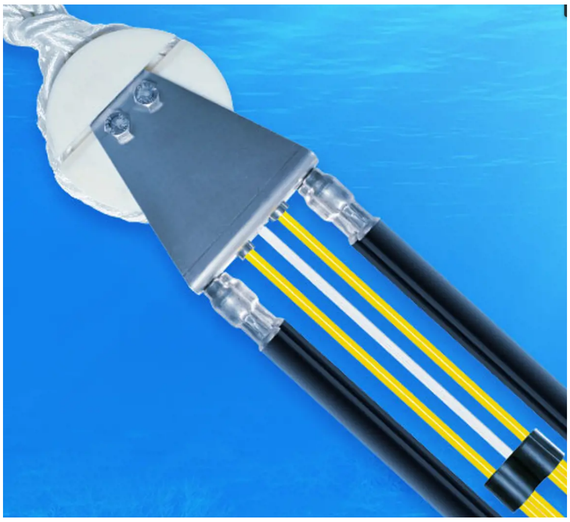


Figure D.11: Elastic Seaflex mooring system, (Seaflex, 2023)

D.3 Marina systems on land

In addition to the practice of mooring vessels in the water within a marina, there are also methods for storing them safely and dry on land. This section will discuss the various ways to store vessels on land.

D.3.1 Dry stacking

Dry stacking is a storage method where vessels are stored on racks or cradles in a specially designed facility. The vessels are lifted by a forklift or a similar mechanism and stacked on top of each other in a secure and organized manner. This system allows for efficient use of space and facilitates easy access when owners wish to use them (Hagadone Marine Group, 2022). See Figure D.12. Dry berthing is normally used for vessel lengths up to 9 metres(Lucy, 1977), but some companies offer possibilities to store vessels up to 14 metres (Scarborough Marina, n.d.). Important to note and keep in mind is that there are some conditions prescribed for the terrain in order to ensure safe usage. Firstly, it should be firm enough to bear the combined weight of the forklift and the vessel. Secondly, it should be completely flat in order to prevent any tilting of the machine.

(a) Putting the vessel in the water with the forklift (Marine Travelift, n.d.)

(b) Stacks (Wickens Engineering Ltd., n.d.)

Figure D.12: Dry stacking concept

D.3.2 Trailers

Another option for storing vessels on land, is to store them on trailers. Trailers are designed for vessel transportation, which offers flexibility in movement and easy transport in and out of water through a ramp. Trailers have sturdy frames, supportive rollers, and adjustable components tailored to the specific vessels shape and size and therefore, there are fewer restrictions for for example use on slightly tilted terrains. According to European guidelines, the following limits apply to trailers:(1) 3.5t towing capacity (vessel incl. trailer), (2) 2.55m width, and (3) 12m vessel length / 18m trailer length. These limits are important to keep in mind (Oechsner Boats, n.d.).

D.3.3 Other types of dry storage

If vessels have a length exceeding 14 metres, dry stacking and storage on trailers is not possible. Then, the vessels should be stored on other supportive elements such as haul-out standards, as can be seen in Figure D.13. In order to transport the vessels to these supportive elements, a travel lift is necessary. Travel lifts consist of various sizes and carry vessels up to very large lengths. Just like the forklift, the travel lifts require strict conditions for the terrain to be satisfied in order to ensure safe usage(Kendrick Equipment, 2023).

(a) Example of haul-out standards (Sea-Help, 2023)

(b) Example of a travel lift (Kendrick Equipment, 2023)

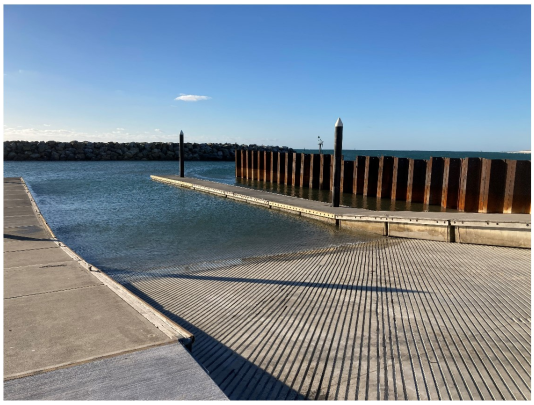
Figure D.13: How to store vessels above 14 metres on land

D.3.4 Launching and retrieving vessels

When considering ways to take vessels out of the water, four options are available. One could choose to (1) place a crane on the pier that lifts vessels out of the water, (2) build a ramp on

which vessels can be driven into the water on a trailer pulled by a motorized vehicle, (3) use a forklift that directly carries the vessel into the water and (4) use a travel lift (Oechsner Boats, n.d.).
Concerning options 1 and 2: both options have their advantages and disadvantages. A crane does not need much space, therefore creating more flexibility in the marina layout. However, cranes need a firm structure as they also need to be accessed by vehicles that transport the vessels to the shore.

(a) A crane lifting a small boat (NauticExpo, 2023)



(b) Ramp for putting vessels in the water (South Australian Department for Infrastructure and Transport, 2022)

Figure D.14: Options for getting vessels in and out of the water

Ramps, on the other hand, might need a lot of space. They also have a bigger impact on the environment, as they are often made of concrete. When considering costs, ramps are often more cost-effective than cranes.

D.3.5 Permeable concrete pavings for ramps

To make the design of the ramp more eco-friendly, there are several options out there. Most of these options are focused on creating space between the concrete elements in order to improve water drainage. An example is the use of wooden sleepers with space between them, but in an ocean environment, concrete is preferred because of durability considerations. Also concrete grid tiles can be used. These tiles have several advantages:

1. The grid pattern of these tiles allows for efficient drainage, reducing the risk of water accumulation on the ramp surface and allowing for vegetation to grow in the openings, promoting green spaces and biodiversity. Such design elements also provide habitat for insects and small animals.
2. The grid pattern avoids the urban heat island effect that is caused when the concrete ramp is subjected to sun. The soil that is placed between the grid will absorb much of the heat and therefore the temperature on the surface will be much lower.
3. The looks of the precast concrete grid tiles come in a variety of sizes, shapes, and designs. In the vulnerable and beautiful environment of San Antonio Este, a large concrete slab which runs for 200 metres is undesirable, and concrete grid pavements can drastically improve the aesthetics.
4. The grid pattern provides slip resistance, enhancing safety for pedestrians.
5. Permeable concrete pavements are the most durable solution, because there is a low risk for cracks and water runs through easily.

Conclusion on ramp top layer

For San Antonio Este, we consider the aesthetic value of the concrete grid tiles most important. We believe it will increase the feasibility of the project because its environmental advantages, despite being a more expensive option.

D.4 Wave action reduction

The marina needs to be designed for a wave height of 0.58 m, provided by the area study. According to previous chapters, the maximum allowed wave height in marinas is set at 0.3 m. It can be concluded that the wave action needs to be reduced. This can be done by either the classical bottom-founded breakwater, a floating breakwater (Dai, Wang, Utsunomiya, & Duan, 2018), or a wave screen.

D.4.1 Traditional breakwaters

Most wave energy is concentrated at the free surface according to classical wave theory. Traditional breakwaters are made to resist the overturning moment at the bottom, which doesn't match the distribution of wave energy. Moreover, factoring in the water depth, the structure would need to be at least 11 metres tall, rendering it economically unattractive as a design choice. Furthermore, these conventional breakwaters strongly interfere with the water circulation and the sediment transport. The latter must be avoided in order to stay away from sediment problems in the protected area.

D.4.2 Floating breakwaters

Floating breakwaters reduce wave energy where it is highest, move coherently with the tidal variation, have little visual impact on the horizon, and are an environmentally friendly alternative. Hence an attractive option for San Antonio Este.

Types of floating breakwaters

McCartney (1985) categorized floating breakwaters based on their shape into four different categories: box, pontoon, mat, and tethered floats. Their goal is to attenuate wave energy and their effectiveness can be measured with the transmission coefficient. The transmission coefficient is defined as "the ratio of transmitted wave height to the incoming wave height" (Dai et al., 2018). For the design of the marina in San Antonio Este, another distinction is made, whether the floating breakwater can be used as a footpath or not. The combined use as a walkway is preferred since it is space-efficient and cost-effective. Cost efficiency comes from the fact that only one mooring structure is needed when the two functions are combined and the large water depth suggests this would be a large part of the costs. This results in the use of the box or pontoon type of breakwater for the current design. Different shapes of the box and pontoon breakwaters are possible. To limit the scope of the research, only the conventional box-type breakwater is examined in detail in order to investigate whether this type of breakwater is good enough.

Box breakwater

Looking into the specifics of box-type floating breakwaters. The question is whether these boxes have the capacity to halve the wave height without growing out of proportion. According to Manuel (1995) the limiting design wave, for a single box or pontoon type breakwaters is 1.2 metres and a four-second period. Furthermore, Dai et al. (2018) added that the widths of both box and pontoon types of breakwaters need to be at least one-third of the target wavelength to achieve effective wave damping.

For the box-type floating breakwater two mooring systems are possible: either mooring lines that are attached to the seabed or piles or mooring dolphins (Manuel, 1995). Since San Antonio Este is dealing with a tidal range that can go up to approximately 10 metres, piles or mooring dolphins are the only option.

D.4.3 Wave screens

A third option is the wave screen. This is, like the conventional breakwater, a bottom-fixed structure. Screens are attached to piles and can be attached to a fixed dock or pier to save space. Where floating breakwaters are usually installed in locations where the design wave period is not larger than four seconds, wave screens are used in locations where the design period is larger. This is because wave screens can provide protection from longer wave periods than a floating breakwater (Overton, 2018).

Research from Thomson (2000) shows that that wave screens could reduce wave transmission by up to 60% for a single screen and 80% for a double screen (see figure D.15). Wave transmission was found to be a function of the number of screens used, screen porosity and orientation, wave steepness, relative depth, d/g^2 and dimensionless gap space.

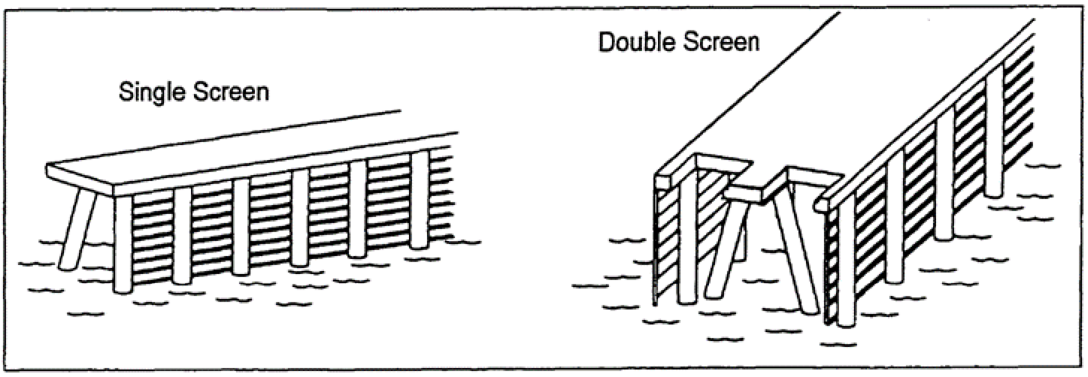


Figure D.15: Diagram showing a single and double wave screen breakwater (Allsop, 1995)

E | Processes

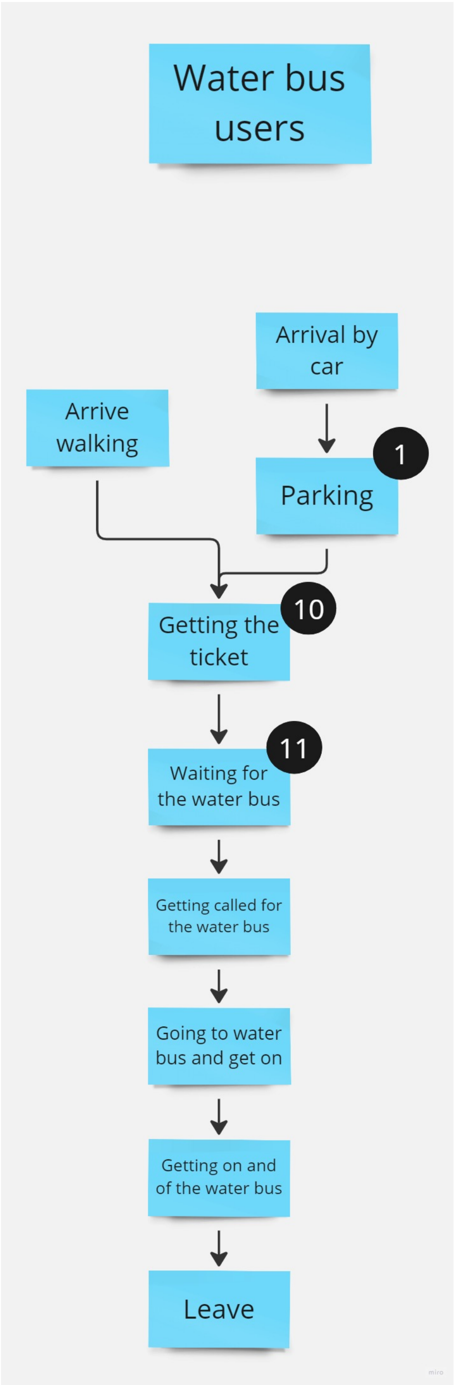


Figure E.1: Processes water bus users

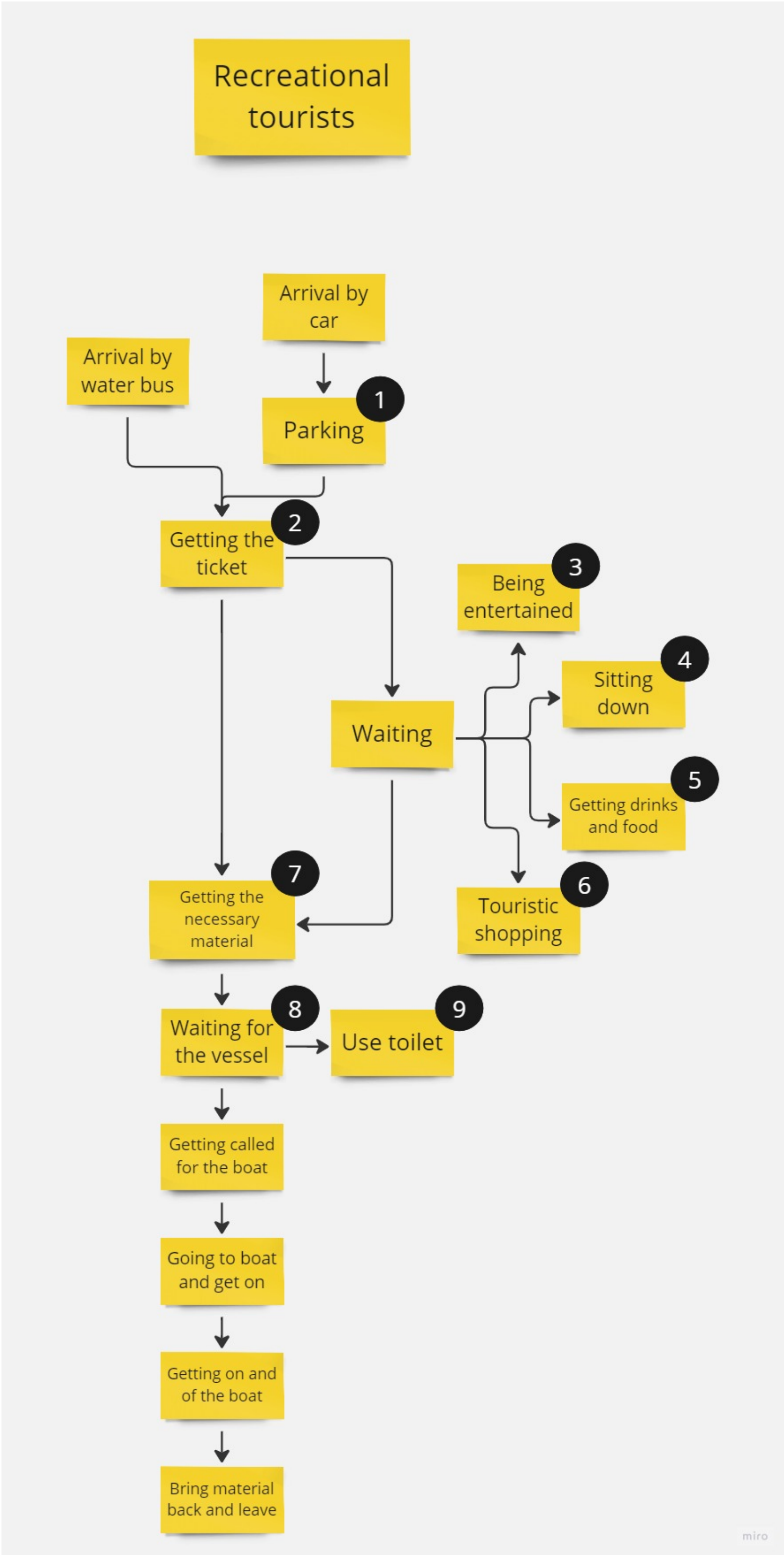


Figure E.2: Processes recreational tourists

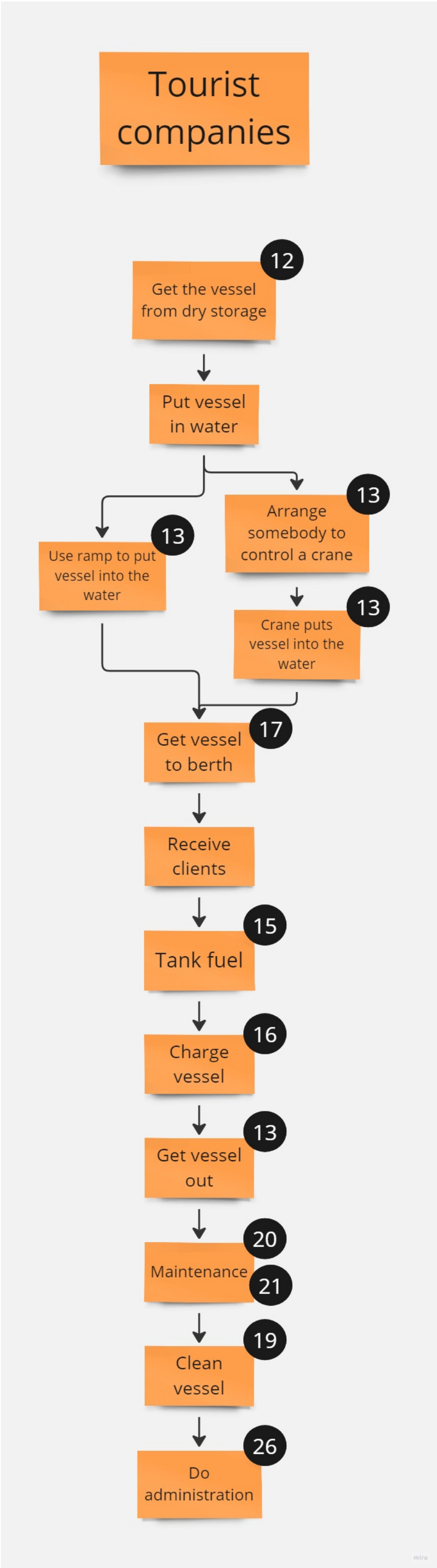


Figure E.3: Processes tourist companies

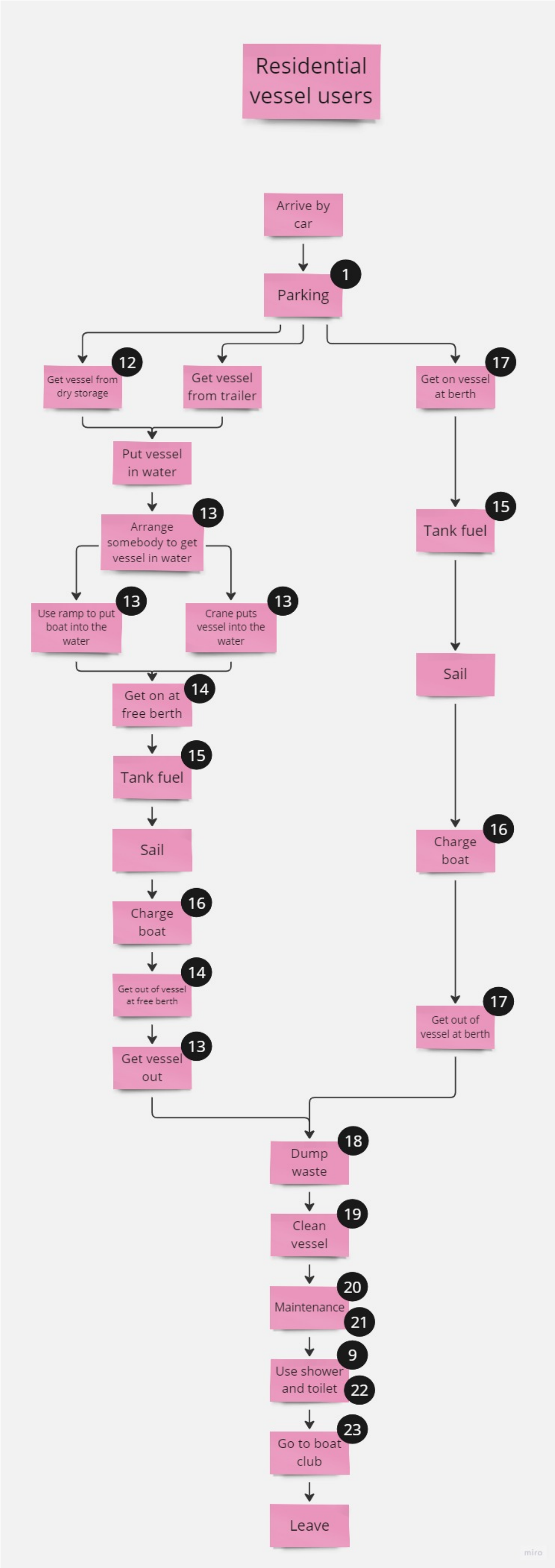


Figure E.4: Processes private vessel users

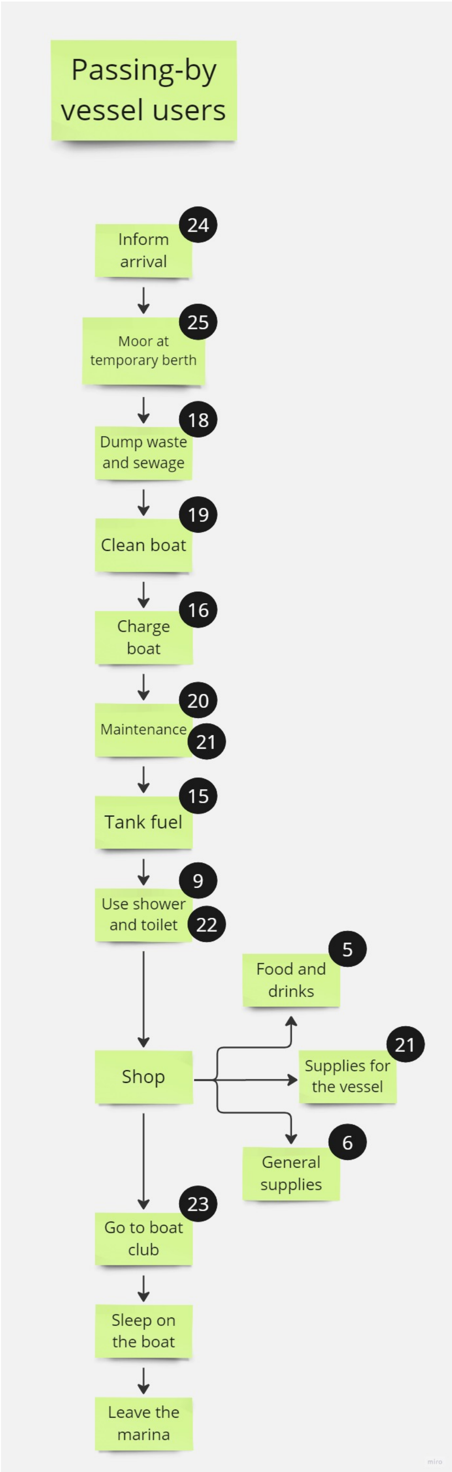


Figure E.5: Processes passing vessel users

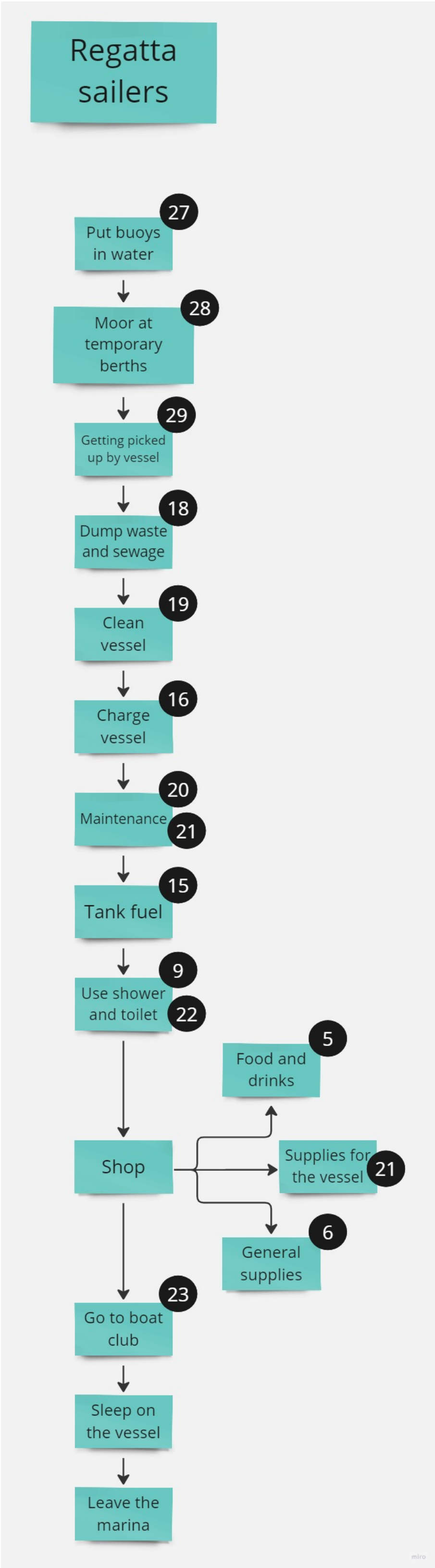


Figure E.6: Processes regatta sailors

Requirements

1. Parking lot
2. Ticket office tourist company
3. Interpretation centre/signs
4. Relaxing spots
5. Shop/Restaurant
6. General shop
7. Material storage for tourist company
8. Waiting spot
9. Toilets
10. Ticket office water bus
11. Terminal water bus
12. Dry vessel storage
13. Ramp or crane with marina office
14. Free berth
15. Gas station
16. Charging point
17. Berth
18. Waste/Sewage dump
19. Water access
20. Access to basic tools
21. Vessel supply shop
22. Showers/Changing room
23. Boat club
24. Harbour master
25. Temporary berths
26. Office tourist company
27. Storage buoys and small vessel
28. Buoys
29. Small vessel (can also be tourist vessel

Figure E.7: Requirements

F | Guidelines

F.1 Guidelines for design marinas

F.1.1 Dimensional criteria

To understand the space that is needed to accommodate the desired amount of vessels, some guidelines have been set, according to the Maritime Structures Standards Australia Committee (2001).

Channel widths

Entrance channel
For an entrance channel, the minimum width should be the greatest of—

(a) 20 m;

(b) $(L + 2)$ m, where L is the overall length of the longest vessel in the marina, in metres; or

(c) $5B$ m, where B is the beam of the broadest mono-hull vessel in the marina, in metres.

The preferred width of an entrance channel is 30 m or $6B$ m; whichever is the minimum. Widening of the channel may be necessary where the channel changes direction.

Interior channels and fairways
The width of interior channels and fairways should be as follows (see also figure F.1):

(a) Interior channel

  (i) Minimum width 20 m or $1.5L$ m, whichever is the greater, where L is the overall length of the longest vessel using the channel, in metres.
  (ii) Preferred width 25 m or $1.75L$ m, whichever is the greater.

(b) Fairways

  (i) Minimum width $1.5L$ m, where L is the overall length of the longest vessel using that fairway, in metres.
  (ii) Preferred width $1.75L$ m.

Where currents exceed 0.5 m/s, the width of interior channels and fairways should be increased to allow for the effect of the current on a vessel as it moves along the channel and turns into its berth.

Water depths

To obtain the required water depth, the draughts given in figure F.2 should be increased by the addition—

(i) a minimum of half the significant wave height for vessel movements resulting from wind-generated waves and boat wake; and

(ii) an appropriate allowance where significant siltation is likely to occur or where it is preferred to reduce the frequency of maintenance dredging; and either

(iii) a minimum under keel clearance of 300 mm or 10 percent of the vessel draught, whichever is the greater, where the base of the dredged channel consists of soft material; or

(iv) a minimum under keel clearance of 500 mm, where the base of the dredged channel consists of hard material such as stiff clay, gravel, or rock.

Berth sizes

Where no specific design criteria are established, guidelines for minimum design criteria are given in figure F.4.

Berth widths
Based on the widest beams of monohull vessels currently being manufactured, the minimum berth widths (the clear width between fingers or piles) are shown in figure F.3. Berth lengths are taken to be the same as the vessel length.

General expressions for berth width (b) are as follows:

(a) Double berth: 2× design maximum vessel beam + 1 m up to 20 m and + 1.5 m above 20 m.

(b) Single berth: design maximum vessel beam + 1 m up to 20 m and + 1.5 m above 20 m.

(c) Multihull vessels can either occupy a double berth, or wider berths can be included, which specifically allow for single or double multihull vessels. The beam of a multihull may be up to $0.7L$.

These dimensions may need to be increased to allow for larger fenders. The maximum length of the vessel for which each berth has been designed should be clearly marked on the marina layout drawing. For alongside berths, the minimum space between vessels should be $0.2L$ up to 3.0 m.

Mooring piles in double berths
Mooring piles between each vessel in a double berth configuration may be required where wind-generated waves or vessel wake exceed(s) 300 mm in height. The width of the double berth should be increased by the width of the pile.

Walkways, fingers and mooring points

Walkways should be not less than 1.5 m wide. Consideration should be given to the need for trolleys passing each other and access and egress in emergencies. The clear width of walkways throughout their length, defined as the clear line-of-sight between any obstruction such as cleats, hose reels, piles, etc., should not be less than the clear width of the gangway that is connected to the walkway. The minimum width of walkways should be—

(a) 1.8 m, for walkways in excess of 100 m in length; or,

(b) 2.4 m for walkways in excess of 200 m.

Unless a mooring pile is provided at the end of a pontoon finger, the length of a finger should be not less than $0.8L$, where L is the overall length of the longest vessel that may use the berths. Where a mooring pile is provided, the finger length may be reduced or the finger omitted.

The width of fingers should be such that it is safe to board or leave the vessel. Fingers may be of uniform width of 900 mm, or be tapered to a minimum width of 600 mm.

Gangway requirements

Width
The clear width of gangways should be in accordance with figure F.5.

Slope
The maximum slope of a gangway and treadplate for a marina should not exceed 1:3.5. For private pontoons with no public access, the maximum slope should not exceed 1:3. Where access for disabled persons is required, the slope of gangways and tread plates should not exceed 1:8. This is only satisfactory where assisted wheelchair access is provided.

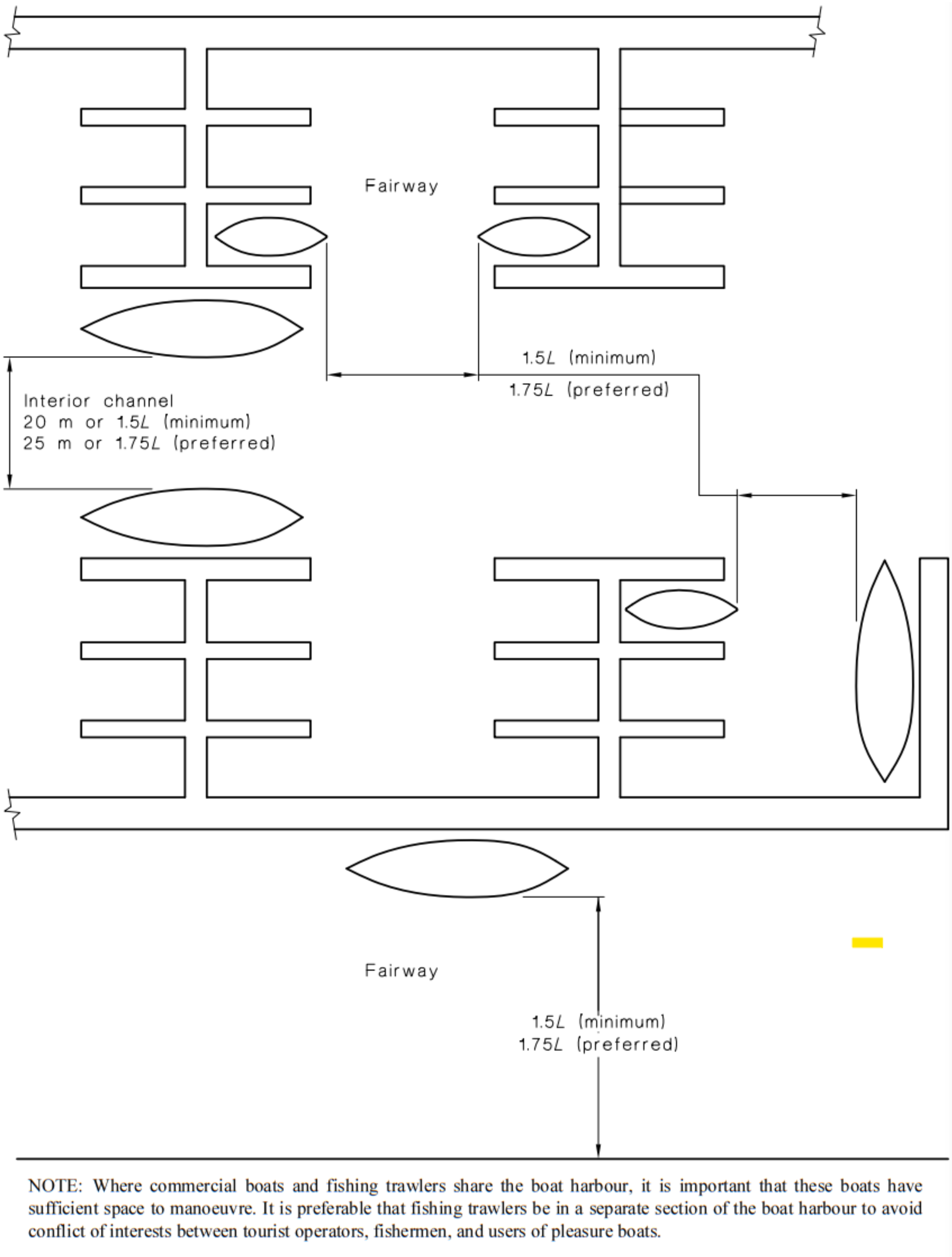


Figure F.1: Widths of channels (Maritime Structures Standards Australia Committee, 2001)

TYPICAL VESSEL DRAUGHTS

Boat length (L), m	Vessel draught, m		
	Power boats	Yachts	Multihulls and house-boats
8	0.9	1.5	1.2
10	1.0	1.8	1.2
12	1.0	2.0	1.2
15	1.2	2.5	1.2
20	1.5	2.9	1.2
25	1.8	3.0	
30	1.9	3.4	
35	2.1	3.8	
40	2.3	4.2	
45	2.6	4.2	
50	2.9	4.2	

NOTES:

1 Some vessels may require additional depth and thus the type and draught of vessels likely to use the marina should be obtained.

2 Some deep draught yachts have retractable keels and for these the minimum water depth may be based on the draught with the keel retracted. Consideration should be given to specific cases that fall outside these guidelines.

3 This Table is prepared on the basis that 95% of boats do not exceed the above draughts.

Figure F.2: (Maritime Structures Standards Australia Committee, 2001)

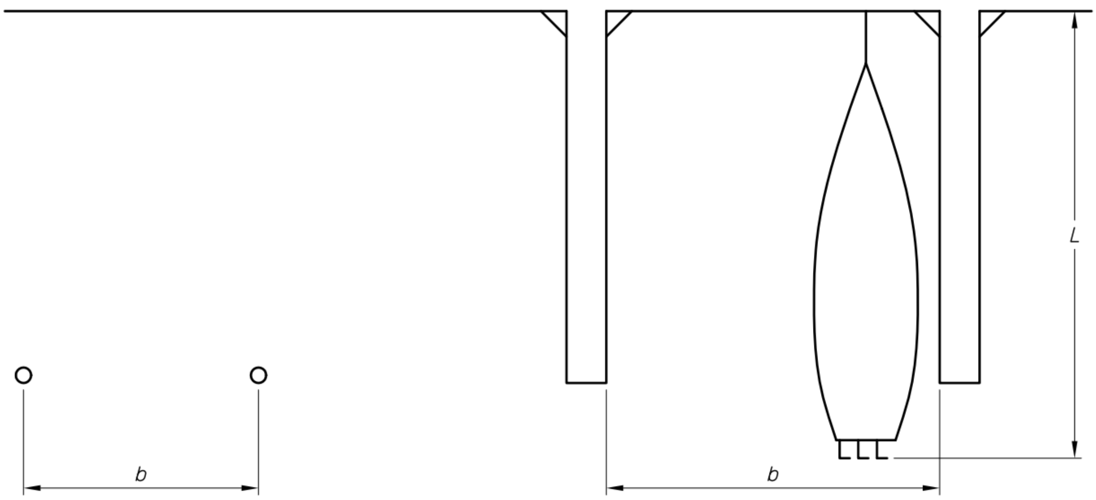


Figure F.3: Minimum berth dimensions for monohull vessels (Maritime Structures Standards Australia Committee, 2001)

MINIMUM BERTH DIMENSIONS FOR MONO-HULL BOATS

Boat length (L), m	Boat beam (B), m	Width of berth (b), m	
		Single berth	Double berth
6	2.8	3.8	6.6
7	3.1	4.1	7.2
8	3.4	4.4	7.8
9	3.7	4.7	8.4
10	4.0	5.0	9.0
11	4.3	5.3	9.6
12	4.4	5.4	9.8
13	4.6	5.6	10.2
14	4.8	5.8	10.6
15	5.0	6.0	11.0
16	5.2	6.2	11.4
17	5.3	6.3	11.6
18	5.4	6.4	11.8
19	5.5	6.5	12.0
20	5.7	6.7	12.4
21	5.8	7.3	13.1
22	5.9	7.4	13.3
23	6.0	7.5	13.5
24	6.3	7.8	14.1
25	6.5	8.0	14.5
27.5	7.0	8.5	15.5
30	7.5	9.0	16.5
35	8.7	10.2	19.0
40	10.0	11.5	21.5
45	10.0	11.5	21.5
50	10.0	11.5	21.5

Figure F.4: (Maritime Structures Standards Australia Committee, 2001)

CLEAR GANGWAY WIDTHS

Number of berths	Width (m)
Up to 2	0.7
Greater than 2, up to 10	0.9
Greater than 10, up to 60	1.2
Greater than 60, up to 120	1.5
Greater than 120	1.8

Figure F.5: (Maritime Structures Standards Australia Committee, 2001)

F.2 Criteria for wave conditions

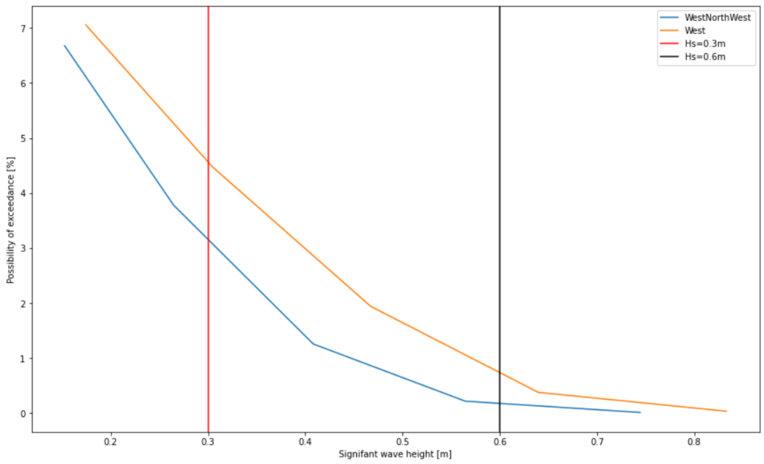


Figure F.6: Exceedance probability of Hs = 0.3m and Hs = 0.6m

G | Multi-criteria analysis

The results of the MCA survey are given in this Appendix, divided into the given scores, the comments and the results. It is decided to keep the clients and experts anonymous.

G.1 Ranking per question

The results of each ranking are given below.

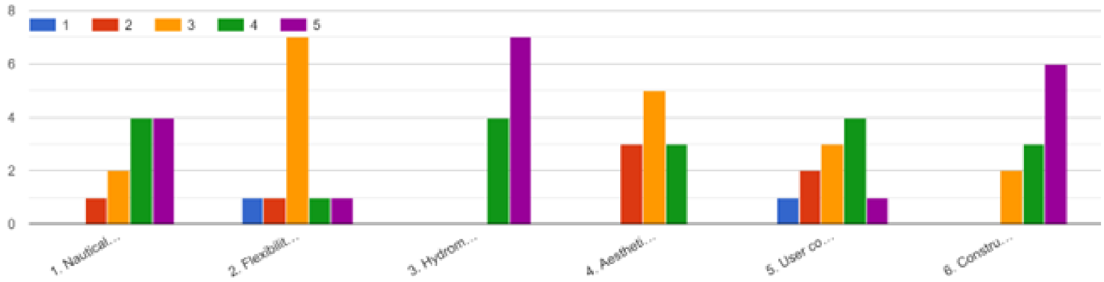


Figure G.1: Ranking based on importance of each criterion

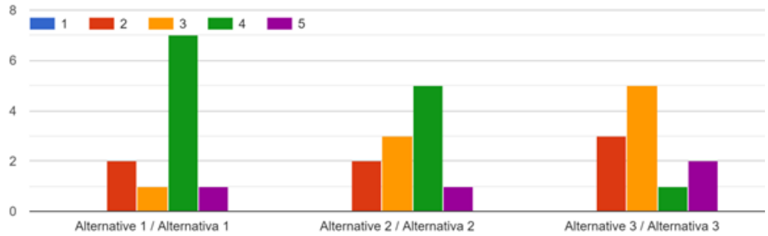


Figure G.2: Ranking based on how much the alternative matches criterion 1

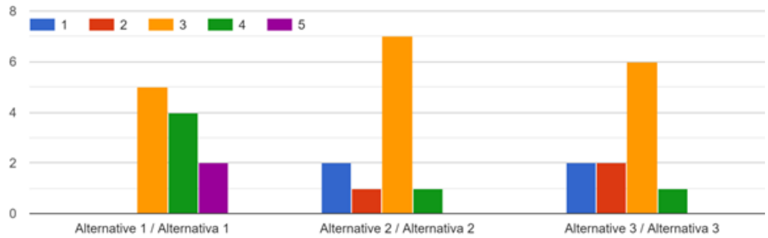


Figure G.3: Ranking based on how much the alternative matches criterion 2

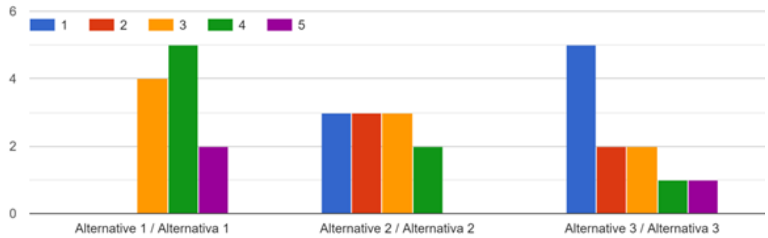


Figure G.4: Ranking based on how much the alternative matches criterion 3

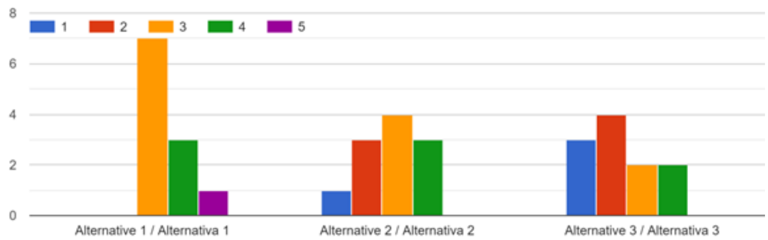


Figure G.5: Ranking based on how much the alternative matches criterion 4

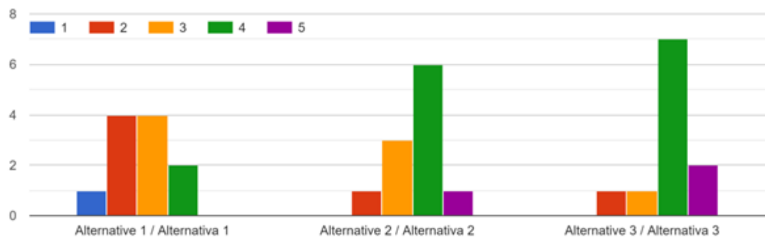


Figure G.6: Ranking based on how much the alternative matches criterion 5

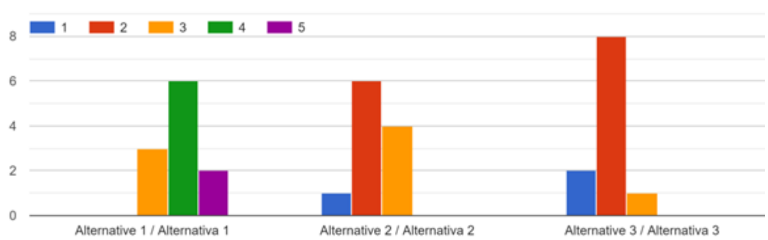


Figure G.7: Ranking based on how much the alternative matches criterion 6

G.2 Comments of MCA survey

The involved parties were asked to comment on the questions to give an argumentation on their decision. These comments are given below per ranking.
Weights criteria

- I consider hydro-meteorological and environmental conditions as critical factors since they are determinants for the design. Costs are significant when making the decision to execute one alternative or another. I believe that other aspects are important for the feasibility study of the project.
- It seems to me that the alternatives vary widely in capacity and may therefore be difficult to compare.

1. Nautical accessibility

- Alternative 1, there are no restrictions for turning, docking, and mooring maneuvers. It may face complications due to wave conditions. Alternative 2 could hinder maneuverability and access. Alternative 3 may restrict turning areas but offers generally acceptable maneuverability.
- You ask two questions: ease of berthing /unberthing and ease of launching from/ recovery to shore. I gave alt 3 a lower score because I don't like the crane idea.
- Keep an eye on available water depth.

2. Flexibility for Marina development

- I consider that it primarily depends on the expansion direction based on the available depths.
- Alternative 1 may be most promising: lowest initial cost to help find out if the demand for a Marina is real.

3. Hydrometeo and environmental conditions

- The smaller the construction works, the lesser the impact. The more success of a Marina, the bigger the impact... The wave screen in alt 3 seems to generate the biggest ecological impact.
- The construction that requires placing fixed infrastructure in the sea generates a significant impact.

4. Aesthetic appeal

- Users will initially be pleased with the service to SAE or with the possibility of berthing there. Only when the Marina starts attracting more users will aesthetics play a role.

5. User comfort

- Depending on the slopes and the level of agitation, alternative 1 may be more competitive in terms of user comfort.
- As indicated above: the first users will be "adventurers" who will appreciate the facilities but actually hope that not too many sailors will find out about this "secret" marina!

6. Construction and material costs

- With alternatives 2 and 3 I hesitated between "high" and "excessive".

An important stakeholder also stated about the choice between a fixed and a floating pier that a floating pier is recommended due to its adaptability to the natural environment, its ability to accommodate tidal variations, and its modular system, which provides flexibility for potential future expansions. Concerns are expressed about the visual impact and cost associated with a fixed pier.

G.3 Results of the MCA survey

The multi-criteria analyses result in a ranking of the three alternatives, in which the best alternative ends up with the highest score. These results are given below in Table G.1.

	Alternative 1	Alternative 2	Alternative 3
Person 1	2	3	1
Person 2	2	1	3
Person 3	3	2	1
Person 4	3	2	1
Person 5	3	1.5	1.5
Person 6	3	2	1
Person 7	3	1.5	1.5
Person 8	3	2	1
Person 9	3	2	1
Person 10	2.5	1	2.5
Person 11	3	2	1
Total	**30.5**	**20**	**15.5**

Table G.1: Results MCA surveys

G.4 Comparison between fixed and floating pier

In the table below, various advantages and disadvantages are shown. Based on this table, a final decision on the type of connection from the land was made.

Fixed Pier	Floating pier
Advantages • Offers greater stability as the deck is fixed (no degrees of freedom) and not subjected to wave forces. In this case, this might be very beneficial as large groups will walk over the pier during high season (for the ferry and touristic companies). • The deck of the fixed pier is placed under zero slope and is therefore more accessible to elderly and mobility impaired people. • Typically have a longer lifetime • Offer a safer installation of utility pipelines under the deck, as they are protected from waves and movements. Disadvantages • Block the free vision during low tide. Especially in this area, where there is such a high tidal range. • Are less flexible, and changes to the structure are generally very cost intensive (PIANC part IV, 2017) • Require more piles to transfer horizontal loads, which are costly to install, disturb the seabed and therefore have a higher environmental impact.	Advantages • Is visually more pleasing as the pier adapts to the level of the tide. However, guiding piles are still necessary, and these will be visible all the time, especially at low tide. • Needs less piles, because horizontal loads will be taken by floating parts, so only vertical loads caused by should be transferred to the foundation. • Offers easy access to the water for people, as the pontoons will be directly on the water level. Disadvantages • Consist of many moving parts, it requires higher maintenance which will result in higher costs during user phase. In addition, more inspections for buoyancy chamber protection are needed to prevent leaking. • Tend to produce a large amount of noise, due to the moving parts. Especially when these moving parts start to rust for example, squeaking sounds could be very disturbing. • Offer less stability, as they move due to waves, currents and people walking on them, which makes them less accessible. • Are under a slope during low tide, which also makes them less accessible. • Block the waterway, by not allowing vessels to pass underneath.

Figure G.8: Table with advantages and disadvantages of each option

H | Calculations

H.1 Calculation vessel swing

The calculation of the vessel swing was performed according to Figure H.1, using a python script. In this script, the depth with reference to the MSL, vessel length and the mooring line length were used as input to calculate the vessel swing. The swing of the buoy was also calculated and printed.

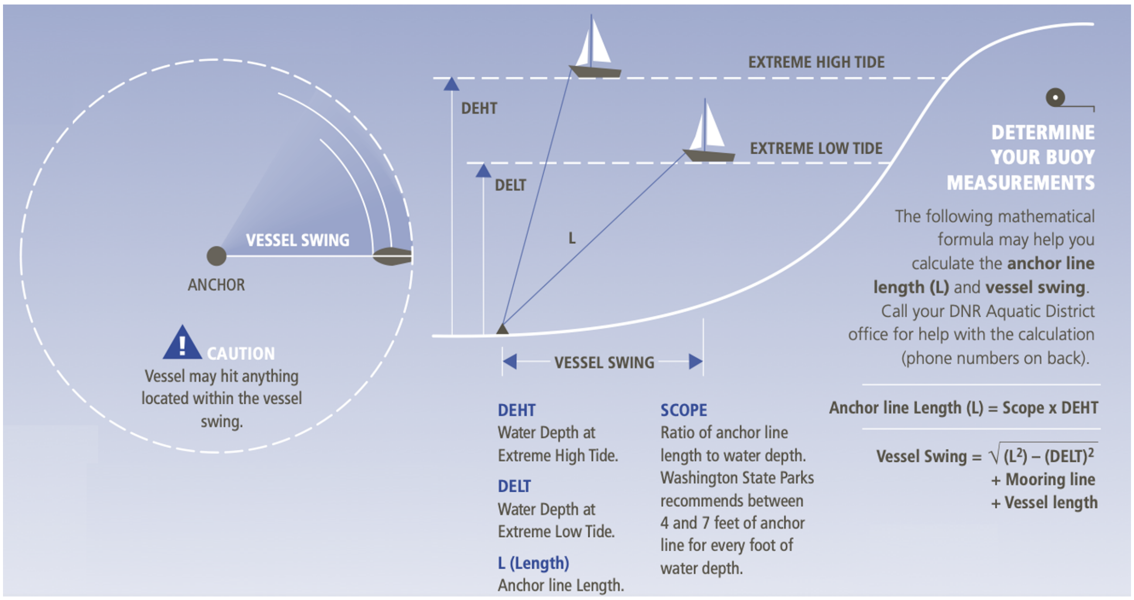


Figure H.1: Calculation of the vessel swing using one-point mooring.

```
In [26]: depth_bathimetry = 6.5 #fill in
         mooringlinelength = 2
         vessellength = 12 #fill in
         scope = 2.5 #from source (https://file.dnr.wa.gov/publications/aqr_qrtrmharbor_map_pg1.pdf)


         waterdepth = 4.75 - depth_bathimetry
         EHT = 9.67
         ELT = 0.15
         DEHT = EHT - waterdepth
         DELT =  ELT - waterdepth

         print(f'DEHT = {DEHT}')
         print(f'DELT = {DELT}')
         L = scope * DEHT
         buoyswing = swing = np.sqrt((L**2) - (DELT)**2)
         swing = buoyswing + mooringlinelength + vessellength

         lengthapart = 2 * swing
         print(f'The calculated swing is {swing:.1f} m')
         #print(f'The buoys need to be placed at least {lengthapart:.1f}m')
         print(f'The swing of the buoy is {buoyswing:.2f}m')

         DEHT = 11.42
         DELT = 1.9
         The calculated swing is 42.5 m
         The swing of the buoy is 28.49m
```

Figure H.2: Python script used to calculate vessel swing

Trot mooring was also considered, but the swing of the buoys make this option also not possible. If current and waves move in different directions, this might lead to collission of vessels as the buoys might go in different directions.

I | Pier component dimensions

The pier exists out of piles, beams, purlins, planks for decking and the handrails is also made out of timber components. In this chapter the dimensions and the calculations are explained.

I.1 Handrails

In Figure I.1 an example is shown of how the used handrails look like.

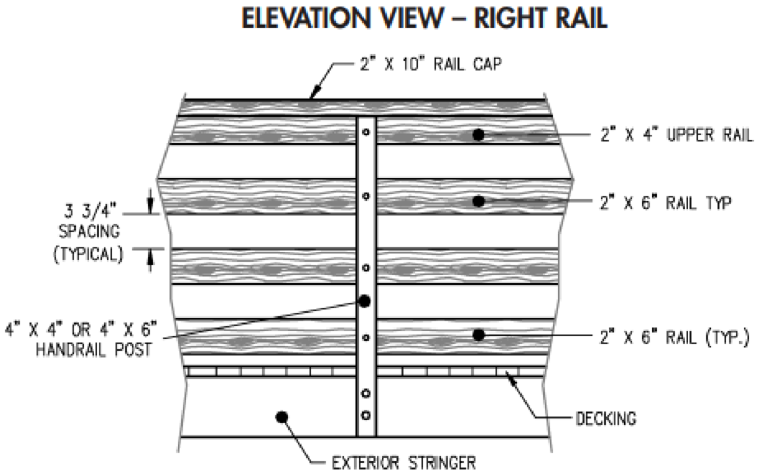


Figure I.1: Example of handrail drawing (Southern Forest Products Association, 2014)

I.2 Calculation of beams and purlins

The components need to be checked on their strength by the maximum allowed moment and shear force. Their deflection will be checked as well. The formulas below from the Eurocode are used for these checks.

$$UGT : Q_{Ed} = 1,35 * G_k + 1,35 * Q_{1;k} + \sum (1,35 * \Psi_{0;i} * Q_{i;k}) \tag{I.1}$$

$$UGT : Q_{Ed} = 1,35 * G_k + \sum (1,35 * \Psi_{0;i} * Q_{i;k}) \tag{I.2}$$

$$UGT : Q_{Ed} = 1,15 * G_k + 1,35 * Q_{1;k} + \sum (1,35 * \Psi_{0;i} * Q_{i;k}) \tag{I.3}$$

$$BGT : Q_{Ed} = G_k + 1,0 * Q_{1;k} + \sum (\Psi_{0;i} * Q_{i;k}) \tag{I.4}$$

where:

$$\begin{aligned} Q_{Ed} &= \text{ design value of the load} \\ G_k &= \text{ characteristic value of the permanent load} \\ \Psi_{0;i} &= \text{ partial factor for the combination of variable loads} \\ Q_{i;k} &= \text{ characteristic value of the variable load} \end{aligned} \tag{I.5}$$

In Figure I.3 the dimensions are verified by performing unity checks. The material properties of the Eucalyptus are stated in Table I.1. The available sizes of Aserradero Silvio (2008) can be found in Figure I.2.

kmod	0,8
M	1,25
fv,0,Rd	2,56 N/mm2
fm,0,Rd	25,6 N/mm2
ft,0,Rd	15,36 N/mm2
fc,0,Rd	16,64 N/mm2
E0,mean	13000 N/mm2
Ed	10400 N/mm2

Table I.1: The material properties of Eucalyptus with a strength class of D40

Producto	Espesores	Anchos	Largos
Tabla Semiclear	1"	2" a 6"	8´a 18´
Tabla Clear	1"	2" a 6"	8´a 18´
Tiranteria	1"-1,5"-2"	2" a 6"	8´a 14´
Tiranteria	1"-1,5"-2"	8"	8´a 14´
Tiranteria	3"	6" y 8"	8´a 14´
Tiranteria	1"-1,5"-2"	2" a 6"	15´a 18´
Tiranteria	1"-1,5"-2"	8"	15´a 18´
Tiranteria	3"	6" y 8"	15´a 18´
Clavaderas	2" y 3"	2" y 3"	8´a 18´
Tabla Comercial Bruto	1"	2" a 6"	8´a 18´
Tabla Comercial Cepillado	1"	2" a 6"	8´a 18´
Machimbre Primera	1/2"	4"-5"-6"	8´a 14´
Machimbre Primera	3/4"	4"-5"-6"	8´a 14´
Machimbre Primera	1"	4"-5"-6"	8´a 14´
Machimbre Comercial	1/2"	4"-5"-6"	8´a 14´
Machimbre Comercial	3/4"	4"-5"-6"	8´a 14´
Machimbre Comercial	1"	4"-5"-6"	8´a 14´
Machimbre Siding	1"	6"	8´a 14´
Columnas Imp. c/10KG	4"-5"-6"	4"-5"-6"	10´a 12´
Columnas Encoladas	4"-5"-6"	4"-5"-6"	10´a 14´
Deck Primera	1"	4"	6´ a 14´
Deck Primera	1,5"	4" - 5" y 6"	7´a 14´
Liston Triangulo Clear	1"	1"	8´a 14´
Liston Pergola Imp. Clear	1"	2"	8´a 14´
Blanck	3/4-1-1 1/2	Varios	Varios
Marco Finger clear	3/4-1-1 1/2	Varios	Varios
Marco p/ Puerta Solido			
Viga Bilam	2"	4"-5"-6"	8´a 14´
Viga LAM	2"- 3"- 4"	6" a 8"	< 12 mt
Viga Multilaminada	3"- 4" y 5"	4" a 14"	< 12 mt

Figure I.2: The available sizes of timber beams from Aserradero Silvio (2008)

	Purlins of 6 metres	Beams of 3 metres
Cross section	355,6 x 127 mm	355,6 x 127 mm
Self weight	6,60*0,3556*0,127 = 0,30 kN/m	6,60*0,3556*0,127 = 0,30 kN/m
Deck weight	6,60*0,0381 = 0,25 kN/m^2	6,60*0,0381 = 0,25 kN/m^2
UGT: governing q_{Ed}	1,35*5*1 + 1,35*0,25*1 + 1,35*0,30 = 7,5 kN/m	1,35*5*6 + 1,35*0,25*6 + 1,35*0,30 + (0,30*6*4)/3 = 46,2 kN/m
M_{Ed} = 1/8 * q_{Ed} * L^2	33,7 kNm	51,9 kNm
$f_{m,0,Ed}$	M_{Ed}/W = 12,6 N/mm^2	M_{Ed}/W = 19,4 N/mm^2
UC = $f_{m,0,Ed}$ / $f_{m,0,Rd}$	0,49	0,76
V_{Ed}	(q_{Ed}*6)/2 = 22,5 kN	(q_{Ed}*3) / 2 = 69,2 kN
τ_{Ed}	(3* V_{Ed}) / (2*A) = 0,75 N/mm^2	(3* V_{Ed}) / (2*A) = 2,30 N/mm^2
UC	0,29	0,90
BGT: q	5*1 + 0,25*1 + 0,30 = 5,5 kN/m	5*6 + 0,25*6 + 0,30 = 31,5 kN/m
w_{inst}	(5/EI*384)*q*L^2 = 18,9 mm	(5/EI*384)*q*L^2 = 6,7 mm
$w_{inst;max}$	L / 300 = 20 mm	L / 300 = 12 mm
UC	0,95	0,56
k_{def}	0,8	
Ψ_2	0	
$w_{fin;G}$	$w_{inst;G}$*(1 + k_{def})	$w_{inst;G}$*(1 + k_{def})
$w_{fin;Q}$	$w_{inst;Q}$*(1 + k_{def}*Ψ_2)	$w_{inst;Q}$*(1 + k_{def}*Ψ_2)
w_{fin}	$w_{fin;G}$ + $w_{fin;Q}$ = 20 mm	$w_{fin;G}$ + $w_{fin;Q}$ = 6,8 mm
$w_{fin;max}$	L / 200 = 30 mm	L / 200 = 12 mm
UC	0,66	0,56

Figure I.3: Calculation of the beams and purlins with vertical loads

I.3 Calculation of piles

I.3.1 Unity check of pile embedment length

This calculation was performed using the same method and parameters used for the pile calculation of the existing pier in San Antonio Este, in order to provide an estimation of the pile diameter of the chosen timber piles. This is NOT a final calculation for the piles and serves solely as an approximation: investigations are needed to determine soil parameters at the project location. The unity check (UC) was calculated by dividing the load by the capacity. Resulting in an unity check which is much lower than 1 for piles with a diameter of 500 millimetres and an embedment length of 4 metres.

PILE PROPERTIES		
depth	4.00	m
diameter	0.50	m
area (Ap)	0.20	m2
circumference	1.57	
D/B	8	

SOIL PROPERTIES		
lateral earth pressure coefficient (Meyerhof)	0.5	between 0.5 and 1, chosen to be 0.5
soil unit weight	10000	kn/m3
friction angle	28	deg
Nq	35	From Brinch-Hansen (1961), based on friction angle

END BEARING CAPACITY			
reduction factor (Berezantsev et al (1961))	0.6		
qp	784000.0	kN/m2	$q_p = f\gamma' D N_q$
	78.4	t/m2	
	15.4	t	
FoS	3.5		
end bearing capacity per pile (Qp)	4.4	t	$Q_p = A_p q_p$

SLEEVE FRICTION		
reduction factor (Berezantsev et al (1961))	0.5	based on friction angle
qfr	5317.1	kN/m2
	0.5	t/m2
	1.8	t
FoS	3.5	
sleeve friction per pile	0.5	t

TOTAL CAPACITY PER PILE		
Total capacity [t]	4.9	
	24.97651199	t/m3

UNITY CHECK		
load applied design value	10.24	t
	20.48	t/m2
UC	0.41	

Figure I.4: Calculation of the pile ultimate bearing capacity using soil parameters of (Vazquez, 2005).

I.3.2 Unity check of vertical loading on piles

In Figure I.5 the dimensions of the piles are verified by performing unity checks regarding normal force and buckling capacity.

	Columns of 17 metres
Diameter	500 mm
Self weight	6,60 * (1/4) * π * 0,5^2 = 1,3 N/m
UGT: governing N_{Ed}	1,5 + 46,2 * (3/2) * + 1,3 * 1,35 = 100,5 kN
$f_{c;0;Ed}$	$N_{Ed}/A = 0{,}51\ N/mm^2$
UC = $f_{c,0,Ed}$ / $f_{c,0,Rd}$	0,03
I_{yy}	3067961576 mm^4
i_y	$\sqrt{\frac{I_{yy}}{A}} = 125$
λ_y	$L_{buc,y}/I_y = 72{,}8$
$\lambda_{rel,y}$	$\frac{\lambda_y}{\pi}\sqrt{\frac{f_{c;0;k}}{E_{0,05}}} = 1{,}13$
k_y	$0{,}5*(1 + 0{,}2*(\lambda_{rel} - 0{,}3) + \lambda_{rel}^2) = 1{,}18$
$k_{c,y}$	$\frac{1}{k_y + \sqrt{k_y^2 - \lambda_{rel,y}^2}} = 0{,}66$
UC	$f_{c;o;Ed}/(f_{c;o;Rd}*k_{c,y}) = 0{,}05$

Figure I.5: Calculation of the piles with vertical loads

J | Calculation of the cost estimation

J.0.1 Calculations for the pier components

The total length of the timber components of the pier is calculated in Table J.1.

Component	Centre-to-centre distance (m)	No.	Length (m)	Total length (m)
Posts	2	242	1.2	290.4
Rails		8	240	1920
Railcaps		2	240	480
Deck		20	240	4800
Purlins		4	240	960
Beams	4	61	3	183
Piles	6	82	12	984

Table J.1: Calculation of the total length of the pier components

J.0.2 Calculations for the floating structure

The amount of material required for the mooring piles of the floating structure is calculated in Table J.2.

Component	No.	Length (m)	Diameter (m)	Area (m^2)	Cubic metre (m^3)	Weight (kg)
Concrete piles	10	34	0,8	0.503	171	
Reinforcement		34		0.005	0.171	1342
Steel casing	1	34	0,812	0.015	0.509	3995

Table J.2: Calculation of the amount of material required for the mooring piles of the floating structure

J.0.3 Calculations for the mooring field

The amount of material required for the mooring piles of the floating structure is calculated in Table J.3.

Component	No.	Length (m)	Diameter (m)	Area (m^2)	Cubic metre (m^3)	Weight (kg)
Concrete piles	34	35	0,6	0.283	336	
Reinforcement		35		0.003	0.099	776.8
Steel casing	1	35	0,6	0.011	0.392	3076

Table J.3: Calculation of the amount of material required for the mooring piles of the mooring field

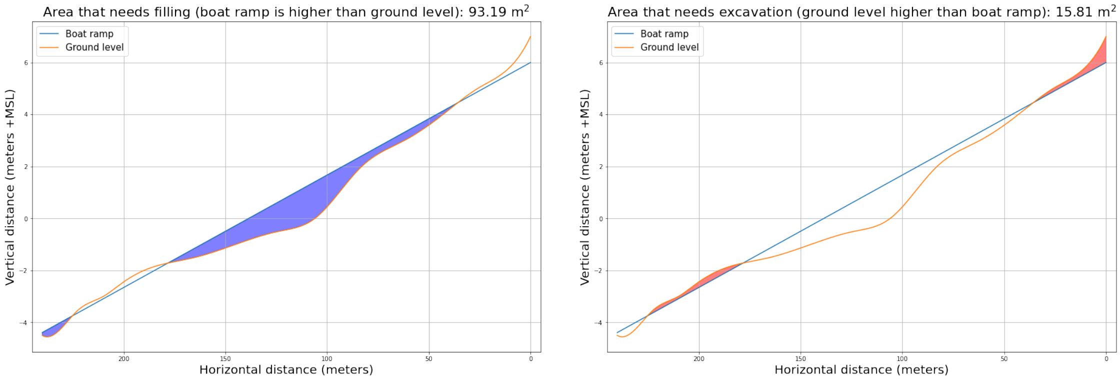
J.0.4 Calculations for the boat ramp

In the next sections the required quantities from table 10.5 are determined in small calculations.

Mobilization

The costs of mobilization of the contractor's forces and equipment were projected to be \$50000,00. This is a one-time cost.

Excavation and fill material
The costs of excavation and filling depend on the volume of material needed to excavate or fill. After a calculation based on the ground level and the level of the boat ramp, the area that needs filling was determined to be approximately 93,19 m^2. The area that needs to be excavated was found to be approximately 15,81 m^2. This is visually represented in figure J.1.



(a) Filling area

(b) Excavating area

Figure J.1: Calculation on excavation and filling area

When multiplying this with the width (4 metres) of the ramp, the volumes of filling and excavating become approximately 373 m^3 and 63 m^3 respectively.

Geotextile
Geotextile quantities were calculated by multiplying the length of the geotextile per metre with the length of the ramp, approximately 240 metres. When considering figure 10.17, the length per metre geotextile is approximately 6,4 metres. This gives an approximated total area of $6,4 \times 240 = 1536$ m^2.

Riprap
To get the volume of riprap needed, an approximation was made of the area riprap needed per metre ramp, then multiplied by the length of the ramp. We get $2 \times 1,44$ m^2 $\times$ 240 m $= 692$ m^3.

Signage
The placement of signs was expected to cost one time \$500,00.

Concrete
Three types of concrete will be applied. Above the average high tide level (MSL +3,21 m) insitu cast concrete will be placed, quantified in cubic yards. Below that, until the average low tide level, the concrete grid blocks will be used. Below the average low tide level, RG4000 precast planks for boat ramps will be placed.

The length of the ramp that is located below the average high tide level is 176 m (similar triangles, see figure 10.14). The length below average low tide level is 35 metres, so the required area of the precast concrete planks is $35 \times 4 = 140$ m^2. The required area of precast concrete grid tiles becomes, therefore, $(176 - 35) \times 4 = 564$ m^2. A price of \$400 was adopted per m^3 (provided by an employee of Besna Argentina) was adopted for the concrete planks and a price of \$60 per m^2 was adopted for the concrete tiles (*Waterdoorlatende Modu Tegel (Grijs)*, n.d.). However, the price of the tiles is highly dependent on the supplier.

The length of the ramp that is located above the average high tide level is $240 - 176 = 64$ m. The required volume of in-situ cast concrete becomes $64 \times 4 \times 0,35 = 90$ m^3 (thickness of 0,35 metres).