

Marina Martín García

Taking a historic island to a new level

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Argentina, December 2011



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General notice to the reader:

In the academic programme for Hydraulic Engineering we have in the 4th year (i.e. in the first year of the Master Programme) the requirement that students should do in a group of four to six persons a so-called "groupwork". It is also called "Master Project". During this groupwork they should make a full design of something. The work should be integral, starting with terms of reference, and ending with the real design. This can be a structure, but also it can be a harbour lay-out, a policy plan design, etc. The total time available for the project is in the order of two months and will provide 10 European Credits. It has to be practical and applied.

It is certainly not an M.Sc. thesis assignment (the thesis work is individual, 6 months and more focussed on research or advanced design work on details). But it is also not an apprenticeship, internship or traineeship where the student has to work together with a group of experienced people. For this groupwork they have to solve the problem on their own (of course with guidance).

This report is the result of such a Master Project. This report has been assessed by staff of TU Delft. It has been provided with a passing mark (i.e. a mark between 6 and 10 on a scale of 10), and consequently considered sufficient for publication.

However, this work has not been fully corrected by TU Delft staff and therefore should be considered as a product made in the framework of education, and not as a consultancy report made by TU Delft.

The opinions presented in this report are neither the opinions of TU Delft, neither of the other sponsoring organisations.

Department of Hydraulic Engineering
Delft University of Technology

Preface

The Delft University of Technology provides master students the opportunity to perform a research project in a foreign country. As a group of six students we embraced this opportunity and started to investigate the possibilities for executing a project abroad in the South American country Argentina. After some interactions between ir. H.J. Verhagen of the TU Delft and M.Sc. Engg M. Schwerdtfeger of the UNSAM (Universidad Nacional de San Martín) an assignment was established. This assignment embraced a research study of designing a marina for the historic and touristic important island, Isla Martín García located in the Río de la Plata between Argentina and Uruguay. The main goal behind this plan is to increase tourism and to create an economic impulse for the island. An attractive marina should force pleasure boat owners to come to the island for leisure and amusement.

As in every project it was difficult to find reliable and up to date information. Gathering and processing the information took most of the time. Besides that, cultural differences made it a very interesting project. In Holland we are more or less used to rational decision making. We found out that in Argentina irrational decision making is part of everyday engineering and life, due to cultural differences.

During this project we worked with our hands, think out of the box, solve problems while creating new ones, use our engineering judgement, apply theories and work as a team. All these aspects make this three months lasting project outmost educative.

This project would never have taken place without ir. H.J. Verhagen, M.Sc. Engg M. Schwerdtfeger and the Island Department of the Province Government who initiated this research project. M.Sc. Engg M. Schwerdtfeger provided us with advice during our stay in Argentina. The scientific level of this report is warranted by our supervisors Dr.ir. L.A. van Paassen, ir. A. van der Toorn and ir. L.J.M. Houben from the TU Delft. They took time to read our report thoroughly and provide us with necessary informative and educative feedback. We would like to thank P.L.W. Louer (retired Royal Boskalis Westminster NV) and Ing. T. De Veth (Royal Boskalis Westminster NV) for their information, advice and support during our stay in Buenos Aires. Besides them, we would like to thank F.C. Iramont (Fundar) who supplied us with detailed knowledge concerning technical information and analyses performed in the Río de la Plata, this information was essential for the quality of our result. We also like to thank Javier Sancristobal from the Island Department, who guided us through the Isla Martín García and supplied us with substantial information. For supplying us with critical information and help in order to succeed this project, we would also like to thank: Dr.ir. P.H.A.J.M. van Gelder (TU Delft), D. Klazinga, MSc (Royal Boskalis Westminster NV), Dr.ir. C. Zwanenburg (Deltares), Dr.ir E. Mosselman (TU Delft, Delft Hydraulics), Dr.ir.drs. C.R. Braam (TU Delft) and Ing. H.J. Everts (ABT). Finally, for making life a bit easier in Buenos Aires, we would like to thank the secretary of Royal Boskalis Westminster NV; Y.L. Litvac.

This report contains the results which we fully support. All the specific information and calculations performed for the report are in the appendices, which can be found on the CD-ROM at the end of this report. In this way we reduce the amount of printed paper and reduce the environmental impact. We hope you enjoy reading this report as much as we enjoyed performing this research, working in a foreign country and establishing this report.

December 2011, Buenos Aires

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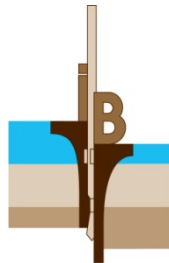
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Abstract

Isla Martín García is founded on a rock outcrop in the Río de la Plata which is a natural protected area between Argentina and Uruguay. Due to the extension of the runway at the local airport, wetlands between Isla Timoteo Domínguez and Isla Martín García developed during the last decades. The bay, where the old port was located, was loaded with sediment. After the waters between the two islands sedimented, Isla Hércules is formed and a channel is created.

The island can be reached by airplane, but is usually accessed by boat. Deep navigational canals run on both sides of the island. Besides these two canals, the island is mainly surrounded by mud banks which are one to two metres below the mean water level.

History tells that the island withholds a military base, protected natural area and tradition in making cakes, called 'Pan Dulce'. The pier, which is poorly maintained, is therefore the most common way to access Isla Martín García for visitors. Because of insufficient capacity, a marina is desired. The eastern side of Isla Martín García holds a protected natural area which is occasionally accessed by researchers; therefore this location is excluded as a location for a marina. The wetlands close to Isla Timoteo Domínguez cannot be used because it is Uruguayan territory and a marina south of Isla Martín García is difficult because of large rock formations.

For the location of the marina, three possible options are selected: at the pier, south of Isla Hércules and in the sedimented bay north of Isla Martín García. By using a multi criteria analysis, a marina at the pier is chosen as the best option because of its small dredging area and minor environmental impact. In consultation with the consultative authorities, a marina at the bay is chosen as the elaborated alternative. The recovery of the old situation in which the marina is located in the bay is the main reason for this choice.

In the detailed design the strong elements of the other marina designs are integrated in the final design. Floating jetties are used for the small and medium boats, because of large differences between design water levels. In this way, small and medium sized boats are always easily accessible. The floating jetties are made of three standardized elements and connected to mooring piles for stability.

The jetty for the large boats and ferries has a fixed deck and is connected to the breakwater. The deck is located at +3.0 m RL, which results in a probability of flooding of once in 25 years. This is five times smaller than the probability of flooding of the airport and is therefore considered to be sufficiently low. The fingers extend from the jetty to the large boats and ferries. The deck of the fingers are also fixed and located on +2.5 m RL. This results in probability of a flooding once every year. Taking the height of these boats in account, the boats are well accessible during normal water levels. To increase accessibility of the ferries during low water stairs go down from the fingers. The breakwater is constructed as a combined wall because a gravity structure has no potential, due to bad soil conditions. The wall consists of sheet pile profiles and H-profiles. To withstand the design conditions, the H-profiles are founded at -17.0 m RL.

At the entrance of the marina, the facilities and services building is constructed and holds a Prefectura office, a tourist shop and sanitary facilities. From this building, a walkway connects the marina with the island. Similar to the fixed jetty, the deck is also located on +3.0 m RL. For boats, the marina is accessible through an approach channel which links Canal Buenos Aires to the marina. Yearly maintenance is necessary, because the approach channel is perpendicular to the predominant flow. Options which cause a significant reduction in dredging maintenance require more and extensive research.

The marina is constructed in a natural area and the accessibility is difficult. Construction takes place from the water and is separated in four phases, which in total takes about six months. In the first stage the approach channel and the area where the breakwater is constructed are dredged. Construction of the walkway is started from the mainland. The elements of floating and fixed jetties are prefabricated and transported to Isla Martín García. In the second stage, the remaining area of the marina is dredged and the construction of the breakwater is started. The third stage consists of installing the piles for the floating jetties and assembling of the fixed jetty. In the last phase the floating jetties are installed. Barges are used to transport material from the mainland to Isla Martín García and because of short building time, they are also used as storage pontoons.

Implementation of the marina at Isla Martín García involves cooperation between two parties: the government and a second investor. The government is responsible for the island, and a certain amount of liquidity is required to boost tourism on the island. A second party, like a private investor, is introduced for the maintenance and exploration of the project. This cooperation needs to invest 22.9 million dollars; this includes the 16.4 million dollars for the government and 6.5 million dollars for the second party. Without involving an external investor the internal rate of return (IRR) is 1.77% which is very low. When involving a private investor the IRR increases, the external investor receives an IRR of 7.71 % over the entire lifetime of the marina.

Low environmental impact is desirable because of the rich flora and fauna which is present on Isla Martín García. Environmental impact is assessed using the Eco-cost value rate concept. This concept expresses Eco-costs as the costs of environmental impact in relation to the carrying capacity of the earth. By taking all possible stages during the lifetime of the marina into account, while determining the Eco-costs value rate, the environmental impact is determined from 'cradle to grave'. The rate is determined by dividing the Eco-costs by the value of the marina. Resulting in a rate of 0.28, which is an indication of the ecological impact and eco-efficiency of the marina. Normally infrastructural projects have an Eco-costs value rate of 0.5, consequently the marina has a relative low impact on the delicate flora and fauna of the island.

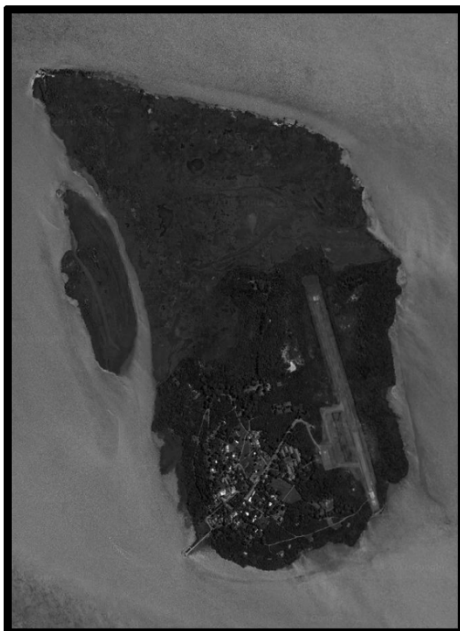
The development of a marina on Isla Martín García can stimulate tourism and therefore creates investment opportunities for the island. This mechanism also works the other way around. When tourism is not stimulated the marina is not used and it creates no investment opportunities for Isla Martín García. Therefore a tourism plan is an important aspect of the marina design. In the tourism plan, four sustainable touristic elements are proposed. These elements are reflected on the carrying capacity of the island and its natural surroundings. The old watch tower north of Isla Martín García and the Chinese Village is revised. Besides this renovation, a new watch tower is build at the end of the fixed jetty and dockings for canoes, kayaks and pedalos are created. The island has a history in creating traditional sweet bread and a military base was located on the island. Showing the traditional way of making these cakes gives visitors an insight in an authentic cooking process. The renovation of some old military buildings and weaponry give an amazing insight in the history of Isla Martín García. Visitors can therefore enjoy the full value of Isla Martín García; from the beautiful wetlands to the ancient traditions.

The designed marina holds enough capacity to fulfil the expected needs for Isla Martín García and increases accessibly of the island. When full potential of Isla Martín García is used and all touristic attractions are developed, the island becomes a beautiful outlet for pleasure craft owners and tourists.

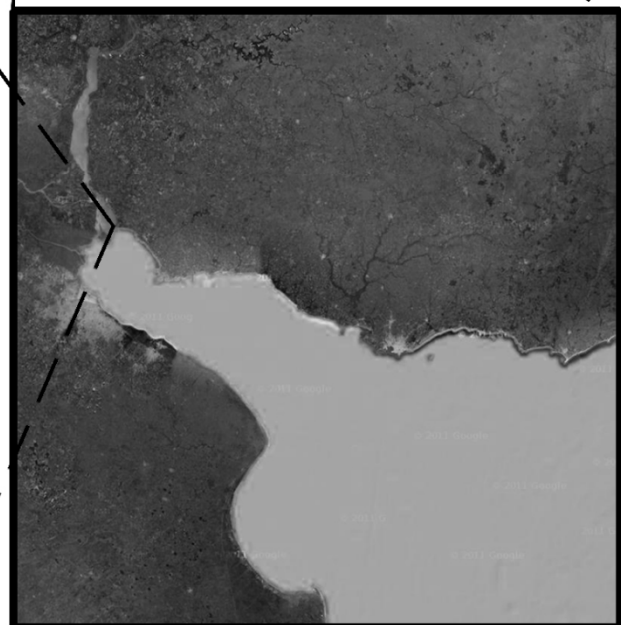
Project location



South America



Isla Martín García



Río de la Plata

Table of contents

1. Introduction	1
2. Foundation of the project	2
2.1. Historical information	2
2.2. Stakeholders	4
2.3. System analysis	5
2.4. Location analysis	6
2.5. Sediment analysis	8
2.6. Development of Río Hércules	9
2.7. Design brief	12
3. Preliminary designs	15
3.1. Locations of the alternatives	15
3.2. General considerations	16
3.3. Marina Muelle	17
3.4. Marina Hércules	18
3.5. Resucitar Puerto Viejo	19
3.6. Multi criteria analysis	20
4. Elaboration of Resucitar Puerto Viejo	21
4.1. Soil profile	21
4.2. Layout Resucitar Puerto Viejo	22
4.3. Dredging activities	24
4.4. Floating jetty	25
4.5. Multifunctional breakwater	27
4.6. Walkway	29
4.7. Facilities and services	31
4.8. Verification Resucitar Puerto Viejo	32
5. Building methods and time schedule	33
5.1. Building methods	33
5.2. Time schedule	36
6. Project finance	38
6.1. Costs	38
6.2. Revenues	38
6.3. Internal rate of return	39
7. Environmental impact	42
7.1. Eco-cost value rate concept	42
7.2. Determination Eco-costs	43
7.3. Value determination	43
7.4. Conclusions	44
8. Tourism plan	45
9. Conclusion	48
10. Discussion	49
Bibliography	50
List of figures and tables	53
Glossary of terms and abbreviations	54

1. Introduction

Isla Martín García, one of the few rocky islands in the Río de la Plata in Argentina, harbours a significant amount of history. Once being a penal colony, having imprisoned important political figures whilst Argentina was under military rule and an often disputed territory. Even though it is closer to the Uruguayan mainland than to the Argentinean mainland and it lays in Uruguayan territorial waters, Isla Martín García is ruled by the government of the province of Buenos Aires.

Having lost its value as a strategic military location, the island became a natural reserve and touristic destination in the past decades, mainly being famous for the pastries being baked on the island, the beautiful nature and its abandoned buildings. The island has about 200 inhabitants, a small fraction of the once twenty times larger population, who mainly live of government funding and tourism. The tourism however is not at the maximum capacity which the island can exploit and the pier is not even sufficient according to today's standards.

Just once a day a boat goes from Tigre (city near Buenos Aires) to Isla Martín García and back and is able to take around 200 tourists to the island. Yet, there are more possibilities on this beautiful island. Scattered around the Río de la Plata are numerous marinas that contain a lot of pleasure boats.

The pleasure boating activity in the Río de la Plata creates an opportunity to design and construct a profitable marina. With it comes expanding the capacity of tourists, the possibilities on the island and improving the docking possibilities of the ferries coming from Tigre (and maybe from different locations in the future). These possibilities give an impulse to the tourism on Isla Martín García. This raises the question:

“What are the options for designing and constructing a marina on Isla Martín García?”

This report describes the process of designing a marina for Isla Martín García, starting in chapter 2 with an analysis of different aspects within the project area. After this aspect, in chapter 3, three different designs are composed, described and eventually one is chosen. This one design is improved further in chapter 4 to a detailed design that shall be presented and evaluated. After the elaboration of the detailed design the building method, planning, costs and revenues are in chapter 5 and chapter 6. The environmental impact is elaborated in chapter 7. How to add more value to Isla Martín García is described in chapter 8, in the form of a tourism plan. Finally the conclusion and discussion of this report are in the last section of this report, chapter 9 and 10 respectively.

2. Foundation of the project

In order to accomplish any project, one needs to know what problems, boundaries and facets can be encountered. This is achieved by several analyses that are performed to map these, such as a stakeholder analysis and (in this case) a sediment analysis. In paragraph 2.1 a brief history of the Río de la Plata and Isla Martín García is given. The next paragraph shows which stakeholders (influenced and influential persons) are involved in this project. In paragraph 2.3 the system analysis of the island indicates the physical project boundaries. Paragraph 2.4 holds an analysis in which the possible locations of the island are narrowed down. Hereafter follows a description of how sediment has influenced the island in previous years, followed by an analysis of the cross section of the Río Hércules paragraph 2.6. Finally this chapter ends with a design brief, where different requirements, assumptions and boundaries are stated.

2.1. Historical information

Incorporating the history of the island is an important fraction in the elaboration of the design because historical elements sometimes include information. Another aspect is the political history of the area which changed significantly during the last decades. This paragraph describes the history of two facets within this project, the Río de la Plata in paragraph 2.1.1 and Isla Martín García in paragraph 2.1.2.

2.1.1. Río de la Plata

The name Río de la Plata suggests it is a river, but it actually is an estuary located between Uruguay and Argentina. The estuary covers a surface of 30,212 km² and originates from the main branch of the Río Paraná and the Río Uruguay.

The estuary can be subdivided into three parts: the Río de la Plata Interior which is the most northern part of the estuary and is separated from the Río de la Plata Medio by a line between Punta Lara and Colonia del Sacramento. The part that covers the Río de la Plata Medio is indicated with a line between Punta Piedras and Punta Brava. The area that covers the Río de la Plata Exterior is restricted by a line between Cabo San Antonio in Argentina and Punta del Este in Uruguay. These subdivisions of the Río de la Plata are shown in Figure 2-1.



Figure 2-1: Classification of the Río de la Plata (Wikimedia, 2011)

Although there is an important interdependency between the different parts; the Río de la Plata Interior is by far the most important, because the project location, Isla Martín García, is located in this area. The Río de la Plata transports between 16,000 and 23,000 m³/s fresh water into the ocean. Annually 160 million tonnes of sediment are being transported downstream the Río de la Plata (Iramont, 2011).

2.1.2. Isla Martín García

For ages negotiations took place between Uruguay and Argentina, in which discussions were held about the boarder lines between Uruguay en Argentina. In 1973 they reached an agreement by signing the Treaty of Río de la Plata. The geographical border between Uruguay and Argentina is located directly in the middle of the two countries but the waters between the two countries are shared. The major difficulty for the geographical border was Isla Martín García. This island is located less then four kilometre from the coast of Uruguay but is in possession of Argentina since 1852. Isla Martín García became a nature reserve intended exclusively for the conservation and preservation of wildlife under jurisdiction of Argentina. Sedimentation caused Isla Timoteo Domínguez, which is property of Uruguay, to get attached to Isla Martín García, see Figure 2-2.



Figure 2-2: Overview project area

(Wikimedia, 2011)

Isla Martín García owes its name to the steward of an expedition in 1516 by Juan Díaz Solís. Martín García, who died on board of the ship, was buried on the island. Throughout the years the island is used for different purposes. Argentina built a prison on the island after which the island was used as a base for the Argentine army. It was taken by the Spanish, the English and the Brazilian and many more activities took place before the island finally became posession of Argentina. This indicates how important this island is for the Argentine government. Nowadays the island is a tourist destination where you can visit, among many other things, the Chinese Village, the remains of the fortifications, the quarantine station and the prison. Although the small production of bread, the island is also famous for its sweetbread; 'Pan Dulce'.

2.2. Stakeholders

In this paragraph the different stakeholders that are involved within the project are analyzed. The stakeholders and their influence on the project are described in short, in order of the expected importance within the project.

2.2.1. Consultative authorities

It is possible to consult authorities and local experts during the design process. These authorities and experts are: Dirección Provincial de Islas (DPDI), the manager of Isla Martín García, CARP and other third parties. They are consulted because of their experience in and knowledge of the project area. This information is valuable during the process in making design choices. All authorities and experts are represented by one contact at the local university UNSAM.

2.2.2. Dirección Provincial de Islas

Dirección Provincial de Islas (DPDI) takes care of planning all actions aimed on economic and social development on the offshore islands and maritime waterways of the Province of Buenos Aires. Isla Martín García is one of the offshore islands of the province. The Dirección Provincial de Islas coordinates all actions with municipalities and has jurisdiction over the islands.

2.2.3. Comisión Administradora del Río de la Plata

The CARP (Comisión Administradora del Río de la Plata) is an international commission between Argentina and Uruguay. It provides a legal framework between the two parties to negotiate over matters with common interest. Isla Martín García is situated in the Río de la Plata which is the work area of the CARP. They control the waters in the Río de la Plata so their influence on the project can be great if they do not approve the design of the approach channel and/or the marina.

2.2.4. Residents of Isla Martín García

The current population of Isla Martín García is about 200 people. This project gives a big impulse to the local economy and possibilities to open stores and hotels on the island become realistic. The residents can experience the economic progress as a disturbance of their rest and peace. They should be informed in an early stage of the project so they can be involved in the entire process. By involving the residents in this process future project difficulties, concerning interference of these stakeholders, are probably reduced.

2.2.5. Pleasure craft owners

Pleasure craft owners are one of the future consumers. To attract as much owners as possible, the wishes of the pleasure craft owners have to be fulfilled. The facilities in the marina and on the rest of the island have to be designed to their desires. Their influence on the layout of the marina is present, but their influence on the external part is negligible.

2.2.6. Ferry companies

The second most significant group of the future consumers are the ferry companies. The users of the ferries are mainly tourists who travel for a day or two to the island. The requirements of the tourists are almost the same as of the pleasure craft owners. The ferry companies need good access to the island to drop off the tourists; a jetty could be a plausible option to suffice their demands. Similar to the influence of the pleasure craft owners is the influence of the ferry companies.

2.2.7. Private investors

To realise the marina the project must be made attractive to private investors. The investors need to be convinced of the fact that in a certain time span they get a positive return on their investment. Eventually the private investors probably have the major vote on whether the project is executed or not. Although the private investors do not have influence on the design of the marina, they are surely needed.

2.2.8. Contractors

When constructing the marina the contractors are the ones who actually do the work. The costs of the different materials which are used must be taken into account. The information on the availability and the costs of different materials must be obtained from the contractors, because it can be of influence on the project. By themselves they do not have any influence on the design of the marina.

2.3. System analysis

In order to specify the area of where the project is conducted and which locations in the area are important, a system analysis is done before further investigation. Within the analysis, two analyses are distinguished: a global and specific system analysis in paragraph 2.3.1 and 2.3.2, respectively. Reason for the separation is the possibility to specify different aspects per viewpoint.

2.3.1. Global system analysis

For this project the most important part of Río de la Plata is Río de la Plata Interior. Isla Martín García and Isla Timoteo Domínguez are both located in this part of the Río de la Plata. Figure 2-3 shows Isla Martín García, Isla Timoteo Domínguez, Canal Martín García and Canal Buenos Aires. Isla Timoteo Domínguez belongs to Uruguay and only since a few years the island is merged with Isla Martín García due to sedimentation. Also the river upstream is important to the project because future sedimentation flow, that influences the propagation of the island, has to take into account. Both Canal Martín García and Canal Buenos Aires are important because many boats use these canals to enter the marina.

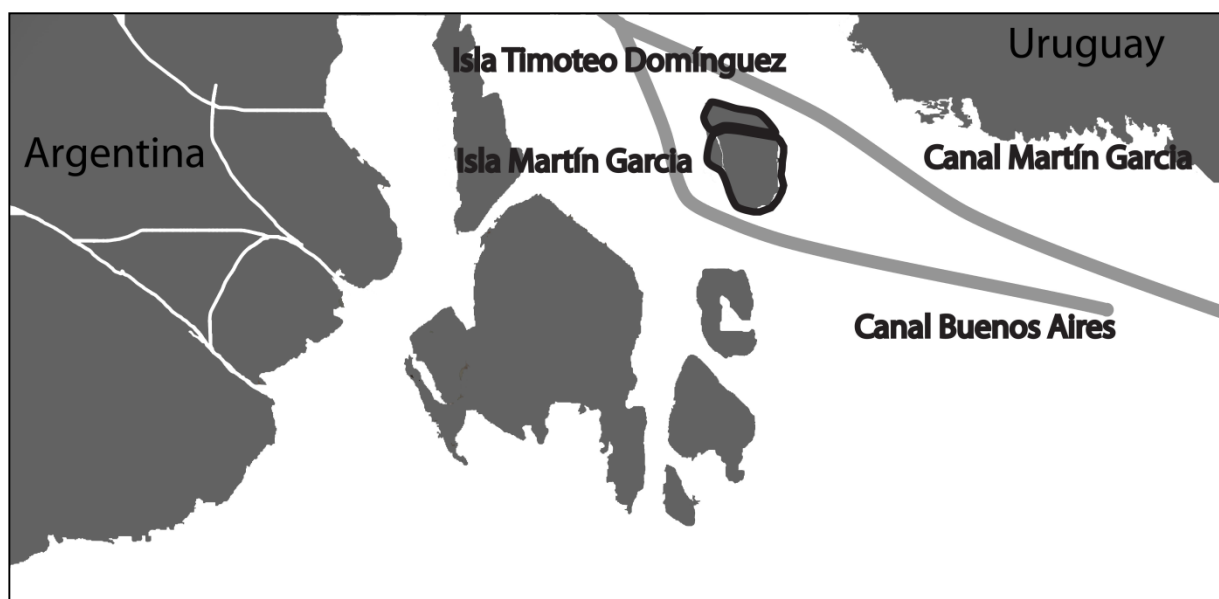


Figure 2-3: Río de la Plata Interior (Google Maps, 2011)

2.3.2. Specific system analysis

Near the island are different aspects that need to be taken into account in the system analysis. As mentioned before, both Canal Martín García and Isla Timoteo Domínguez are important for this project. As visible in Figure 2-4 Canal Martín García just passes Isla Martín García and can have an influence on the design. Local adjustments to the shape of the island can cause changes to the morphology of the entire island. One challenging aspect is Isla Hércules. This island is deposited very recently and creates a natural channel between Isla Hércules and Isla Martín García. In the report this channel is given the name: Río Hércules. It would be interesting if this channel can be used as an entrance for the marina. The propagation of this island needs to be taken into account in order to describe the possibilities of the island.

Besides all the influential elements located on the waterfront the systems on the island also play an important role. Infrastructure and buildings also need to be adjusted according to the increase in demand.

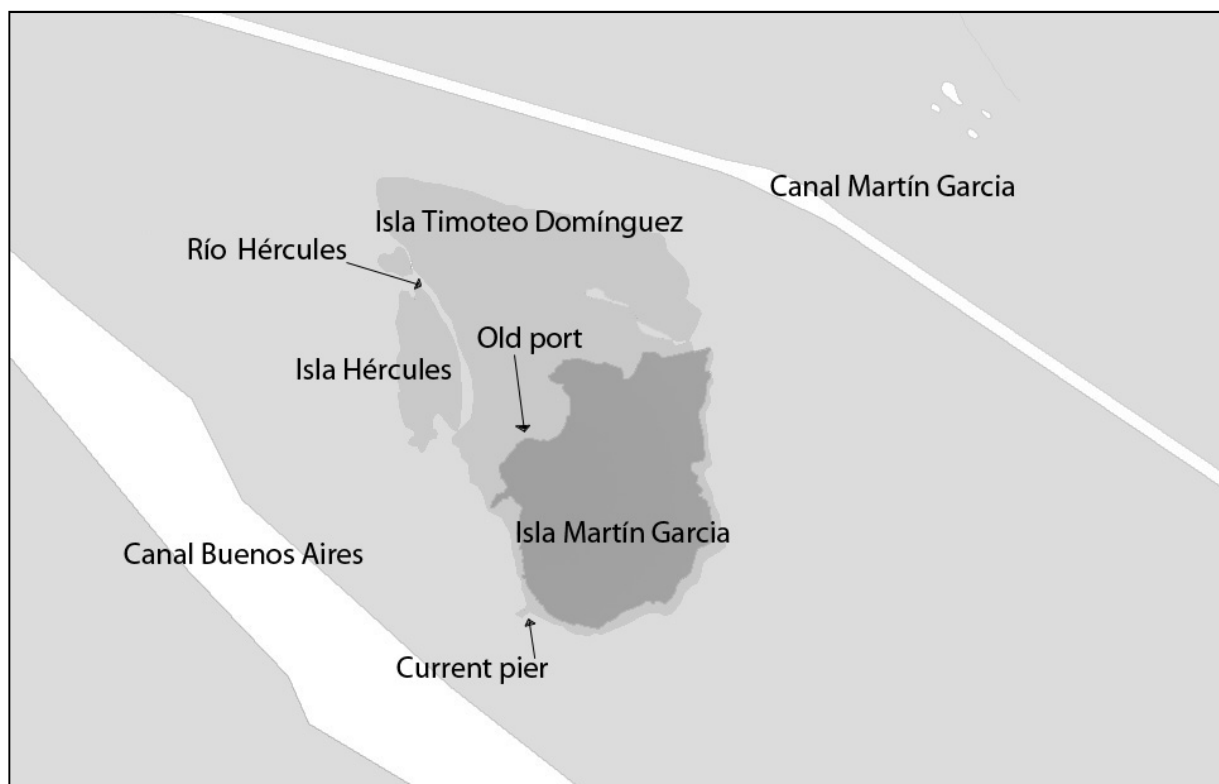


Figure 2-4: Isla Martín García (Iramont, 2011)

2.4. Location analysis

In order to find out which locations are or are not suitable to design a marina, a location analysis is performed. This is to pinpoint locations that are restricted by any reason or cause. For a marina several reasons can be considered in such as weather conditions, law or unfavourable conditions regarding the soil. On Isla Martín García roughly four different areas can be determined, a northern, eastern, southern and western area, where the three least favourable (northern, eastern and southern) are discussed in paragraph 2.4.1 till 2.4.3. A more favourable location, the western area, is described in paragraph 2.4.4.

2.4.1. Northern area

As is visible in Figure 2-5, the northern part (which has been marked with a blue colour) is restricted by the wetlands. This land has been created in the last five decades and mainly consists of sediment, mostly clay. This, however, is not a huge problem, since the clay substance can be easily removed, creating an area to construct the marina. Diplomacy is unfortunately a difficult aspect facing this area. Where Isla Martín García is an island under Argentinean jurisdiction, the waters surrounding it are that of both Argentina and Uruguay. This makes that the land of Isla Timoteo Domínguez belonging to Uruguay and it can become quite complicated to develop a marina in the given area, if not impossible.

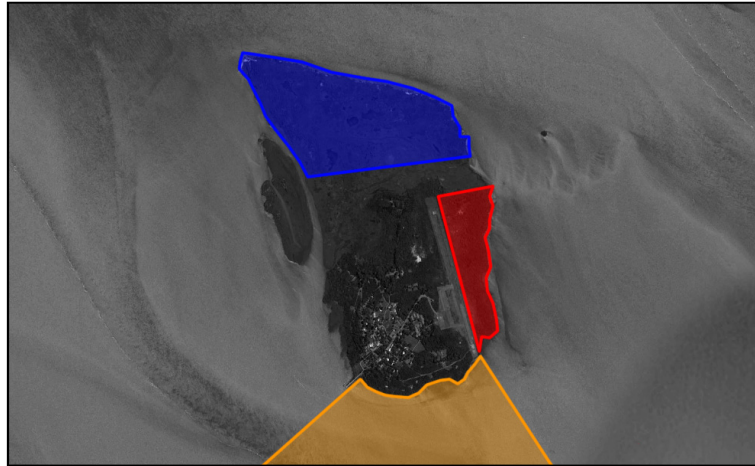


Figure 2-5: Location analysis of Isla Martín García (Google Maps, 2011)

2.4.2. Eastern area

The area east of the airport (in red) is restricted by Argentinean law. No one is allowed to get on this part of the island, not even its residents. Only scientists and/or researchers, under strict regulations and pre-selective can enter the area to do research on the ecological system in this area. This restriction renders this area of the island impossible to design a marina.

2.4.3. Southern area

The southern part (in orange), despite the lack of problems with the sedimentation, is under influence of the so called 'Sudestada', a severe south eastern storm. The waves hitting this part of the island can be extremely rough, which makes a very strong and expensive breakwater necessary. This is not just the only problem with this area, since the soil is of the very hard granite type. In order to get the depth of a marina in that area sufficient, it needs a lot of blasting to get the granite out of this area. This makes this side of the island unfavourable as well.

2.4.4. Western area

In the western part (non coloured) of the island a pier is already present for mooring ferries, even a century ago a port existed, now difficult to recognize due to sedimentation and vegetation, but still known as Puerto Viejo (old port). Thus the circumstances are satisfying to construct a marina. Nevertheless, the last few decades showed a significant growth of sedimentation in this area, which is explained in the next paragraph. This phenomenon creates an extra design challenge but not an obstacle.

2.5. Sediment analysis

Isla Martín García has been under the influence of sediment for many years, the composition of the sediment is in paragraph 2.5.1. However, in the last 50 years there has been a significant change in the shape of the island. With the effect of sedimentation getting more severe each year, a number of remarks can be made. With aerial photographs, see Figure 2-6, with the usable photographs starting in 1969.

This sedimentation in the surroundings of Isla Martín García is caused by the extension of the airstrip in the 1950s. For military purposes the Argentineans decided to extend towards Isla Timoteo Domínguez into the waterway. This resulted in sedimentation in the area between Isla Timoteo Domínguez, Isla Hércules and Isla Martín García described in paragraph 2.5.2 till 2.5.4. Finally a conclusion is added in paragraph 2.5.5.

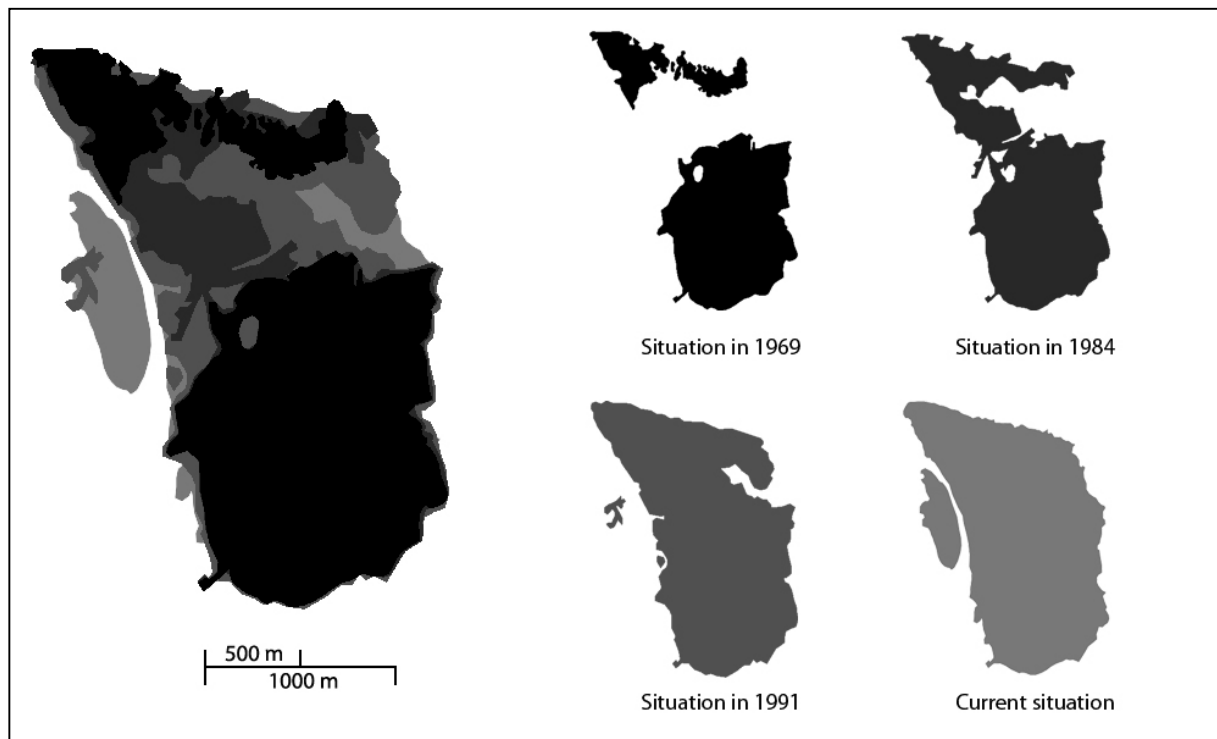


Figure 2-6: Sedimentation at Isla Martín García (aerial photographs)

2.5.1. Sediment composition

Most of the sediment that arrives in the Río de la Plata originates from the Río Paraná, a small part originates from the Río Uruguay. In total 160 million tonnes of sediment is annually passing through the Río de la Plata, of the transported sediment, 9% is bed load and 91% is suspended load. In this, the bed load contains mainly sand and silt and the suspended load contains mainly clay. The depositional gradient occurs similar to the particle size, where the larger particles are deposited in the upper part of the Río de la Plata and the smaller are transported towards the sea or the lower part of Río de la Plata (AABA, 2011). On average the mean grain size varies between 6 and 20 μm (Menéndez, 2001), which is relatively small.

The main mechanism behind the sedimentation is the so called flocculation, formation of cloudlike aggregations. This process occurs during all circumstances, however is stimulated in three events affecting the Río de la Plata. Significant rainfall in the hinterland cause high discharges with more sediment. More sedimentation is caused by: storm conditions, the Sudestada (which causes setup of the water level resulting in deposition of sediment) and finally El Niño, a quasi periodic climate pattern. All these phenomena are noticeable by local dredging companies. More detailed background information about the phenomena is elaborated in Appendix K; Dredging activities.

2.5.2. Isla Timoteo Domínguez

This island has been growing significant for the last 40 to 50 years. Starting with a small island in the north-western part of the island, it has been growing to a size which is almost half the size of Isla Martín García. The island, being a part of the Republic of Uruguay, is mainly composed of sediment. Isla Timoteo Domínguez is currently connected (over a large area) to Isla Martín García, by a wetland connection. Since humans do not access the island frequently, due to soft soil, nature is having free play on the island.

2.5.3. Isla Hércules

In the western waters of Isla Martín García a new island is forming. This island, Isla Hércules, has taken shape in the last 25 years with its biggest change in the last decade. Between Isla Martín García, Isla Timoteo Domínguez and Isla Hércules is small channel appeared of approximately half a metre in depth; which is completely formed by nature. The island is formed with sediment, just like Isla Timoteo Domínguez, resulting in a wetland where nature can act freely.

2.5.4. Isla Martín García

The sediment in the Río de la Plata is having influence on the island, small areas, such as the shore on the eastern part and the bay on the western side of the island are being slowly filled with sediment, due to their unfavourable shape. The southern part of the island is being influenced on a much smaller scale; this part is also under influence of the Sudestada, these south eastern winds can easily wash the previously dropped sediment from the rocky bottom.

2.5.5. Conclusion

Isla Martín García is under a severe influence of sediment, but this mainly applies to the northern part of the island Timoteo Domínguez and Isla Hércules. These areas are the phenomena where, when building the marina on that site, a lot of attention should go to.

2.6. Development of Río Hércules

Between Isla Martín García and Isla Hércules runs the channel Río Hércules which is orientated in a north south direction. Isla Hércules emerged around 1980; this also marks the beginning of the Río Hércules. From that point on the Río Hércules grew to its current length of 1.25 km, the width differs from 50 to 180 m and the depth varies from 0.20 to 0.80 m. The shape and cross sections are elaborated in the following paragraph.

The characteristics of the Río Hércules are mainly determined by the discharges from the Río Uruguay and the Río Paraná, which are coming from the north and not by the hydraulic regimes originating from the Río de la Plata and Atlantic Ocean, which are coming from the south. This development is described in paragraph 2.6.2.

2.6.1. Shape and cross sections

The discharges of the Río Paraná and the Río Uruguay merge upstream of Isla Martín García and continue in a south east direction towards Isla Martín García and the Río Hércules. The entrance of the Río Hércules is also orientated in a southeast direction and thus the flow can enter the channel without any obstacles. The dept at the entrance of the channel is about 0.4 m. This is the first cross section in Figure 2-7. The flow approaches Isla Martín García and changes direction, following the profile of Isla Martín García. The consequence is that there is a sharp transition between land and water at the east side of the channel. This jump is between 0.20 and 0.40 m, depending on the position in the channel. This curve affects the water depth and width of the channel. This results in higher flow velocities near Isla Martín García increase which causes erosion and therefore the depth on the eastern side increases to about 0.80 m. All the predominant flow is now concentrated at the east side of the channel, this causes sedimentation in the west part of the channel. The depth at the western side is about 0.20 m and it gradually decreases until Isla Hércules is reached.

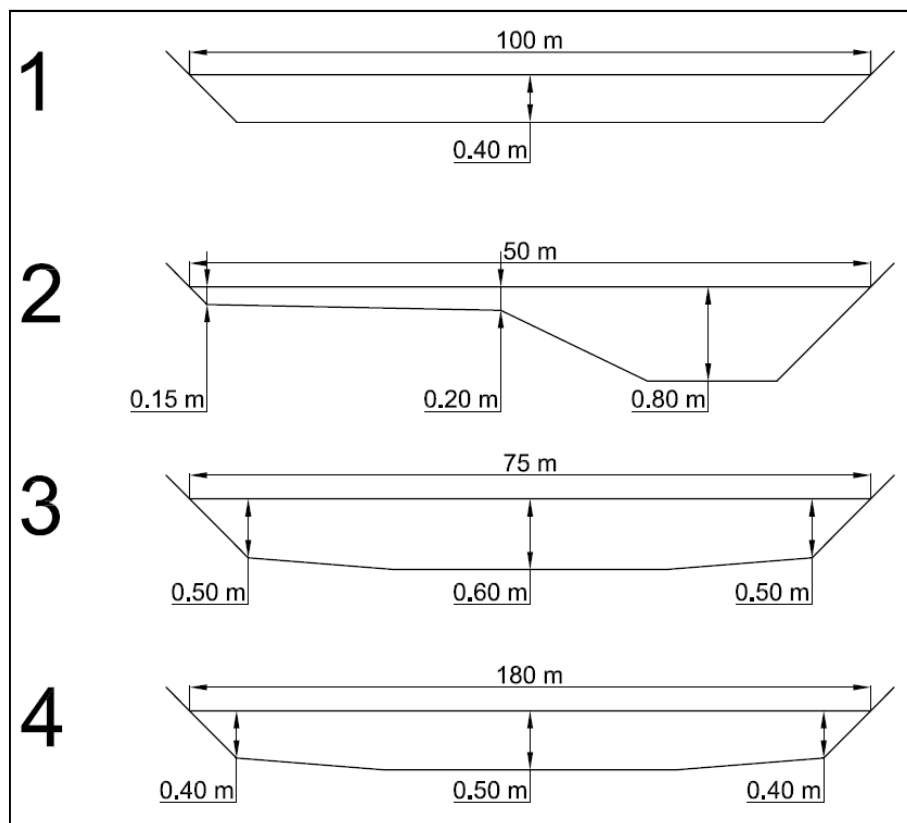


Figure 2-7: Cross sections Río Hércules (Appendix T - No. 7)

Section two is most narrow, because of the relative standing waters and additional sedimentation at the western side of the channel. This is the second cross section, which is shown in Figure 2-7. The curve continues after the first bend but it is less sharp than in the top of the channel. This results in a flat bottom. The average depth in this part is about 0.60 m, the third cross section. After this point the width of the channel increases to 180 m and the channel also gets shallower. The depth at the end of the channel is about 0.4 m, shown in cross section number four.

At the end of the channel the difference between land and water at Río Hércules and Isla Hércules is not clearly visible; this is because Isla Hércules is extending southwards. The overview of the channel and the positions of the different cross sections are shown in Figure 2-8 (orange lines). In this figure the yellow hatched part are the parts where the vegetation emerges and the red line is the main stream.

2.6.2. Development of Río Hércules and Isla Hércules

Since Isla Hércules formed, it propagates in northern, southern and eastern direction. South of the island new land is forming which is about 0.10 m under the average low water. This part is already vegetated. This vegetation decreases the water velocities and speeds up sedimentation which makes settlement of the small clay particles easier.

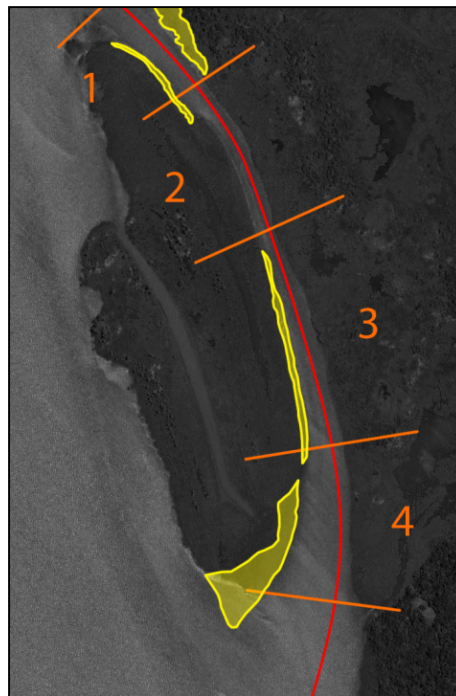


Figure 2-8: Development Isla Hércules

(Google Maps, 2011)

This process is also going on at the eastern and northern side of the island. The western part of Isla Hércules has fewer problems with sedimentation because it suffers more from wave impacts originating from the Pampero winds. Due to the sedimentation, which may be accelerated by vegetation, Isla Hércules gets longer and wider. This accelerates the flow in the channel and causes erosion. The suspended material settles when the water slows down and forms a sand bank south of the channel. When this sand bank increases in time it starts to be a barrier for the water exiting the channel. This decreases the velocity of the water in the channel and causes sedimentation in the channel, which eventually blocks the channel completely. It is not easy to predict in which timeframe this process happens, but it is very likely to happen.

2.7. Design brief

For this project the boundary conditions and requirements are given in paragraph 2.7.1 and 2.7.2, respectively. These conditions mainly consist of specific numbers that are determined for the designs and background of the values can be found in the corresponding appendices.

2.7.1. Boundary conditions

Wind conditions

An average wind velocity, over five minutes, results in the design wind velocity of 111 km/h. This wind velocity is coming from the southern direction, with an exceedance probability of once in 100 years. More information about the wind characteristics can be found in Table 2-1 and the statistical analysis is elaborated in Appendix B; Statistical data analysis.

Table 2-1: Design wind velocities

Wind direction	Design wind velocity [km/h]
N	53
NNE	50
NE	45
ENE	39
E	41
ESE	47
SE	55
SSE	93
S	111
SSW	103
SW	79
WSW	67
W	64
WNW	54
NW	58
NNW	56

Wave conditions

The design wave differs around Isla Martín García. The highest wave comes from the SSE and is 1.21 m. In Table 2-2 the design waves for the different directions are shown. Besides the design wave, the accompanying peak period and minimum storm duration are presented in Table 2-2. The calculations of several parameters are explained in Appendix B; Statistical data analysis.

Table 2-2: Design wave conditions

Directions	Wave height; H_s [m]	Storm duration; T_s [min]	Peak wave period; T_p [s]
N	0.32	63	2.6
NNE	0.48	26	2.7
NE	0.51	11	2.6
ENE	0.42	11	2.4
E	0.57	48	3.0
ESE	0.41	119	2.9
SE	1.08	234	4.5
SSE	1.21	163	5.0
S	0.87	6	3.3
SSW	0.64	5	2.8
SW	0.39	15	2.6
WSW	0.55	20	2.8
W	0.72	19	3.3
WNW	0.49	43	2.7
NW	0.34	74	2.7
NNW	0.45	52	2.9

Wave conditions inside marina

The maximum allowed wave height inside the marina should be 0.30 m (Blain, 1992).

Design water levels

- Design high water level +3.89 m RL (design criteria of once in 100 years)
- Mean high water level +0.90 m RL
- Mean water level +0.64 m RL
- Mean low water level +0.41 m RL
- Design low water level -1.26 m RL (design criteria of once in 25 years)

All the calculations of the different water levels are performed with the data from two measuring stations nearby Isla Martín García. This calculation is shown in Appendix B; Statistical data analysis. The data is measured in the Uruguayan LIMB reference level. This is transformed into the Argentine reference level. Lots of systems for measuring altitudes are present in Argentina. The reference level used on Isla Martín García is the 'Cero del Riachuelo' and is abbreviated as: RL (Riachuelo level).

Depth of waterways

- Approach channel -3.80 m RL
- Marina -4.40 m RL

The origins of these numbers are given in Appendix K; Dredging activities.

2.7.2. Statement of requirements

General

- Lifetime of 100 years for the marina
- Lifetime of 50 years for individual elements within the marina

Marina - Design vessel

- Length: 32.0 m
- Width: 9.0 m
- Draft: 2.5 m

The dimensions of the design vessel are imaginary and determined by different vessel types, elaborated in Appendix E; Design marina layout.

Marina - Hydraulic

- Approach channel with a width of 40.0 m
- In total 100 moorings, the total amount of the individual moorings is given by the consultative authorities:
 - 10 moorings of 25.0 m times 6.5 m
 - 45 moorings of 15.0 m times 5.5 m
 - 45 moorings of 9.0 m times 4.0 m
- For ferries: 2 moorings of 35.0 m times 10.0 m

The marina should be designed in a way that the sediment inflow is reduced to a minimum. Overview of the more specific design rules is given in Appendix E; Design brief marina layout.

Marina - Facilities

- Facilities and services (100 m²), including:
 - Harbourmaster office
 - Sanitary facilities
 - Ticket office ferry

Marina - External

- Infrastructure to connect the marina to the existing infrastructure on the island and provide a safe passage for tourists
- An approach channel from the marina to the existing navigational routes

3. Preliminary designs

The next step in the process towards a final design is to study different alternatives. First the locations are presented in the paragraph 3.1, followed by paragraph 3.2 about general aspects that apply for every alternative. The options to construct a marina, linked to a specific location, are considered. In total, three different studies are done on three different locations at the west side of Isla Martín García, these are summarised in the following three paragraphs. For the more elaborated preliminary designs, see Appendix G; Preliminary designs. Paragraph 3.6 explains the MCA (multi criteria analysis) made out of the three different alternatives, where multiple criteria of the different studies are considered and evaluated. This results in one final design.

3.1. Locations of the alternatives

Every design is located on a different location on Isla Martín García, which is determined by various aspects. The location analysis plays an important part in this process, moreover the history and common sense are equally important for determining these locations, see Figure 3-1.

One of the alternatives is at the location where the old harbour was located, see Figure 3-1, in the yellow circle. The second location is more to the west of the island, in the red circle. The third alternative is located near the pier, in the blue circle.



Figure 3-1: Locations of the alternatives (Google Maps, 2011)

3.2. General considerations

In total three different alternatives are presented in the following paragraphs, every alternative contains aspects that are general applicable. These aspects are: approach channel alignment, mooring systems and reference projects, presented in paragraph 3.2.1 till 3.2.3.

3.2.1. Approach channel alignment

All the alternatives are connected with an approach channel to Canal Buenos Aires. The design of the canal is not elaborated and consists of a long canal that is subjected to a lot of sedimentation, resulting in significant maintenance costs. In the detailed design of the final alternative, the approach channel is elaborated with a detailed and costs efficient design.

3.2.2. Mooring systems

Different types of mooring systems are described in Appendix E; Design brief marina layout. In this appendix three types of mooring systems are possible in the area of Isla Martín García: buoyed moorings, floating jetties and fixed moorings. All these types are possible in estuaries, like the Río de la Plata, but have some limitations. These limitations are given in Table 3-1, including the possibilities.

Table 3-1: Possible mooring systems

	Possibilities	Limitations
Buoyed moorings	Have the possibility to create a flexible and adjustable layout of the marina.	Requires an area that is equal to a circle with a radius of the boat. Also experienced sailors are preferred.
Floating jetties	Boats can be visited by foot. And this system has the flexibility to be adjusted to the boat size.	Piles to support the structure are constantly visible and difficult to adjust.
Fixed moorings	These moorings have the capacity to transport larger amount of people in a short time.	Only possible with larger boats, due to the height of the jetty (approximately +4.0 m RL).

3.2.3. Reference projects

In Appendix A; Reference projects, several reference projects are analysed and evaluated; these are a rough guideline for the three alternatives that are presented in this chapter. A full overview can be found in the appendix and only a brief summary of useful aspects is given in Table 3-2.

Table 3-2: Summary reference projects

Location	Positive aspect	Negative Aspect
Carmelo, Uruguay	Minor environmental impact	Moorings on one long quay
La Plata Port, Argentina		Major environmental impact
Colonia del Sacramento, Uruguay	Durable (concrete) design	Abandoned during storm conditions from north and east
Nueva Palmira, Uruguay	Functional cheap solution	Limited draft approach channel
Puerto del Buesco, Uruguay	Organised jetty layout	Sedimentation problems
Yacht club Argentino, Argentina	Combined wall constructed as breakwater	Limited protection against incoming waves

3.3. Marina Muelle

Marina Muelle is located near the pier (Muelle is Spanish for pier), assumed is that the pier meets the boundary conditions as stated in the design brief. In this design the pier is dominant for the layout of the marina, which is constructed northwest of the pier. The pier fulfils the following functions: mooring place and breakwater. As breakwater it provides shelter for the incoming waves from the south allowing two ferries and four large boats to moor, see Figure 3-2.

Due to the location it is possible to construct a relative compact marina layout, with efficient use of the available space. As a consequence the required space in the marina is limited; resulting in minimum dredging area and short breakwaters. Inside the marina two floating jetties are included to accommodate most of the boats. This marina is located as close as possible to the village on Isla Martín García, thus extra infrastructure is not necessary.

A disadvantage of this compact marina is the more complex internal manoeuvrability. This requires more time, as well as skills for a skipper to enter and manoeuvre his boat. Finally, during the building stage of the project, some of the building activities are planned near the pier. Hindrance of the current activities is almost unavoidable, because this pier is already in use by a ferry for tourists. Of course by using a proper time schedule and layout for the building stage, this could be limited to a minimum. Besides those aspects the ecological value of this location is not that high compared to the other locations.

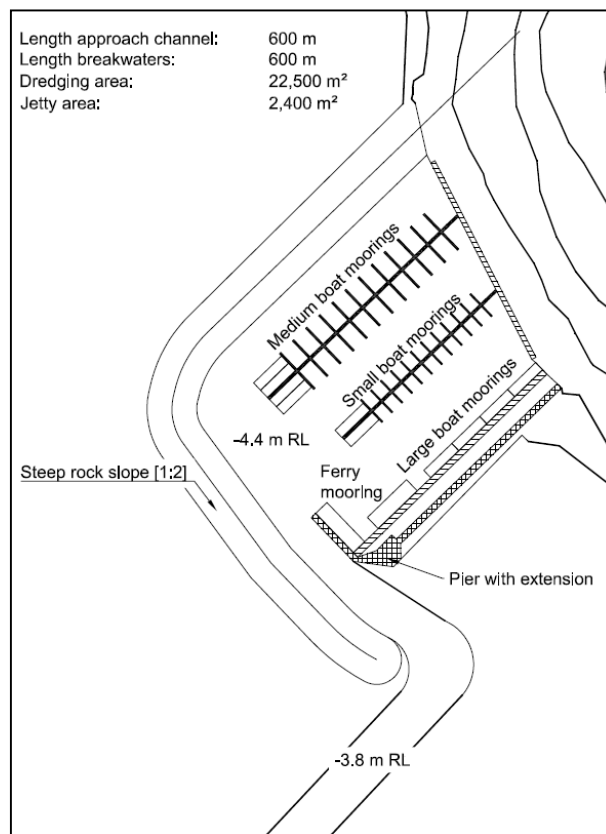


Figure 3-2: Design of marina Muelle (Appendix T - No. 9)

3.4. Marina Hércules

The second design is called Marina Hércules; the name is derived from the island on the west side of Isla Martín García, called Isla Hércules. The exact location of the marina is in the channel between Isla Hércules and Isla Martín García, at the southern end of the channel. This location is in the middle of a beautiful and ecological diverse area. There is a large area of wetlands in the north and a view over the Río de la Plata in the west.

This location has the advantage that the building site is very open and outlying. As a result this makes it easy to get materials and equipment to the site, but also the nuisance is negligible. The designed marina uses combined walls for mooring spots and as a breakwater, resulting in another design option. This makes it possible to design the marina in a compact manner, and reduce the possibility of failure due to the soil layer smaller. By installing the jetties on convenient locations, the necessary area for jetties is relatively small. An advantage of this aspect within this design is the reduction of the costs.

Marina Hércules also brings a problem, namely the amount of turns that have to be taken inside the marina due to the compact layout, see Figure 3-3. Also the breakwater design brings some disadvantages. The 180 degrees turn for the ferry increases the complexity of manoeuvring. Furthermore the relatively large distance between the marina and the centre of the village has to be covered by new infrastructure. The road over the higher grounds of the island is in proper condition. In the wetlands from the marina to the higher grounds, an elevated walkway is necessary. Despite any effort, this distance is still long and potentially annoying. Therefore, if the potential tourism sites in the north are not further developed, this becomes a negative point of the design.

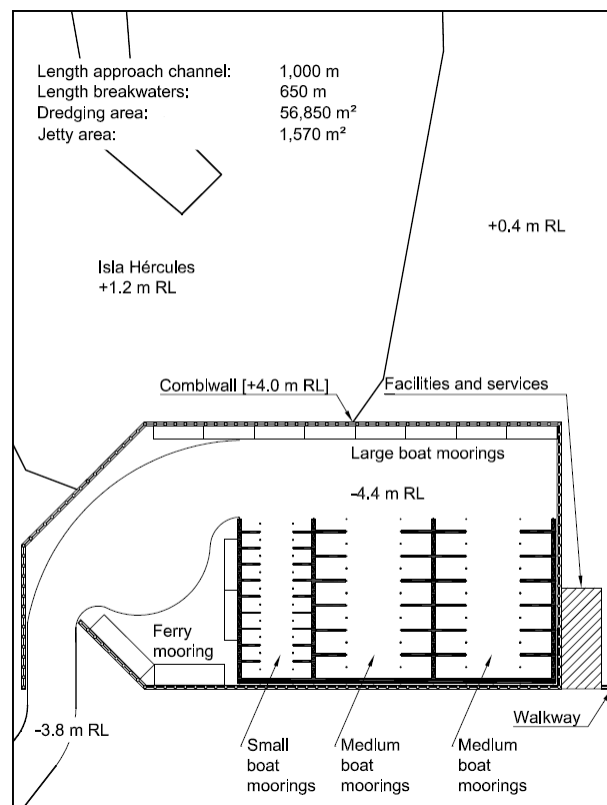


Figure 3-3: Design of marina Hércules (Appendix T - No. 10)

3.5. Resucitar Puerto Viejo

The design Resucitar Puerto Viejo is fully integrated in the natural surroundings of Isla Martín García. The name of this marina directly indicates its purpose. ‘Resucitar Puerto Viejo’, which literally means ‘revive of the old port’, includes a marina at the old location and revives the glory and history of the old port. This design includes the construction of two breakwaters south of Isla Hércules, in order to protect against the design storm coming from the south. A third breakwater is constructed north of Isla Hércules to prevent sediment deposition in the Río Hércules, visible in Figure 3-4.

Floating jetties extend into the marina from the fixed jetties. By using floating jetties the variety in water levels is taken into account. The largest part of the fixed jetties is below the design water level to minimize the impact on nature and visual pollution. The top of the fixed jetties at which the large boats moor are at design water level. During these extreme water levels the fixed docks of the medium and small boats are inaccessible. For these situations, emergency berths are created at the southern side of the fixed jetty. The marina is located relatively far from Canal Buenos Aires in comparison to the other designs. This design focuses on stimulation of tourism on and around the island. Watchtowers and possibilities for aquatics, such as kayaking and canoeing, take full advantage of the beautiful ecological valuable wetland area.

This design has both advantages and disadvantages. As a result of this location, the protection against design waves and the protection against sedimentation requires almost a kilometre of breakwater. Besides that Resucitar Puerto Viejo is located relatively far from Canal Buenos Aires. This significantly increases the amount of area to be dredged. A positive aspect is that constructing the marina on this location does not cause that much hindrance and annoyance, because it is located far from the village and the pier. This design revives the old port of Isla Martín García. It fully integrates with the unaffected and undisturbed natural area surrounding Isla Martín García.

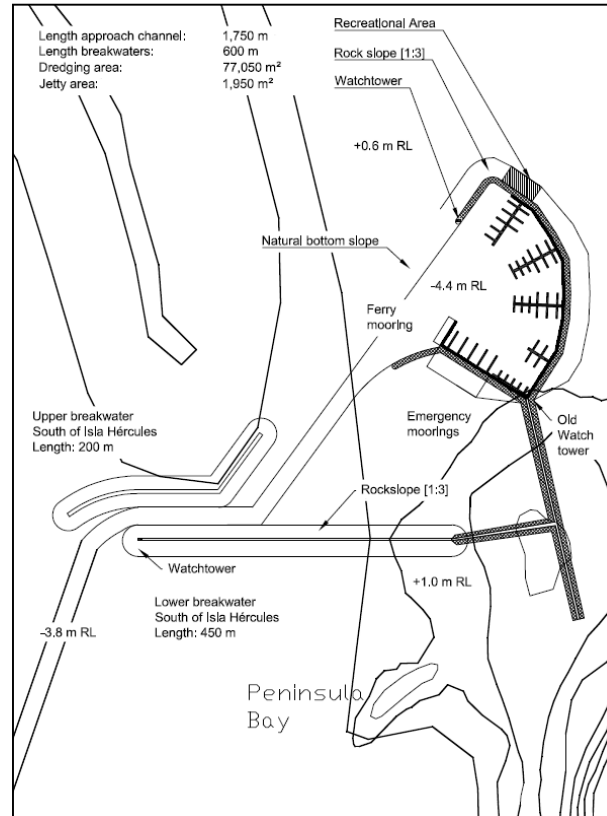


Figure 3-4: Design Resucitar Puerto Viejo (Appendix T - No. 11)

3.6. Multi criteria analysis

In the MCA (multi criteria analysis) the three designs, which are elaborated in the previous three paragraphs, are compared. To each criterion a score is assigned which is multiplied with the weight factor, see paragraph 3.6.1. The design with the highest score is the preferred alternative. A justification and implementation is in paragraph 3.6.2 and 3.6.3.

3.6.1. Result MCA

The criteria costs and labour are not calculated in the preliminary design because this design is too superficial to do a reliable estimation of the costs and labour. Costs and labour are not explicitly mentioned in this analysis but are included in the other criteria. For example, by setting the length of the breakwater as a criterion, costs and labour are explicitly included, see Table 3-3. The scores (S), the weight factor (Wf) and the reasoning are given in Appendix H; Multi criteria analysis.

Table 3-3: Scores multi criteria analysis

	Marina Muelle			Marina Hércules			Resucitar Puerto Viejo		
	S	Wf	S*Wf	S	Wf	S*Wf	S	Wf	S*Wf
1. Dredging area	9	0.07	0.64	6	0.07	0.43	4	0.07	0.29
2. Length breakwater	8	0.21	1.71	7	0.21	1.50	5	0.21	1.07
3. Hindrance building stage	6	0.04	0.21	8	0.04	0.29	8	0.04	0.29
4. Environmental impact	8	0.14	1.14	7	0.14	1.00	6	0.14	0.86
5. Internal manoeuvrability	6	0.25	1.50	6	0.25	1.50	7	0.25	1.75
6. Jetty area	6	0.18	1.07	8	0.18	1.43	7	0.18	1.25
7. Maintenance	7	0.11	0.75	7	0.11	0.75	7	0.11	0.75
			7.04			6.89			6.25

3.6.2. Verification MCA

According to the MCA, Marina Muelle is the design with the highest score, indicating the preferred preliminary design. Option two, Marina Hércules, scores similar compared to Marina Muelle and is a good alternative. In consultation with the consultative authorities, Resucitar Puerto Viejo is chosen as the elaborated alternative. The recovery of the old situation in which the marina is located in the bay is the main reason for this choice. Nevertheless, good aspects from the other preliminary designs are implemented in the final design.

3.6.3. Implementation of Resucitar Puerto Viejo

Resucitar Puerto Viejo, the third option, is the alternative that is elaborated, but some good aspects are used from the other alternatives. As shown in Table 3-3, the scores on dredging area and length breakwater are better, so apparently these alternatives have a more efficient mapping. These aspects can be more optimised in the final design, also the possibilities of a combined wall or gravity structure is investigated. None of the alternatives has buoyed moorings. In paragraph 3.2.2 is shown that floating jetties is the best solution for these circumstances.

A good aspect of Resucitar Puerto Viejo is the internal manoeuvrability, compared to the other two alternatives. Thus creating more space in combination with a simple canal system can create a better manoeuvrability for sailing. Creating a very compact marina, which is done in the first and second alternative, is not that convenient. The last aspect that is challenging is the environmental impact. Some significant interference is expected. In order to reduce this impact, create a higher score, the impact exact on the environment is determined. When adapting aspects of Resucitar Puerto Viejo, most attention should be paid to the aspects with highest weight factors.



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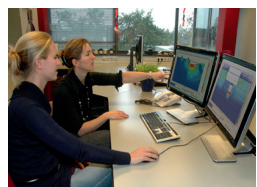
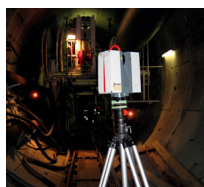
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4. Elaboration of Resucitar Puerto Viejo

In the previous chapter several designs were elaborated and one was chosen to be designed in detail. This chapter covers the process, starting with a determination of the soil profile. The following paragraph shows the layout of the marina in a more detailed manner than was done in chapter 3. In paragraph 4.3 the dredging activities are described, with the design of the floating jetties after that in paragraph 4.4. Paragraph 4.5 contains the description of the multifunctional breakwater which is both a breakwater and a jetty for the large boats. After this the walkway, which connects the island with the facility platform, is elaborated in paragraph 4.6, an elaboration of the facilities is in paragraph 4.7. The chapter ends with a verification of this design in paragraph 4.8, based on the previous conducted MCA.

4.1. Soil profile

The soil profile is the basis of designing a marina. Stability calculations, dredging depth and cost calculations all depend on an accurate soil profile. Soil profiles are created although not much information is available about the rock outcrop on which Isla Martín García is formed. Many assumptions are made in order to make this soil profile, explained in Appendix J; Geotechnical stability. In this chapter the soil profile typical for the location Puerto Viejo is given in Figure 4-2. An overview is given in Figure 4-1 including the rock depth propagation.

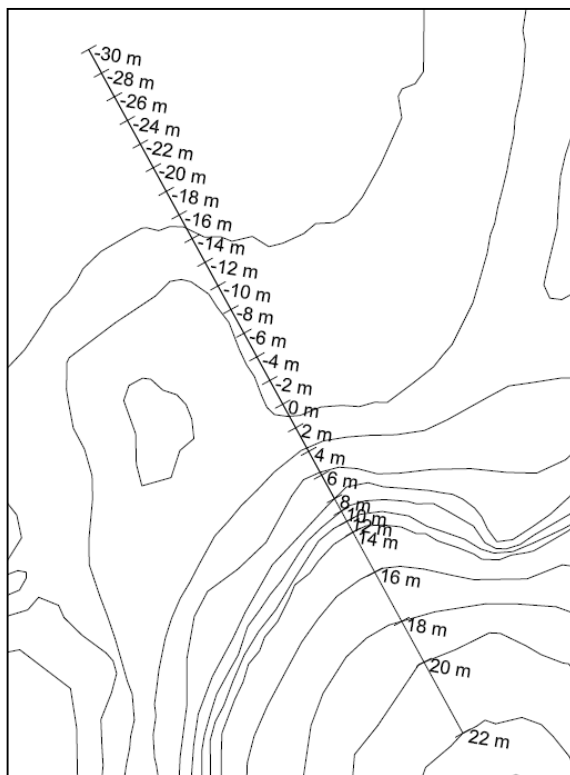


Figure 4-1: Soil profile Puerto Viejo
(Appendix T- No. 19)

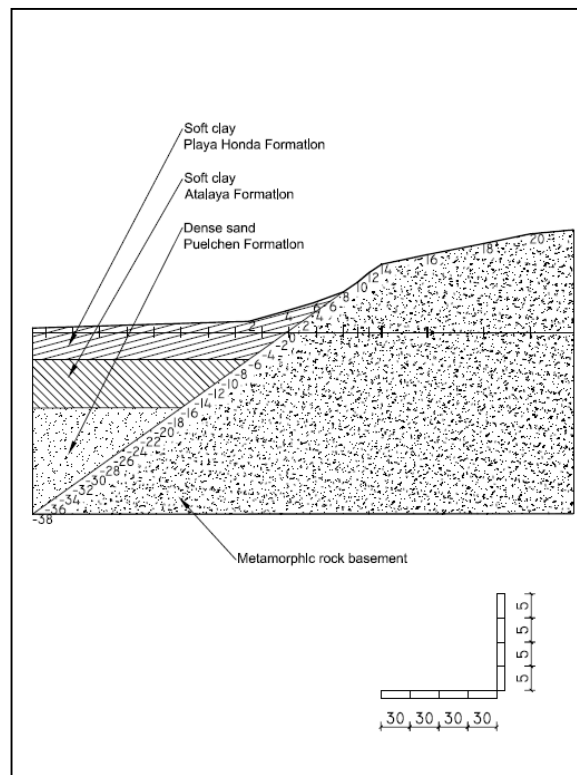


Figure 4-2: Overview soil profile propagation
(Appendix T - No. 20)

4.2. Layout Resucitar Puerto Viejo

The design of the marina is located at the old port, in the bay, see Figure 4-3. The approach channel is aligned perpendicular to Canal Buenos Aires. Different options for the approach channel are examined and one is further elaborated in paragraph 4.3, which is about the dredging activities. Isla Martín García is accessible from the marina through the Chinese Village. The connection is made by a wooden walkway that integrates with nature. See paragraph 4.6 for more details about the walkway.

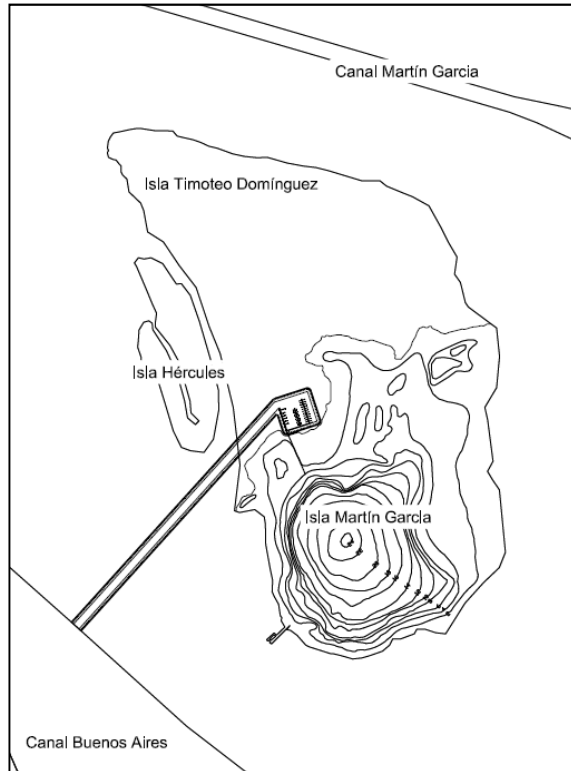


Figure 4-3: Location of the design

(Appendix T - No. 12)

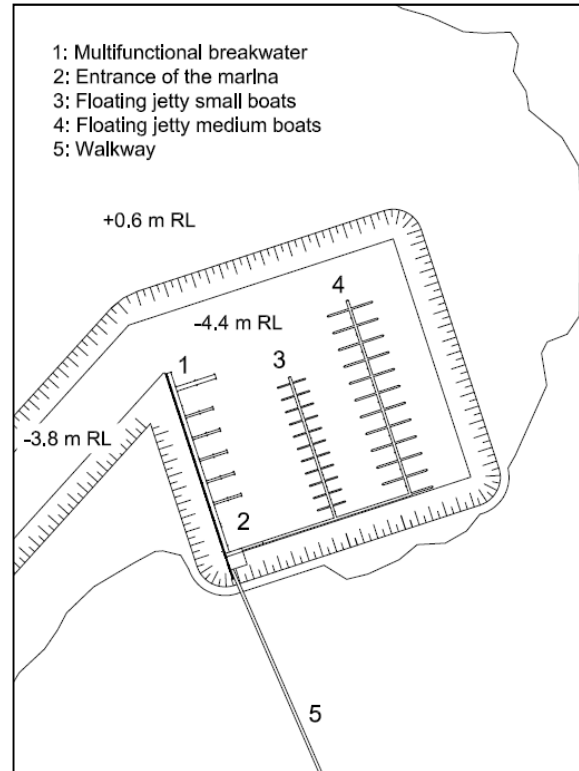


Figure 4-4: Components within the design

(Appendix T - No. 13)

The marina is rotated in such a way that it fits into the bay, see Figure 4-4 where the numbers indicate the most important components of the design. With this rotation the breakwater alignment is such that it protects the marina against wave attack. Given the natural slope of 1:6 on the sides, the marina is located as much as possible towards Isla Martín García to reduce the length of the breakwater, fixed jetty and walkway. Also the dredged area is partially located within the wetlands so nature is somehow affected by these activities. Behind the breakwater two floating jetties are located to moor the small and medium boats, see paragraph 4.4.

A fixed jetty, with a length of 130 m, is attached to the breakwater on which the ferries and large boats moor (see Figure 4-5). The breakwater, which is 20 m longer than the fixed jetty, consists of H-profiles with sheet piles in between, see paragraph 4.5. The finger closest to the tip of the breakwater can hold two ferry boats. Passengers from the ferries walk towards the island over the fixed jetty with a view over the wetlands between Isla Martín García and Isla Timoteo Domínguez. The height of the fixed jetty along the breakwater is +3.0 m RL. To reduce the difference between the boat deck and the jetties the fingers have a height of +2.5 m RL. For more details on the fixed jetty see paragraph 4.5.2.

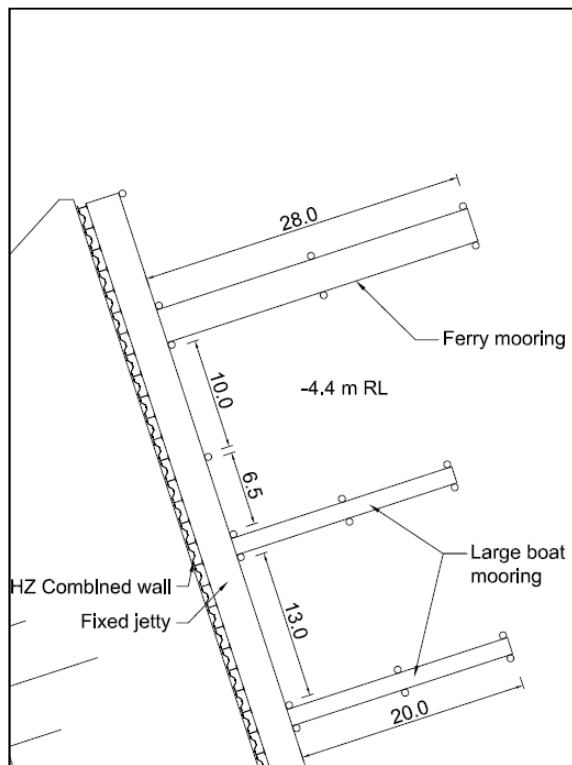


Figure 4-5: Multifunctional breakwater
(Appendix T - No. 14)

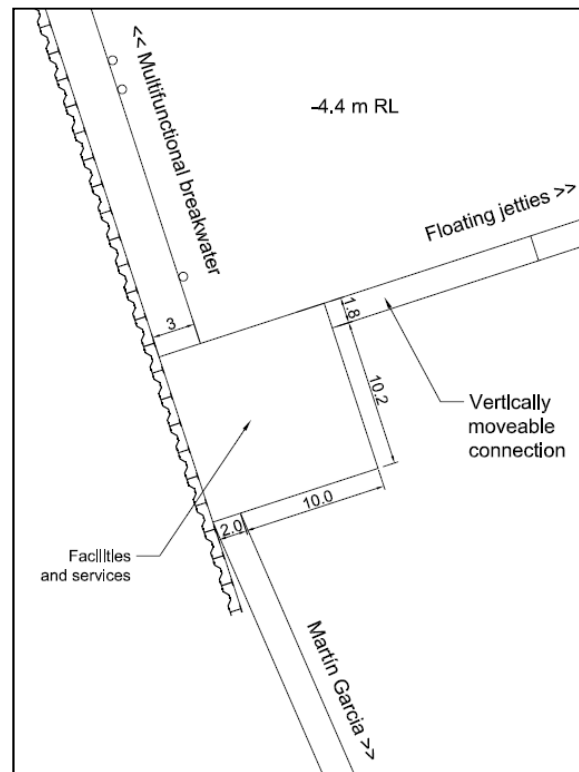


Figure 4-6: Entrance marina
(Appendix T - No. 15)

The facility platform is the centre of the marina, see paragraph 4.7. From there the floating jetties, fixed jetties and Isla Martín García are accessible. Within the facility platform: a tourist shop, sanitary facilities and an office for the Prefectura are included, see Figure 4-6. The floating jetties are reached by a vertically moveable connection, so the floating jetties are accessible with the most common water levels.

4.3. Dredging activities

In the preliminary designs the approach channel was assumed in a set alignment and not further investigated. For the final design several options of the alignment are considered and these are elaborated in Appendix K; Dredging Activities. In this paragraph only the final design of the waterway is treated, which is very similar to the layout during the preliminary stage. Nevertheless it should be stated that the appendix contains an alternative that is better from a technical point of view. However there are too many uncertainties in this alternative, that it only could be elaborated with more investigations.

The bottom level of the approach channel and marina are located at respectively -3.8 m RL and -4.4 m RL. The depth of the approach channel consists of the design draft of the design boat (3.41 m) and the expected sedimentation during two years (1.0 m). This depth is constructed from the MLWL (mean low water level), which is at +0.41 m RL.

The depth of the marina consists of the following dimensions; draft of the design boat (2.5 m) and expected sedimentation during three years (0.6 m). This depth is constructed from the DLWL (design low water level), which is at -1.26 m RL. So the final depth is at -4.4 m RL.

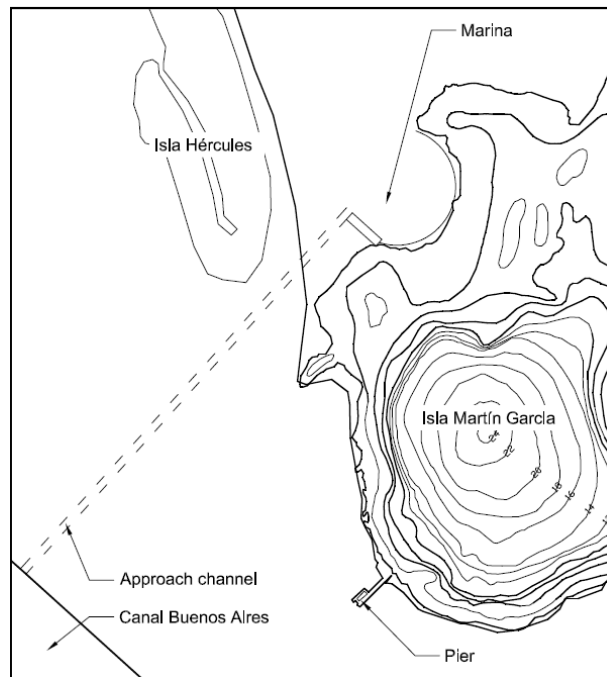


Figure 4-7: Alignment approach channel

(Appendix T - No. 21)

Every part of the waterway requires maintenance, for the approach channel this is performed every year. Although the design is made for two maintenance years, the uncertainties in the sedimentation process are significant. It is advised to dredge once a year, certainly during the first years after construction. For the marina less sedimentation is expected and maintenance is performed once every three years.

Finally the alignment of the approach channel is determined, see Figure 4-7. The reason behind this elaboration can be found in Appendix K; Dredging activities. In total an amount of 480,000 m³ of dredged material needs to be removed; 250,000 m³ from the approach channel and 230,000 m³ from the marina.

4.4. Floating jetty

As stated before, floating jetties are used; these consist of two main parts. First, a steel frame covered with wooden boards to make the walkway of the jetty and fingers. This is done in line with the large jetty and the walkway connecting the breakwater with the marina. Second, the pontoons are made of plastic (such as polyethylene) filled with a hard polymer foam (such as expanded polystyrene) to prevent leaks from having a severe effect. Paragraph 4.4.1 discusses the considerations used to design the main elements, followed by the calculations of the stability of an element. After this, the complete design of the main elements, fingers, foundation and final design is shown in paragraph 4.4.3 till 4.4.6.

4.4.1. Considerations main element

The jetty has several boundaries to be considered. At first; the freeboard in the maximum loaded stage is taken at a minimum of 0.20 m. The freeboard in case of only the deadweight as a working force, must have difference with the freeboard in case of a fully loaded situation that is as small as possible. Using Archimedes' principle, the necessary pontoon height and pontoon length are calculated. The pontoons are made of plastic, which has a durable character, and polymer foam. Although pontoons can be often made of concrete, it can become troublesome when moving them from the prefabrication site to the building site due to their large weight.

4.4.2. Stability main element

When the previous statements are considered, there are two different stability checks to be made. First there is the caisson stability (Molenaar, 2008), where the height of the centre of rotation of the caisson has to be above the centre of gravity (h_m should be positive).

Another part of the stability is when one half of the jetty is loaded, and the second half is not. The jetty starts to rotate under the applied live load, until a balance in buoyancy forces and weight is regained. The minimum freeboard allowed on the submerged side is 50 mm; the opposite chine should remain in the water (Nichol and White, 1997).

Eventually the size of one (out of four) pontoon is 1,800 mm wide, 1,600 mm long and 850 mm high. This gives an angle of 17.75 degrees in case of loading on one side and fulfils the one side loaded requirement. The maximum freeboard is 0.61 m, the freeboard difference is 0.43 m and h_m is 0.23 m. With bolts sticking out of the pontoon, a connection to the steel framework is made possible. For more precise calculations, see Appendix L; Design floating jetties.

4.4.3. Design main element

On the jetty, there are three locations where a boat can attach the lines to. There are two piles where a boulder is near and one close to the connection of the fingers to the main jetty. These forces are to be distributed from the boulder to the pile in the water, which can be distributed through normal forces, see Figure 4-8.

With a maximum span of 0.90 m, due to a third 13 m long IPE80 girder in the middle of the element, the wooden boards on top of the structure are the exact same height and width as the boards on the bridge connecting the mainland and the marina, which makes them 1,800 mm x 100 mm x 30 mm. In order to connect the fingers and the pile rollers (to connect the piles to the jetty) on different locations of an element, a wooden beam of 100x100 mm² is attached to the 13 m long UNP180.

4.4.4. Design fingers

The fingers are different from the jetty in several points. The length of the larger finger is 14 m, the width 1.2 m. With a live load of 1.25 kN/m^2 , a dead load of 1.0 kN/m^2 and two pontoons for every finger. The length of the smaller finger is 8 m, the width 0.9 m and two pontoons for every finger. The values for the freeboard should be the same for both types of fingers.

Eventually the size of one pontoon of the small fingers is 900 mm wide, 1,240 mm long and 970 mm high. The pontoon of the medium finger is 1,200 mm wide, 2,180 mm long and 970 mm high. With bolts sticking out of the pontoon, a connection to the framework is made possible. The stability is secured through a fixed connection (in the horizontal plane) with the main elements. The framework uses the same profiles as the main element, however, the core to core distances of the cross girders are 2.0 m.

4.4.5. Foundation of the floating jetties

The piles are designed according to two boats being moored on one pile and pulling with the maximum mooring force on the highest possible point in any direction. For the calculations is referred to Appendix J; Geotechnical stability. The diameter of the two piles is 610 mm and 406 mm, the thickness is 12.1 mm and 8.8 mm for the large jetty and small jetty respectively.

4.4.6. Final design

There are three different sections of the jetty, the longer jetty, where the medium sized boats moor, the smaller jetty for small boats and the section to connect those two to the coast. All of these can be constructed out of multiple segments of 13 m, where the longer jetty consists of eleven segments. The small jetty is made of eight segments and the section between these two jetties of four segments. These can be connected with two or three simple hinges capable of transferring 20 kN of normal force.

The fingers are connected to the impact beam of a main element, which can be screwed or bolted on at the worksite, making it easy to construct in-situ. The pile rollers that are attached to the end of the finger and the main element have the same connection. This is made on the impact beam of the fingers and main element. In Figure 4-8 an impression is given of a finger connected to a main element and a pile. Technical drawings can be found in Appendix L; Design floating jetties.

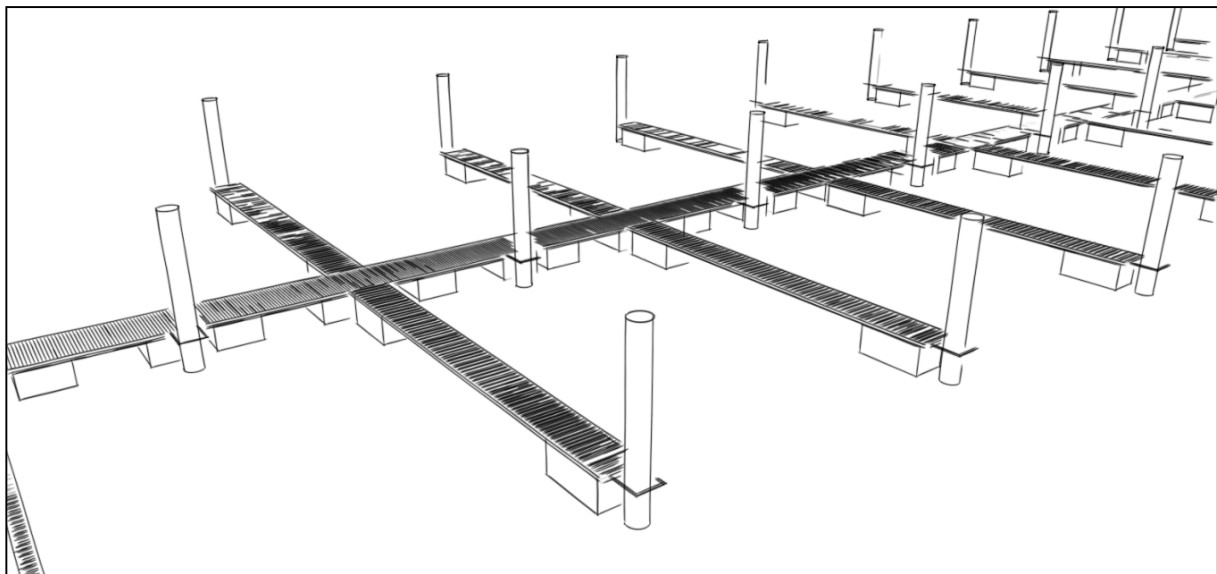


Figure 4-8: Impression floating jetties

4.5. Multifunctional breakwater

The designed breakwater structure consists of three parts. First the breakwater, in this case a combined wall, is elaborated in paragraph 4.5.1. The second part is the fixed structure just behind the wall, this jetty is build to reach the fingers where large boats and ferries moor. This structure is elaborated and shown in paragraph 4.5.2. In the final and third paragraph the fingers, which provides the mooring options for large boats and ferries, are elaborated. These fingers are elaborated and illustrated in paragraph 4.5.3. An overview of the entire breakwater structure can be found in Appendix M; Design breakwater.

4.5.1. Design combined wall

The main reason designing a combined wall and not a gravity structure, made of concrete or rubble, is the soil condition. The large amounts of clay under the structure make it extremely challenging to base a gravity structure without a large quantity of soil improvements. Soil improvements are more expensive and therefore a structure on a pile foundation is chosen. Nevertheless, there are still multiple types of combined wall systems; with as most convenient ones the tubular combined wall and the HZ combined wall. The deliberation between these two types is mostly based on the cost of both elements, but also the construction possibilities in relation to the fixed jetty are taken into account. Finally the decision is made in favour of the HZ combined wall, with a total length of 150 m.

To determine the dimensions of the different elements of the wall, undrained calculations are performed using Msheet. This program can calculate a safety factor of a specific combined wall type, given all parameters of the soil and loads on structure. The details about the entered soil parameters can be found in Appendix J; Geotechnical stability, specific water levels are determined in Appendix I; Design conditions breakwater and the specific loads on the structure are elaborated in Appendix M; Design breakwater.

Based on the stability factor calculated by the program, the final dimensions of the structure are found by the deflection at the top. This deflection appears to be governing, because it cannot be very significant with the fixed jetty connected to the structure. The jetty should still be functional after the displacement of the combined wall. The corresponding dimensions of all the elements can be found in Appendix L; Design floating jetties. The stability factor found for this structure has a value of 6.34 and the deflection during design conditions is 65.0 mm. These numbers are safe and therefore convenient for this type of breakwater structure.

4.5.2. Design fixed jetty

The fixed jetty, with a length of 130 m, is located behind the breakwater at +3.0 m RL which corresponds to a probably of flooding once in 25 years. In this case, flooding does not result in a collapse or failure of the structure. The deck of the jetty is supported by the mooring piles which have a diameter of 0.61 m and extend to +4.25 m RL. A minimum freeboard of 0.35 m (Schwarzenegger, 2005) is added to the DHWL to determine this height. The deck of the jetty is constructed of planks of 0.06 m thick and 0.20 m wide and is placed on three steel beams which are made of a HEA280 profiles. Finally steel beams are placed on a girder which is connected to the mooring piles and made of a HEA180 profile. The structure is checked on the maximum occurring stress and deflection. Calculations to determine the safety of this structure are elaborated in Appendix M; Design breakwater and Appendix O; Design fixed jetty. All units in the jetty fulfil the requirements. The only remark is made on the beams of the jetty; they need to have a chamber of 74 mm to fulfil the deflection requirement. In Figure 4-9 and Figure 4-10 the details of the structure are visible.

4.5.3. Design fingers

In order to get owners and passengers off their boats, the fingers extend from the fixed jetty. Ferries and large boats are moored at the fingers which are attached to the fixed jetty. This means two types of fingers are used. Fingers for the ferries are 3.0 m wide and 28.0 m long. An intermediate support is created because of the long span. By using this intermediate support the same situation is created as for the fixed jetty. The same elements as for the jetty are therefore used for the fingers of the ferries, a girder of a HEA180 and a HEA280 beam with a chamber of 38 mm and planks with a thickness of 60 mm. The deck of the fingers is fixed to the three mooring piles. Ferries need three mooring piles in design conditions and are placed next to the fingers; all piles have a diameter of 0.61 m. The deck of all fingers is located on +2.5 m RL. In this way there is a small height difference between the fixed jetty and the fingers, so getting on and off is still possible. Fingers are flooded about once every year. From the fingers, stairs go down to increase accessibility during low water levels.

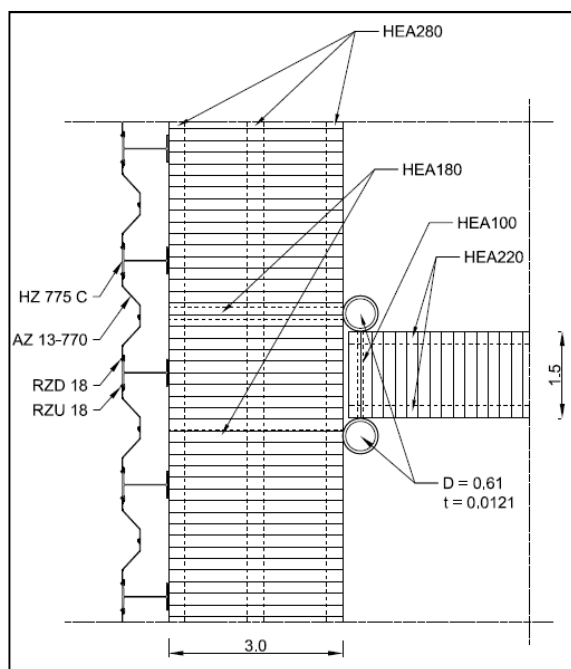


Figure 4-9: Top view multifunctional breakwater
(Appendix T - No. 34)

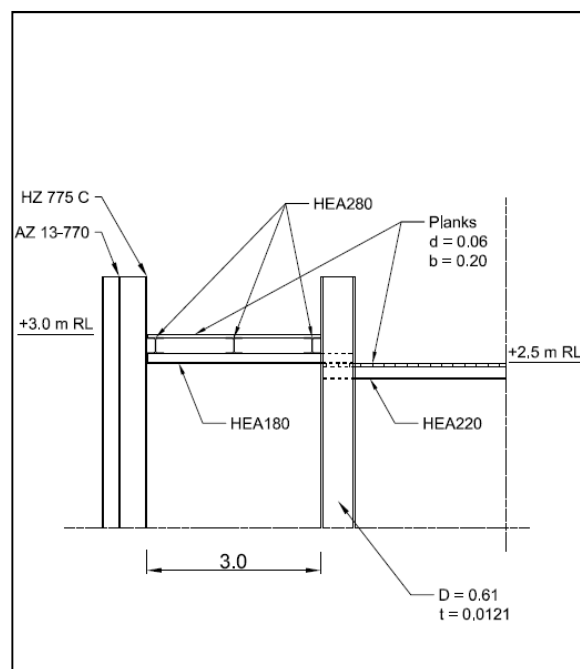


Figure 4-10: Side view multifunctional breakwater
(Appendix T - No. 35)

Fingers for the large boats are 1.5 m wide 20.0 m long, see Figure 4-9. This span is also too long and an intermediate support is created. Supporting piles do not have to resist the total mooring force; a pile with a diameter of 0.40 m is therefore used. Between the two piles a HEA100 profile is used so the forces from the boats are not transferred by the planks but by the steel profile. Like all other planks of this structure, the planks of these fingers are 0.06 m thick. Beams of the fingers need to have a chamber of 9.0 mm to fulfil the deflection criterion. All other elements do not need adaptations to meet the requirements, calculations are shown in Appendix L; Design floating jetties.

4.6. Walkway

A walkway connects the marina with the main land of Isla Martín García via the Chinese Village. This connection is made out of wood; the main dimensions are given in paragraph 4.6.1. Part of the structure is a detail of a connection within the structure; this is displayed in paragraph 4.6.2. All the calculations of this structure are elaborated in Appendix N; Design walkway.

4.6.1. Final design walkway

The marina should be accessible during storm conditions; therefore a connection between the marina and the mainland of the island is constructed at a height of +3.0 m RL. All the floating and fixed jetties are connected to the facility platform. Starting at this facility platform the walkway leads towards the Chinese Village on the mainland of Isla Martín García. The village is also situated at +3.0 m RL and from there on the elevation of the island is only increasing. In order to integrate the walkway in the surrounding area, it is made out of wood and also build on a pile foundation.

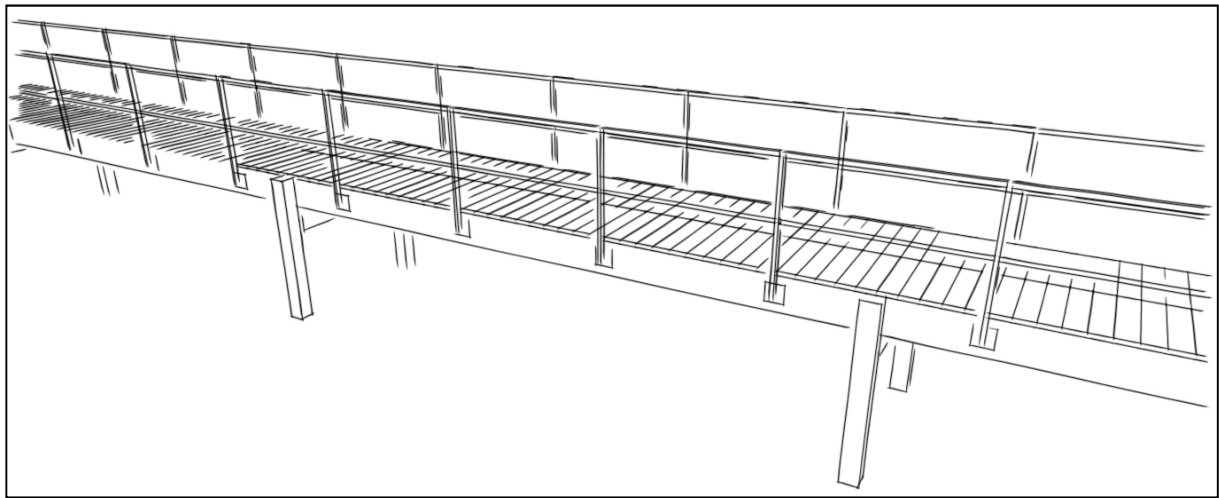


Figure 4-11: Final dimensions walkway

Different elements, and the accompanying dimensions of the walkway, are designed according to the Eurocode 5 (Normcommissie 351 001, 2008). Before the dimensions are calculated, the width of the walkway is needed; this is assumed to be 2.0 m. Secondly, the length of the walkway is approximately 240 m and third, one must find a value for the representative strength, found via the type of wood. Tropical hardwood from Brazil is one of the easier wood types to find and use. For instance: *Angelim vermelho* or *Dinizia excelsa* can be imported and used as construction material (Centrum hout, 2007). This wood type is has been tested for the strength, classifying it as a D50 type, given by the Dutch research institute TNO (TNO, 2005).

The walkway of the construction is formed by planks. These planks are supported by three girders and a crossbeam supporting these girders. All four of them are also made out of D50 tropical hardwood. The beams run over a length of 8.0 m, resulting in having 30 times three girders over the full length with a cross-sectional area of $0.4 \times 0.1 \text{ m}^2$. The crossbeam runs between the two piles and thus has a length of 2.0 m and the same cross-sectional area as a girder. This beam is supported by two wooden piles with a cross-sectional area of $0.2 \times 0.2 \text{ m}^2$ and they are penetrated in the soil until -7.0 m RL. This means they are mainly in the Playa Honda Formation, final dimensions of the walkway are shown in Figure 4-11.

4.6.2. Connection walkway

For the connection of the pile to the crossbeams joist hangers are used, which are checked on the two different connections: pile to joist hanger and crossbeam to joist hanger. An impression of the connection is shown in Figure 4-12.

Only one type of dowel is used, although with different lengths. The connection of the pile and the joist hanger uses dowels that are 11 mm in diameter and have a length in the pile of 50 mm. Connecting the beam to the joist hanger uses four dowels as well, yet these go all the way through. The exact elaboration and calculation of this connection is in Appendix N; Design walkway.

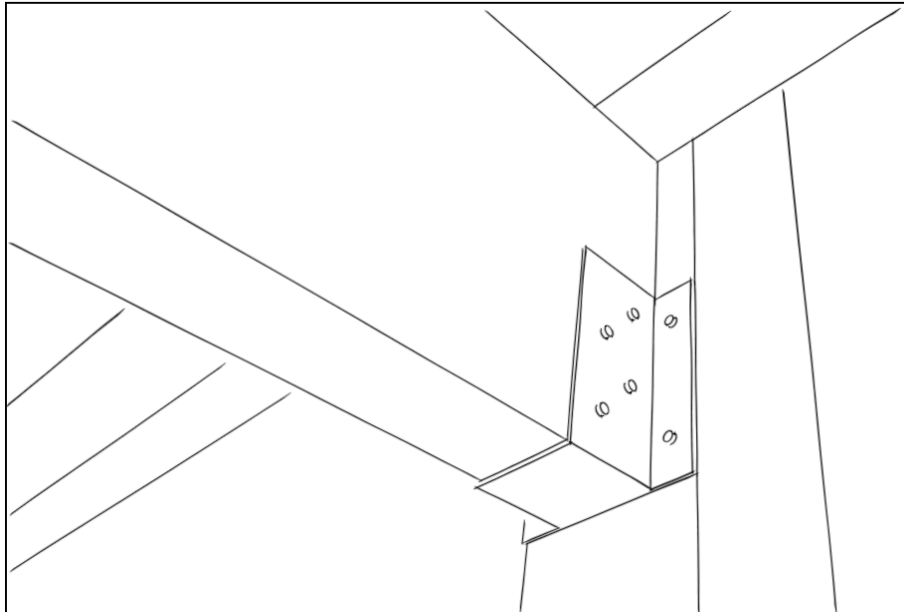


Figure 4-12: Impression of the connection

4.7. Facilities and services

Each marina requires some common facilities and services. In this case some sanitary facilities are needed, including toilets, showers and sinks. Also a small shop is required; not only for snacks, beverages and tourist items, but also to buy tickets for the ferry. Finally a small office for the Prefectura is located inside the marina, for safety and support. These facilities are located in the southwest corner of the marina as can be seen in the layout, paragraph 4.2. This layout is based on the fact that from the Prefectura office must be able to see the entire marina and a part of the approach channel, see Figure 4-13. The shop is placed east of the office, so it is also visible from a large section of the marina. The restrooms are on the south side and can hardly be seen from the marina, but are subtly indicated by a sign on the building.

The floor of the building is located at a height of +3.0 m RL; this means the building is flooded ones every 25 years with a maximum of about 1.0 m. The bottom level of +3.0 m RL is reached by building the structure on piles. In total 16 piles are used as foundation, with a centre to centre of 2.5 m, calculations are presented in Appendix M; Design breakwater.

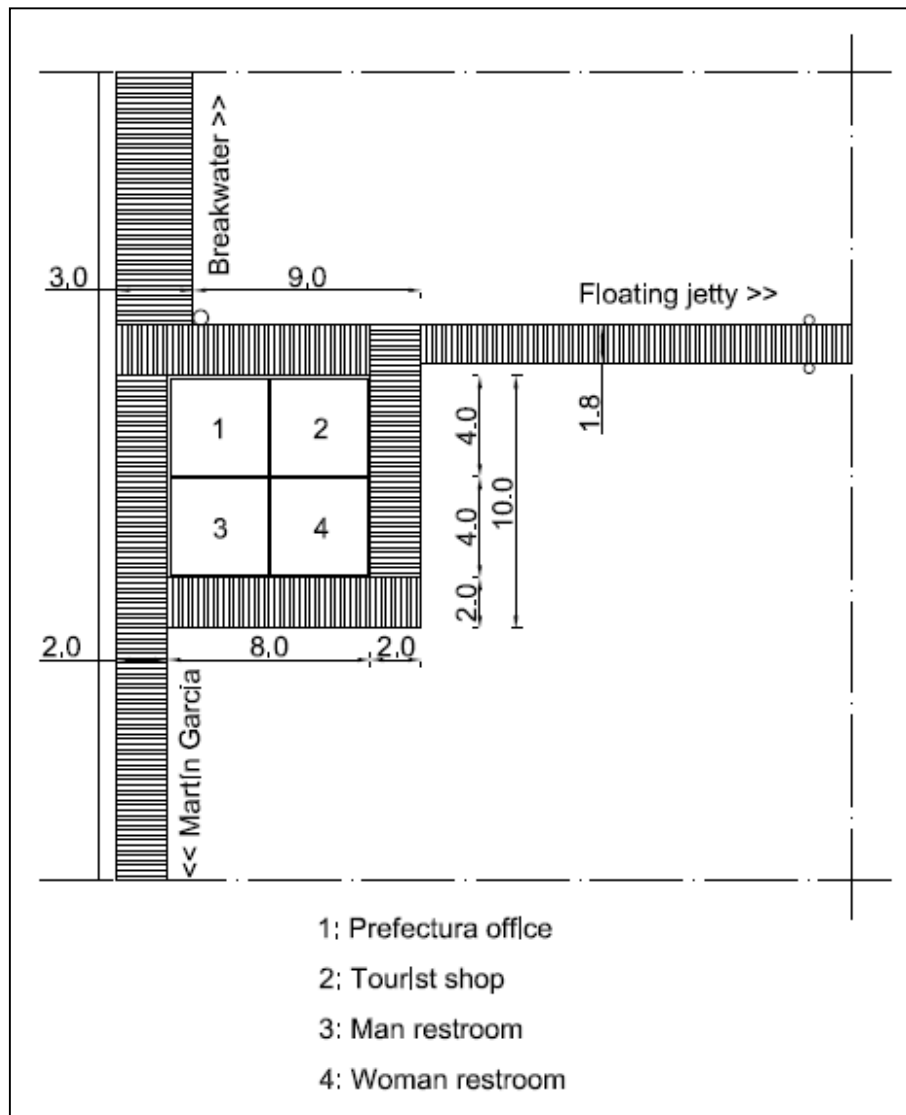


Figure 4-13: Facilities and services platform (Appendix T - No. 37)

4.8. Verification Resucitar Puerto Viejo

After the design is fully elaborated, it is again evaluated via a multi criteria analysis to check on the improvements. Improvements are mainly made on the layout and position of the marina see Table 4-1, resulting in higher scores (S) for the breakwater and jetty length. Weight factors (Wf) stay the same as stated in the MCA in paragraph 3.6.

Table 4-1: Results verification

	S	Wf	S*Wf
1. Dredging area	4	0.07	0.29
2. Length breakwater	9	0.21	1.89
3. Hindrance building stage	8	0.04	0.29
4. Impact surroundings	6	0.14	0.86
5. Internal manoeuvrability	7	0.25	1.75
6. Jetty length	8	0.18	1.43
7. Maintenance	7	0.11	0.77
			7.27

Length of the breakwater is reduced because the marina is protected against waves from the west to northeast directions by the wetlands and Isla Hércules, which is described in Appendix M; Design breakwater. The layout is more efficient because the marina is rotated into the bay, in this way the marina is better protected and the jetties are shorter.

In the detailed design, the design is considerably improved as is shown in Table 4-1, the length of the breakwater is the most important factor in this. It is not likely that these large improvements can be performed to the other designs because these cannot be closer to the island because of the existing rock layer. Taking probable optimizations of the other designs in account, final scores probably do not differ much. This makes elaboration of Resucitar Puerto Viejo not as inconvenient as presumed after the preliminary design.

5. Building methods and time schedule

The building method and planning are important for the practical aspect of this design. It elaborates what equipment is necessary and how the equipment and materials are transported to the construction site. Full elaboration of the building methods and time schedule are given in Appendix P; Building method and Appendix Q; Time schedule. In paragraph 5.1 the building methods of different aspects within the design are given, paragraph 5.2 contains the corresponding time schedule.

5.1. Building methods

This paragraph explains the manner in which all different parts are constructed and how construction takes place. In paragraph 5.1.1 the dredging activities are discussed, paragraph 5.1.2 explains all the manners of transportation and finally the construction of the marina is treated in paragraph 5.1.3.

5.1.1. Dredging activities

For the dredging activities the so called DOP-pump is used, see Figure 5-1. This is attached to an A-frame, excavator or crane and placed on a pontoon. The dredged material is pumped into a barge which lies in the vicinity of the DOP-pump, after loading the barge can be transported to the dumpsite.



Figure 5-1: DOP-pump (Damen Dredging, 2011)

First the approach channel from the Canal Buenos Aires to the marina is dredged; this activity takes a total of four weeks, as described in Appendix K; Dredging activities. Next the area around the breakwater is dredged, so the fabrication of this main element can start as soon as possible. Duration for dredging of this area is about two week. However, as a lower limit in the planning two weeks are taken into account. The last two and a half weeks are required for the dredging of the remaining area inside the marina. A period of eight and a half weeks is expected to finish all the dredging activities.

5.1.2. Transportation

As discussed in Appendix P; Building methods, transportation takes place in three phases. First the elements necessary for constructing the walkway are transported over water and via the island. This is about 43 tonnes and includes construction equipment; the total amount is about 50 tonnes. For this transportation a small barge is necessary and since the material is transported onto the island it is not necessary to keep the barge at the island.

Transportation phase two includes materials for the breakwater, the fixed jetty, foundation piles for facilities and services and a part of the mooring piles. The elements transported in the second transport: king piles HZ 775-C, sheet piles AZ 13-770, small piles fixed jetty, large piles fixed jetty, the elements for constructing the fixed jetty and piles necessary for the service and facility platform. Altogether this is about 807 tonnes. This weight does not include equipment necessary for construction which is about ten percent of the weight. The total weight to be transported is about 900 tonnes. An average sized barge (1500 tonnes) suffices this load and even a smaller barge can be used.

The third transport contains: construction material, small piles floating jetty, large piles floating jetty and the floating jetty elements. Altogether this is about 300 tonnes and including ten per cent construction equipment the total transported load is about 350 tonnes. Both transport two and three are performed using averaged sized barges, these barges are used as temporary storage, so the materials do not have to go via the island.

5.1.3. Marina

Breakwater

The breakwater is installed using a crane mounted on a pontoon, this crane carries a diesel hammer which is used to hammer the sheet piles and king piles into the soil (Arcelor, 2011). On the mainland of Argentina, the king piles and sheet piles are produced and transported to Isla Martín García using a flat bottom barge. This barge is also used as temporary storage facility.

One of the main uncertainties is the level of the rock basement. If the rock horizon is higher than the required penetration depth of the king piles they can be secured by dowelling the king piles into the underlying rock. Since the rock basement consist of partly metamorphosed rock this could be very difficult. The solution to this is to use pre-drilling in order to penetrate the king pile into the rock basement.

Mooring piles

There are two types of mooring piles are installed; one with a diameter of 0.61 m and the other with a diameter of 0.41 m. The crane used for installing the breakwater is also used for installing the mooring piles. A proper design requires each pile to be driven to or near design penetration, without damage. Lifting eyes are used to facilitate the handling of the pile since pile handling tools are sensitive to maintenance. The driving of each pile should not be interrupted. Interruption could cause extra driving resistance and a workable back-up hammer should always be available.

A hydraulic hammer is more efficient than steam hammers because the weight of hydraulic hammers is situated on the pile. For steam hammers the weight of the cage is generally held by the crane, which is less efficient. Both systems can be used below and above water level. Hammer performance cannot be judged visually when using a hydraulic hammer, so it is important that measurements are taken. The working environment that is encountered, is not ideal for measuring: impact velocity, stroke, pressure of accelerating medium and blow rate. Working in wet circumstances and with an Argentinean contractor can be difficult and could prevent reliable instrumentation, for these reasons the use of a steam hammer is chosen.

Floating jetty

The floating jetty consists of three parts. The main jetty is built of elements of 13 m long and in total there are 26 of these elements. There are two different types of fingers. One type is 8 m long and the other is 14 m long, there are with 22 pieces of each type. These elements consist of a floating structure made of polystyrene, a steel framework and a wooden deck. Construction and assembly takes place on the mainland of Argentina.

All the elements are transported from mainland of Argentina to Isla Martín García using a barge. Here these elements are temporarily stored on the barge with which they are transported. Later on, the elements are transported from the storage area to the location where they are installed by a MultiCat, see Figure 5-2.



Figure 5-2: MultiCat (Damen Dredging, 2011)

Fixed jetty

The fixed jetty consists of elements with a length of 14.5 m. These elements are assembled on the mainland of Argentina and transported to Isla Martín García. To finish the jetty the wooden planks are installed in-situ.

All the elements are transported from the mainland of Argentina to the storage area near Isla Martín García. Here these elements are unloaded and stored adjacent to the storage area located at the jetty, for further processing. It is a disadvantage that there is relatively much transportation necessary between the storage area and the marina, the advantage is that the elements are safely stored close to the construction area. This storage location is used until there is enough storage area in the marina, the breakwater is finished and a part of the mooring piles is installed.

5.2. Time schedule

The time schedule is subdivided into four phases, elaborated in Appendix Q; Time Schedule. Each phase is one major event in the entire construction period. This is for example; construction of the breakwater, installation of mooring piles or installation of floating jetties. These phases cause the construction equipment to shift to another location and each phase is subdivided into different sections with certain durations. The time it would take to finish a section is estimated and multiplied by a probability of delay. This probability of delay can be 10%, 20% or 30% dependent on the factors that could cause a delay. The outcome of this is visible in Table 5-1 till Table 5-4, concerning working weeks of five days.

These outcomes result in a time schedule, visible in Figure 5-3. An imaginary project start is set on 2 January 2012. The handover date is set on 11 April 2012. This means a construction time of about three months. Argentina contractors are perhaps not familiar with this construction method, so the construction time is expected to be 6 months, based on opinions of local experts. Construction of the different elements (floating jetty and parts fixed jetty) have not been taken into account, because it is prefabricated (in advance) by different contractors and stored on the mainland of Argentina.

Table 5-1: Time schedule phase 1

Phase 1	First transportation	0.2 weeks
	Transportation construction material	0.2 weeks
	Constructing the walkway	7.5 weeks
	Dredging the approach channel	4.0 weeks
	Dredging area breakwater	2.0 weeks

Table 5-2: Time schedule phase 2

Phase 2	Dredging for installing piles floating jetty	2.5 weeks
	Second transportation	0.2 weeks
	Installing breakwater	4.0 weeks

Table 5-3: Time schedule phase 3

Phase 3	Installing piles facilities and services platform	1.0 weeks
	Installing tubular piles fixed jetty	2.0 weeks
	Constructing fixed jetty	5.0 weeks

Table 5-4: Time schedule phase 4

Phase 4	Third transportation	0.2 weeks
	Installing tubular piles floating jetty	2.0 weeks
	Installing floating jetty	2.0 weeks

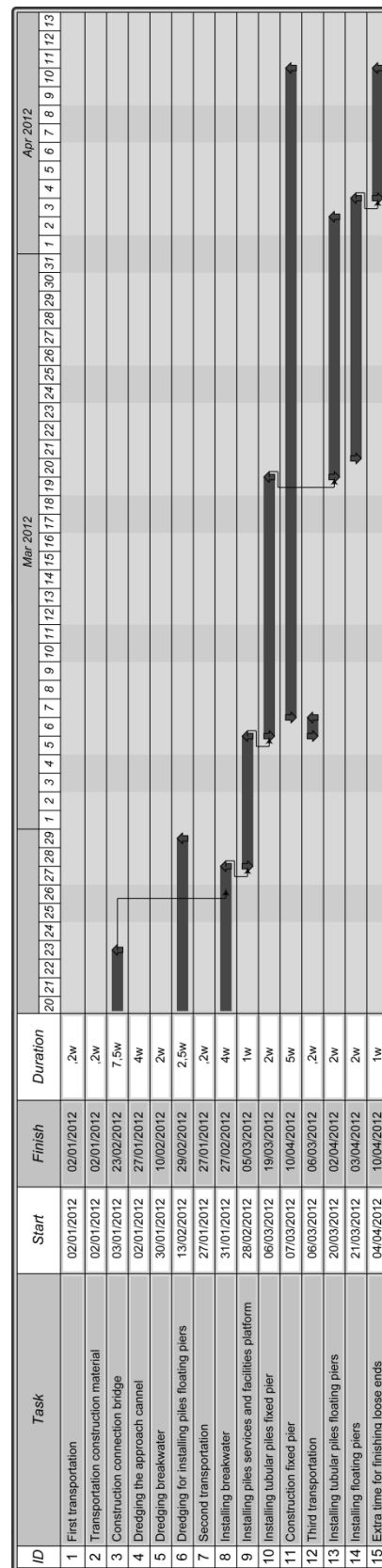
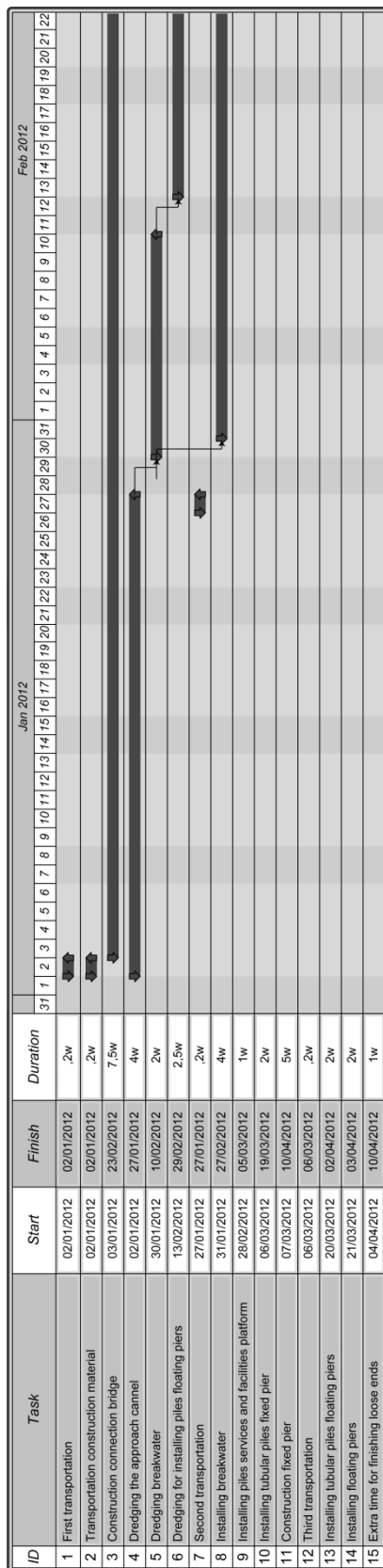


Figure 5-3: Time schedule of all phases

6. Project finance

In paragraph 6.1 the total structural costs and project costs are given. Besides initial costs, maintenance costs are important over the lifetime of the marina. Paragraph 6.2 the yearly revenues are presented due to exploitation of the marina. Finally, paragraph 6.3 presents the internal rate of return when the government decides to fully invest the initial cost and the investment plan recommended in order to keep the expenses low.

6.1. Costs

In order to make a reliable cost benefit calculation it is necessary to define costs per unit or product. Since less is available about unit prices in Argentina, reference values from experienced people are used. Besides product costs, the entire project costs contains other indirect expenses such as general costs, risk, profit and taxes. These percentages are also based on reference values (Schwerdtfeger, 2011, pers. comm., 28 November).

There are three different types of maintenance costs. Yearly dredging maintenance is calculated in Appendix K; Dredging activities. Yearly structural maintenance is assumed to be 0.05% of the total structural costs per year for the years 5 to 20, 0.1% for the years 20-50 and 0.25% for the years 50-100.

The structural cost of the project is 13.8 million dollars and when other project expenses such as risk, financial cost and taxes are included, the project cost turns out to be 22.9 million dollars. An overview of the complete calculation is given in Appendix R; Project finance.

6.2. Revenues

Besides maintenance, yearly direct revenues are taken into account. Direct revenues are revenues that are directly related to the investment. The positive aspects like increase in over-all value, increase in employment and increase in income for existing restaurants and shops are not taken into account. Besides those indirect revenues, increase in value is also not taken into account. Revenues of different elements are based on practical experience and reference values (Iramont, 2011, pers. comm., 28 November).

When using the initial project cost, a yearly net income and a discount ratio, the net present value and internal rate of return are calculated. There are two main resources of income. The first resource is the moorings spots and the second is the offered facilities. Revenues because of mooring spots are calculated using an occupation of 50%. Besides the costs for the mooring spots, the ferry company has to pay 5% of a passengers ticket. This is a small investment knowing this marina increases in demand. In total the yearly revenue is 0.62 million dollars.

6.3. Internal rate of return

The concept of the internal rate of return (IRR) is explained in paragraph 6.3.1. The IRR is used in order to determine the financial impact of the project. Next the IRR is calculated when the project is financed by a total governmental investment, this is done in paragraph 6.3.2. Finally the investment plan is presented in paragraph 6.3.3.

6.3.1. Concept

Internal rate of return (IRR) is discounted rate of return based on the condition that net present value for an investment is zero within a specific period. Normally the IRR is compared to a company's discount rate of return to decide if the investment is profitable or not (rational decision making). This project is not a company investment but a governmental investment. More benefits play an important role in deciding whether or not this project is profitable (political decision making). Benefits such as increase in labour, increase in value for Isla Martín García, increase in value for pleasure boat owners and increase in status are important for the decision making process. The investing governmental organisation should decide whether the ratio between costs and gained value/benefits is positive or not. The net present values (NPV) is calculated with different nominal discount rates (the rate of return that could be earned on an investment in the financial markets with similar risk) and over a total lifetime of 100 years. A lifetime of 100 years seems long but this concerns mainly the fixed and permanent constructions. It is possible that the floating jetties need to be renewed after a certain amount of time. By that time, an independent cost evaluation is made to examine the investment. Costs concerning renewal of constructions are not taken into account. The nominal discount rate for which the NPV is zero equals the IRR. A real discount rate can be approximated by subtracting expected inflation from the nominal discount rate and takes into account probable inflation.

6.3.2. Total governmental investment

The IRR of 1.77% is calculated over the lifetime of 100 years. It is graphically explained in Figure 6-1. In this figure the NPV for different nominal discount ratios are plotted against the associated nominal discount ratios. The discount ratio belonging to a NPV over the lifetime of 100 years is the IRR.

An IRR of 1.77% is extremely low. When the government would rationally choose between this investment and a bank deposit, a bank deposit is chosen because of higher interest rates. As mentioned before, this is of provincial state interest and a profitable investment is just one part of the entire decision making process. Since indirect benefits play a role in the government's decision, the profitability of an investment is not governing in the decision making process.

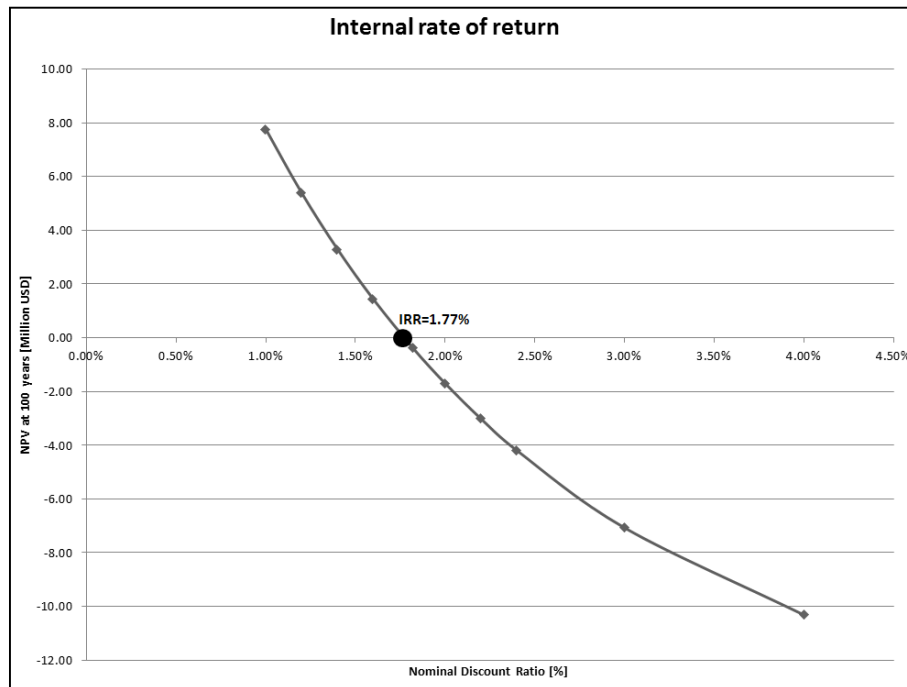


Figure 6-1: NPV versus nominal discount ratio and IRR

6.3.3. Investment plan

In paragraph 6.3.2 the assumption is made that the entire investment is done by the government and that maintenance costs and revenues are also regulated by the government. To reduce initial cost for the government an investment plan is constructed.

In order to receive an IRR of 7% over 35 years the external investor needs to make an initial investment of 6.5 million dollars taking into account an interest rate of 5% on the total invested amount. It is optional to change this initial payment to a rent over a certain amount of years. An IRR of 7% is equal to a nominal discount ratio of 7% and an inflation ratio of 5% is taken into account such that the nominal discount ratio equals 2%. Over the entire lifetime of the investment the IRR equals 7.71% (Figure 6-2). The total project cost minus the governmental investment equals the total investment of the investor, an amount 16.4 million dollars remains to be invested by the government.

Although the government still loses money, this financial structure has many advantages. For the government it is much easier to leave the entire operation of the marina to an external investor. The initial investment is reduced by 6.5 million dollars. The IRR of the government investment increases since the investment of 6.5 million dollars from the external investment can be seen as a profit the first year. This is only relevant when the assumption is made that the marina is built, and the increase in IRR depends on the IRR of the 6.5 million dollars that can be invested further by the government. So assuming the government pursues with the construction, involving a secondary investor is more profitable.

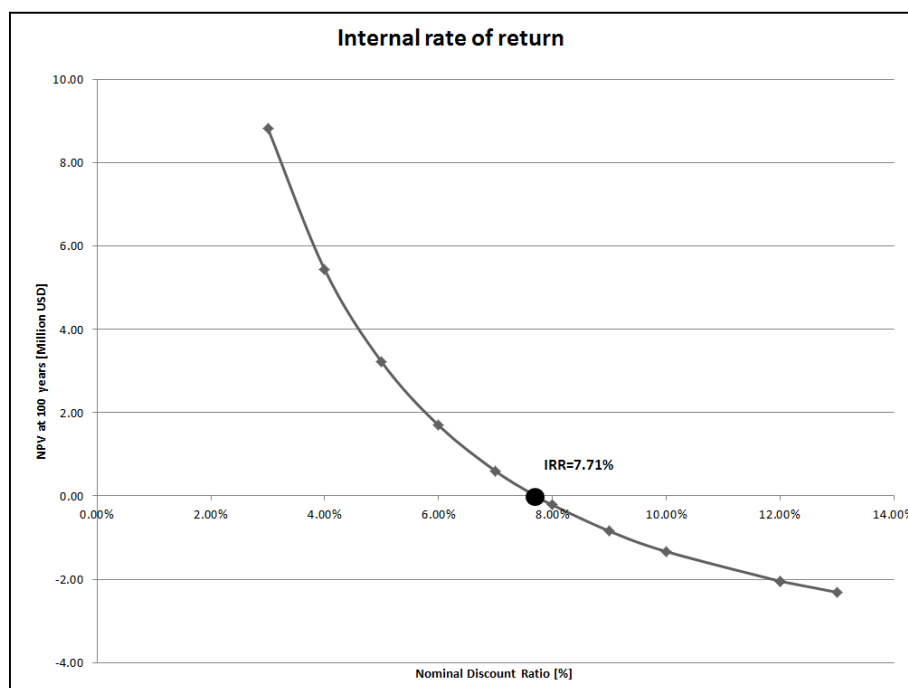


Figure 6-2: NPV versus nominal discount ratio and IRR (life time), investment plan

7. Environmental impact

Isla Martín García has a variety of rich flora and fauna, environmental impact should therefore be minimized. To analyse the environmental impact the Eco-cost value rate (Vogtländer and Mestre, 2009) is calculated. The concept is explained in paragraph 7.1, the Eco-costs are calculated in paragraph 7.2 and in paragraph 7.3 the value of the marina is determined. In final paragraph the Eco-costs value rate and the conclusions are elaborated.

7.1. Eco-cost value rate concept

These days environmental impact becomes more and more important, because of strict environmental regulations, environmental burden of products and services need to be low. For project feasibility, this has to be combined with creation higher product value, described by the World Council for Sustainable Development in November 1993 (WBCSD, 1995):

"The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity, throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity."

To meet this statement, a balance has to be found between the burden on people, the burden on the planet and the profit. The ratio between the burden on the planet and profit is expressed in the Eco-cost value rate (EVR), see Figure 7-1. The EVR is a life cycle analysis (LCA) based tool which has been developed to assess the eco efficiency of the products and expresses the environmental impact form 'cradle to grave'.

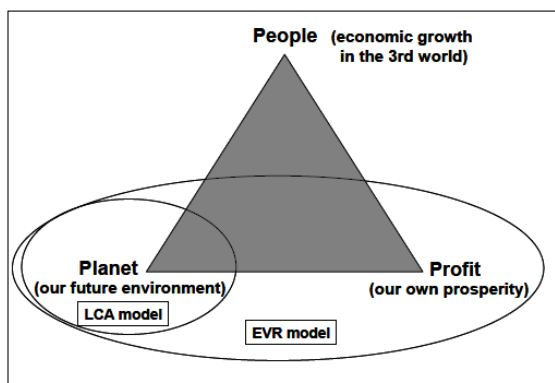


Figure 7-1: EVR in relation to the 3P-model
(Vogtländer and Mestre, 2009)

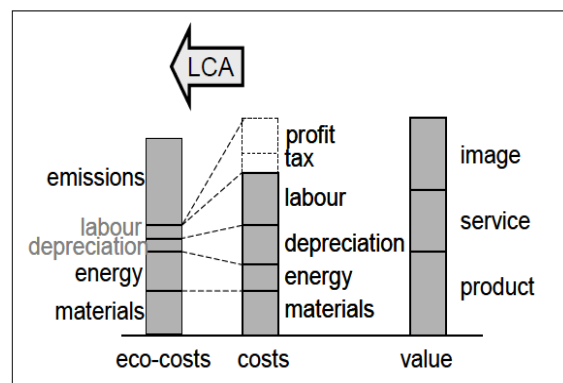


Figure 7-2: Transformation costs to Eco-costs and value
(Vogtländer and Mestre, 2009)

The Eco-costs are expressed in monetary units; the calculation is therefore transparent and easily understood. As stated:

"Eco-costs are the costs which should be made to reduce the environmental pollution and materials depletion in our economy to a level which is in line with the carrying capacity of our earth. As such, the Eco-costs are virtual costs, since they are not yet integrated in the real life costs of current production chains (life cycle costs). According to Vogtländer et al., Eco-costs should be regarded as hidden obligations"

(Vogtländer and Mestre, 2009)

A LCA is used to transform costs to Eco-costs, see Figure 7-2. It is clearly visible that aspects with high environmental impact, like energy, increase when transformed from costs to Eco-costs and aspects with low environmental impact, like profit and labour, decrease after the transformation.

All the costs in the EVR-concept are expressed in perceived customer value. The marina design has three value dimensions: the value of a product, the value of the provided services and the social value of a product (expressed in image). Perceived customer value, also called the 'fair price', is the price the customer is prepared to pay for a product. It is the usage and pleasure expected after the purchase.

When Eco-costs and values are known, the EVR is calculated. The Eco-costs value ratio has a much wider background than just dividing the Eco-costs by the value. This ratio is an indicator for a sustainable society. The EVR is an E/E indicator, which means that it is an indicator to describe the Eco-efficiency of a product and/or service. And is a dimensionless number which indicates to what extent a product contributes to the de-linking of economy and ecology, which has to be accomplished to preserve nature and stimulate economy.

7.2. Determination Eco-costs

As mentioned, the Eco-costs of the marina are virtual costs to reduce the environmental impact and material depletion in the economy to a level which is in line with the carrying capacity of the planet. The Eco-costs are calculated using reference values (Vogtländer and Mestre, 2009; Vögtlander, 2011) and the main costs are shown in Table 7-1. The calculation of the Eco-costs is shown in Appendix S; Environmental impact. The total Eco-costs of the marina are approximately 1.46 million dollars.

Table 7-1: Total Eco-costs

	Costs [USD]
Total Eco-costs material	780,000
Total Eco-costs building process	220,000
Lifetime Eco-costs maintenance	460,000
Total Eco-costs	1,460,000

7.3. Value determination

A market conform assumption is made for the value of the marina design. This value normally is a bit higher than the price (a buyer's market), but might also be a bit lower than the price (a seller's market).

Most of the time, full marina capacity is not used and it is unlikely that the marina on Isla Martín García is used as a permanent mooring spot. On the other hand is the marina, for regular visitors, the only access to the island. Therefore a neutral (fair price) market is assumed for the designed marina. This results in a value which is equal to the price of the marina, the fair price.

When full potential of Isla Martín García is used and all touristic attractions are developed, the marina can become a buyer's market. The value of Isla Martín García is increased by tourism development, mooring spots become more popular and the buyer's market is created. This is positive for the value of the marina.

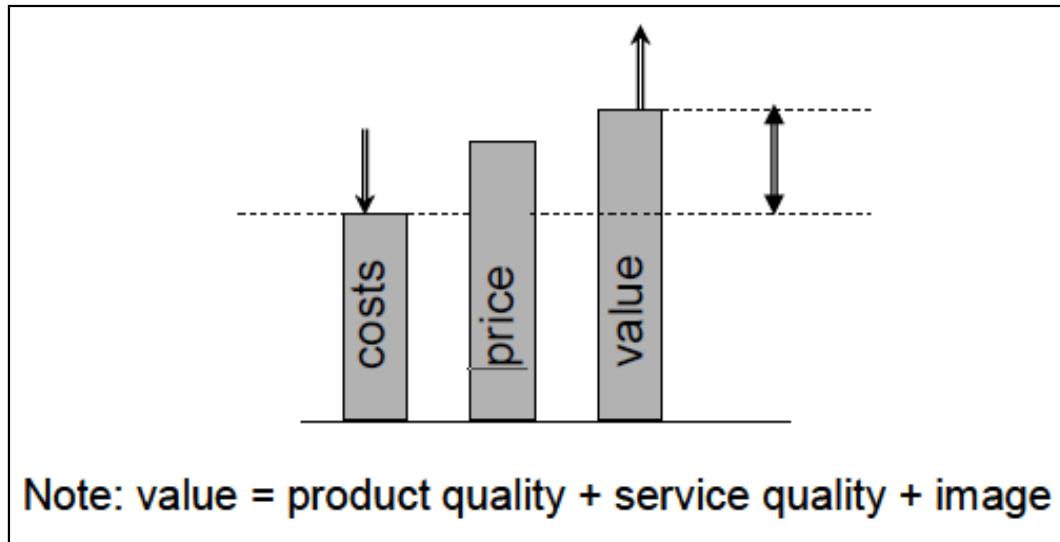


Figure 7-3: Product value (Vogtländer and Mestre, 2009)

Founded on the conditions of Isla Martín García a neutral market is most probable; the value is equal to the market price. This assumption is realistic when the marina is profitable, otherwise the price does not correspond to the market price. In case of Isla Martín García the marina is not profitable. It is therefore assumed that the value is equal to part of the costs that is paid by an external investor. The external investor has to pay 6.5 million dollars. The value of the marina is therefore 6.5 million dollars. Costs in relation to price and value of the marina are shown in Figure 7-3.

7.4. Conclusions

The determination of the ratio is the final step in the EVR process. This ratio is composed of two elements, the Eco-costs and the value. Eco-costs divided by value results in a ratio of 0.28.

Averaged reference values of infrastructural projects are compared to the EVR (Vogtländer and Mestre, 2009; Vögtlander, 2011), resulting in an average Eco-costs value rate of infrastructural projects of 0.5.

The EVR of Resucitar Puerto Viejo is 0.28 meaning that, in comparison to similar infrastructural projects, the EVR is low. This design has low environmental pollution and material depletion in relation to the carrying capacity of the earth.

8. Tourism plan

The development of a marina on Isla Martín García can stimulate tourism and therefore create investment opportunities for the island. This mechanism also works the other way around. When tourism is not stimulated the marina is not used and does not create investment opportunities for Isla Martín García. Therefore a tourism plan is an important aspect of the marina design.

An important aspect to take into account when you are introducing tourism activities is the carrying capacity. The World Tourism Organisation defines this aspect as:

“The maximum number of people that may visit a tourist destination at the same time, without causing destruction of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic, socio-cultural, environmental and an unacceptable decrease in the quality of visitors’ satisfaction”.

The different kinds of carrying capacities which are described in this definition can be defined in the following way:

Physical:	the maximum number of people that area is actually able to support
Economic:	the extent to which a tourist destination is able to accommodate tourist functions without the loss of local activities
Socio-cultural:	relates to the negative socio-cultural related to tourism development
Biophysical:	the extent to which the natural environment is able to tolerate interference from tourists

These aspects are reflected on the different tourist attractions, which are described in the following paragraph. These are not only new ideas, but also improvements or restorations of old buildings on the island. An overview of all the locations of the different tourist attractions are shown in Figure 8-1.

The marina is constructed in ecological valuable wetlands. This area does not only include beautiful flora, but the area also contains a wide variety in fauna. There are many different kinds of birds that nestle in the area, including herons. The wetlands can be observed from the breakwater of the marina, because of its elevation. This function as a look-out to have an overview of the wetland with indigenous flora and fauna can even be increased more. Therefore an observation tower is build at the end of the breakwater. This is not the only location where an observation tower is build. The design also includes a tower at the north side of Isla Martín García, this can be seen in Figure 8-1 At the moment there already is a tower at that location, but this one is demolished and rebuild to increase the capacity. Also the walkway towards this tower should be renewed and the trees and bushes around it are trimmed.

If these ideas are reflected to the carrying capacity, especially the physical factor is of importance. Many of the tourist are transported from mainland to Isla Martín García by ferry thus the arriving amount of tourist is not equally divided over the day, but clustered to small timeframes. The capacity of a watchtower is not that large, so if one assumes a personal area of 1.0 m^2 per tourist and the top of the watchtower has an area of $3 \times 3 \text{ m}^2$; no more than nine people can be at the top. Of course much more people come off the ferry at one moment, thus the Prefectura should supervise the tower when a ferry is unloading. An idea to increase the capacity of the tower is building two ladders to enter the tower, one to go up and one to go down. The other aspects of the carrying capacity do not have a large influence for this attraction.

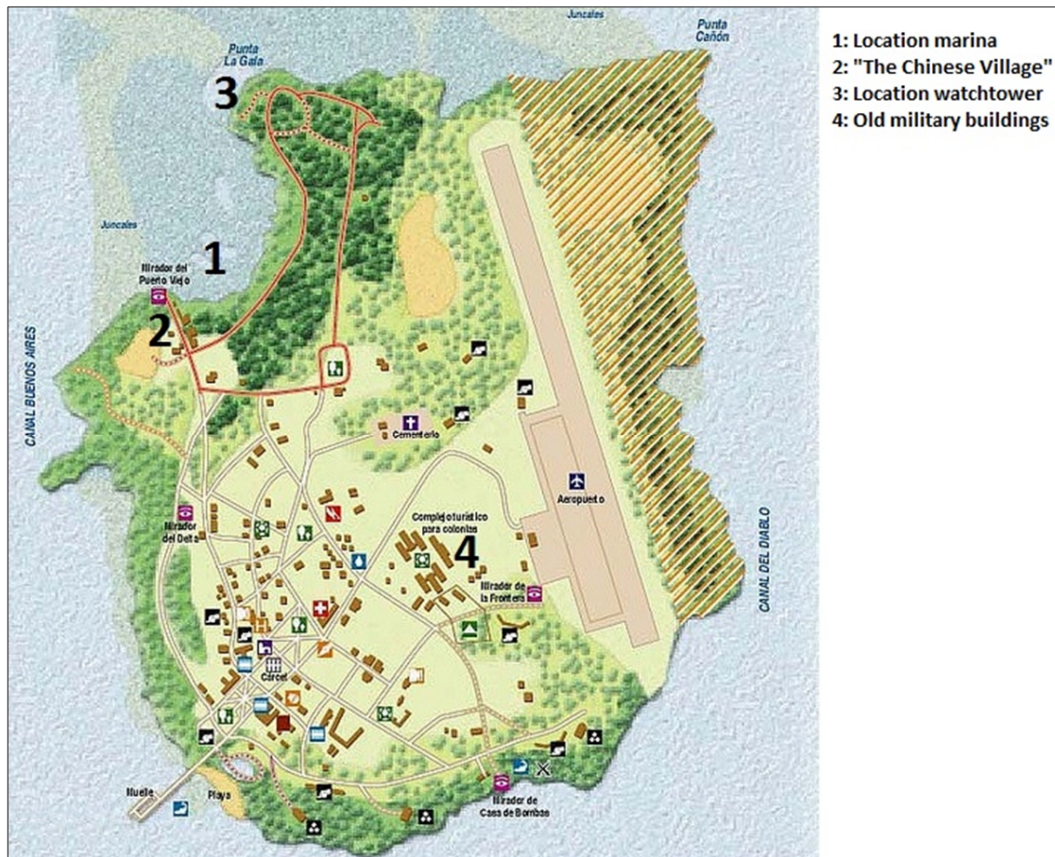


Figure 8-1: Tourism map of Isla Martín García (Dirección Provincial de Islas, 2011)

The water in Río Hércules is most of the time relatively calm. This makes the water ideal for aquatics, e.g. canoes, pedolas, kayaks and other small not motorized boats. In this way visitors can see the beauty of this unaffected, undisturbed and bio diverse natural area. Therefore a rental station is constructed east of the facilities and services building, on the outside of the marina and the floating jetty. The rented vessels can then go around the outside of the marina, through the less deep areas, towards Río Hércules, the wetlands and Isla Timoteo Domínguez.

This rental station influences the biophysical aspect of the carrying capacity. When people paddle through the wetlands, it is most likely the wetlands suffer under these activities. Paddles, boats and rudders can touch the flora on the bottom, but also an increase of garbage can end up on the bottom of the wetlands. It is important to monitor these effects, to keep the flora and fauna in their current conditions. Minimising the impact on carrying capacity can be achieved by setting out tracks for people that rent a vessel. Three types of tracks can be made with different difficulties and each has its own characteristics. By guiding people through pre-installed tracks the impact on carrying capacity is concentrated on these paths. Using bottom protection and regular maintenance the effect on the environment, induced by aquatic activities, can be concentrated to the pre-installed paths only. Also people who would like to rent a vessel should be pointed to codes of conduct. These codes of conduct should include regulations to prevent the reader from interfering with the environment. Regulations should educate the reader such that they understand that their activities influence the bio diversity. The renter should stay within the pre-installed paths. He should not pick any flowers or plants and should never harass wildlife. They should stay in their boat on behalf of their safety, others safety and the natural resources.

About 500 m from the marina an old village is situated, some of the buildings were used by the navy. During that time bamboo was imported into the area. Bamboo was used as construction material and for gardening. Since bamboo is not being used anymore there is an abundance of it in the old village. This is the main reason for changing the name into Chinese Village. All the buildings are abandoned a long time ago and thus dilapidated over time. After renovating these buildings they are changed into a restaurant, a shop and some other facilities. Also the playground in the village is renovated.

The carrying capacity of this activity most likely influences the economic and socio-cultural aspect. There is a chance the tourists stay or only use the facilities at the Chinese Village. This might affect the amount of tourists that are visiting the actual centre of Martín García, which is not only a social problem but also financial. A way to deal with this problem is also increase the attraction of the centre. This can be highlighted by placing signs at the Chinese Village towards the actual centre of Martín García with several interesting points on it. The best way to develop both locations is to increase the attract ability of the locations to the same level. For tourism it should not be an easy choice where to go to and they should even consider visiting both locations. By spreading the visitors over two locations the carrying capacity of the two locations should not be exceeded.

At last, in this design the history of the island is used as a touristic attraction. The island has a history in creating traditional sweet bread called 'Pan Dulce' and a military basis was located on the island. Showing the traditional way of making these cakes gives visitors a new insight in an authentic cooking process. The renovation of some old military buildings and weaponry give an amazing insight in the history of Isla Martín García. Local guides are used to guide visitors over the island. This way the visit is not only a touristic trip but it should also be educative. Local guides are used and although they know a lot about the island they should get some extra education. In time this could be an extra income to the island. Overall, these activities probably have no effect on any aspect of the carrying capacity.

9. Conclusion

Isla Martín García is a rock outcrop in the Río de la Plata which is a protected area because of its biodiversity and natural beauty. It is possible to visit the island by airplane, but it is usually accessed by boat. The poorly maintained pier is therefore the most commonly used entrance to Isla Martín García for visitors. Because of insufficient capacity, a marina is desired. The island has a historic military base, tradition in making cakes and holds a protected natural area. These tourist attractions are further developed and give an economic impulse to the island, together with the marina.

The colonial port area, which is completely sedimented in the past decades, provides a safe environment for a marina. This location is preferred over a marina at the pier because of the protective function of the island and the historic value of this location. After the necessary dredging activities of the approach channel towards the building site are completed, a marina is constructed. This marina holds 46 mooring spots for small boats, 46 moorings spots for medium boats, 10 mooring spots for large boats and 2 moorings spots for ferries. The small and medium boats moor at floating jetties, which are constructed out of pontoons, steel frames and wooden planks. These elements are designed in such a way a minimum freeboard of 0.2 m is always maintained. The large boats and ferries moor at fixed jetties. The fixed jetty is attached to the breakwater which protects the marina against waves induced by storms from the southwest. The breakwater is constructed as a HZ combined wall and on the backside of this wall a steel construction is build to serve as walkway towards the mooring spots and ferries. These jetties, but also the floating jetties, merge together at a facilities and services platform. From this platform a wooden walkway continues towards the mainland of Isla Martín García.

All these segments of the marina are placed in such a way the dredging activities in the area are minimized; this reduces the maintenance costs needed to keep the bottom at the preferred level. Another aspect that is taken into account during design is the environmental impact. This research showed that the environmental impact of the marina is relatively low. The same line is continued in the tourism plan for the island, which results in a few innovative but also environmental friendly options, for example a boat rental and a guided tour by locals along the historical important sites of the island.

The marina does not turn out to profitable what was imaginable on beforehand. Other benefits than costs play an important role in deciding whether or not this project is worth the investment (political decision making). Benefits such as increase in labour, increase in value for Isla Martín García, increase in value for pleasure boat owners and increase in status are important for the decision making process. When the initial project cost of 22.9 million dollars is invested by the government the internal rate of return is 1.77%. That is why it is recommended to cooperate with an external investor on basis of an investment (6.5 million dollars) of which the discount rate over 35 years equals 7% and increases the IRR of the governmental investment (16.4 million dollars). Although the government still loses money, this financial structure has many advantages. For the government it is much easier to leave the entire operation of the marina to an external investor. Besides that, the remaining 6.5 million dollars can be deposited on the bank or invested in other projects. When the full potential of Isla Martín García is used and all tourist attractions are developed, the marina becomes a beautiful location for pleasure craft owners.

10. Discussion

This report contains several assumed design aspects. The assumptions are mainly done because of a lack of information. In this chapter the main assumptions are discussed.

In the analysis, several assumptions are done regarding the soil profile and soil characteristics. A fully undrained analysis is performed for the geotechnical stability. Since drained soil parameters were not available this analysis is not executed. Drained behaviour of the soil also plays an important role in the stability calculations because it affects the long term stability of the structures. Besides the used analysis, the values of several parameters should be reconsidered. The permeability and OCR (over consolidation ratio) value might be too low in this situation. Besides that, the available parameters do not contain the secondary consolidation coefficient which is estimated. Great uncertainty about the results of the settlement calculations exists because of the variance in these parameters. The permeability values are probably on the low end and result in a situation which is more stable. A conservative design for the breakwater, the combined wall, is made because of these uncertainties. For additional research, soil investigations are strongly recommended. Extensive in-situ and laboratory research provides more reliable soil parameters and insight in the inhomogeneity of the soil. If the uncertainties are reduced by these investigations, a gravity structure might be possible.

Besides soil characteristics, sedimentation processes are very complex phenomena. Little is known about the sedimentation processes around Isla Martín García. Predictions on sedimentation around Isla Martín García and in the approach channel are therefore complicated and have high uncertainties. Based on local experience of dredging companies, yearly sedimentation of the approach channel is assumed to be 25% of the originally dredged volume. Maintenance costs increase drastically if this value is higher than assumed, which leads to a project which is not feasible. Additional investigations on sediment transport and expected maintenance of the approach channel are therefore strongly recommended.

The marina is protected against waves from the south western direction by a breakwater. Waves coming from the west have the possibility to enter the marina, because Isla Hércules is located west of the marina, it is assumed that waves reduce to a level in which they do not damage the boats. Additional investigation on the correlation between extreme water levels and extreme wind conditions is recommended because of the uncertainty about this assumption. In this way the necessity of an extra breakwater can be excluded.

Several facilities are already present in the marina, for instance: a Prefectura office, a tourist shop and the restrooms. However there are also some facilities absent, especially for the boats inside the marina, for instance: water provision, a gas or oil station, wastewater treatment installation, boatlift, fire control installations and medical assistance. These facilities are common in marinas and it should be investigated how these can be implemented in the design. This requires an extensive research into environmental regulations, cost benefit analysis and specialised regulations.

The breakwater is constructed as a combined wall system with HZ king piles and sheet piles. The possibility of concrete slabs instead of sheet piles between the king piles should be investigated. As the costs of concrete are lower than the costs of steel in Argentina, this might be a more profitable solution for the breakwater. Also the costs of tubular instead of H-profile piles should be investigated. As a first assumption the tubular piles are expected more expensive, because of the larger steel quantities. This might change if the construction costs of tubular piles turn out to be cheaper than H-profiles. Therefore additional research into the costs is preferred.

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List of figures and tables

Figure 2-1: Classification of the Río de la Plata (Wikimedia, 2011).....	2
Figure 2-2: Overview project area.....	3
Figure 2-3: Río de la Plata Interior (Google Maps, 2011).....	5
Figure 2-4: Isla Martín García (Iramont, 2011).....	6
Figure 2-5: Location analysis of Isla Martín García (Google Maps, 2011).....	7
Figure 2-6: Sedimentation at Isla Martín García (aerial photographs)	8
Figure 2-7: Cross sections Río Hércules (Appendix T - No. 7).....	10
Figure 2-8: Development Isla Hércules	11
Figure 3-1: Locations of the alternatives (Google Maps, 2011)	15
Figure 3-2: Design of marina Muelle (Appendix T - No. 9).....	17
Figure 3-3: Design of marina Hércules (Appendix T - No. 10)	18
Figure 3-4: Design Resucitar Puerto Viejo (Appendix T - No. 11).....	19
Figure 4-1: Soil profile Puerto Viejo	21
Figure 4-2: Overview soil profile propagation.....	21
Figure 4-3: Location of the design.....	22
Figure 4-4: Components within the design	22
Figure 4-5: Multifunctional breakwater	23
Figure 4-6: Entrance marina	23
Figure 4-7: Alignment approach channel	24
Figure 4-8: Impression floating jetties	26
Figure 4-9: Top view multifunctional breakwater.....	28
Figure 4-10: Side view multifunctional breakwater.....	28
Figure 4-11: Final dimensions walkway.....	29
Figure 4-12: Impression of the connection	30
Figure 4-13: Facilities and services platform (Appendix T - No. 37).....	31
Figure 5-1: DOP-pump (Damen Dredging, 2011)	33
Figure 5-2: MultiCat (Damen Dredging, 2011)	35
Figure 5-3: Time schedule of all phases	37
Figure 6-1: NPV versus nominal discount ratio and IRR.....	40
Figure 6-2: NPV versus nominal discount ratio and IRR (life time), investment plan	41
Figure 7-1: EVR in relation to the 3P-model.....	42
Figure 7-2: Transformation costs to Eco-costs and value	42
Figure 7-3: Product value (Vogtländer and Mestre, 2009)	44
Figure 8-1: Tourism map of Isla Martín García (Dirécción Provincial de Islas, 2011).....	46
Table 2-1: Design wind velocities.....	12
Table 2-2: Design wave conditions.....	13
Table 3-1: Possible mooring systems	16
Table 3-2: Summary reference projects.....	16
Table 3-3: Scores multi criteria analysis	20
Table 4-1: Results verification	32
Table 5-1: Time schedule phase 1	36
Table 5-2: Time schedule phase 2	36
Table 5-3: Time schedule phase 3	36
Table 5-4: Time schedule phase 4	36
Table 7-1: Total Eco-costs.....	43

Glossary of terms and abbreviations

A-frame	triangular frame for stability, shaped like the capital letter 'A'
Atalaya formation	very soft, very impermeable clay layer which is located between -6.0 and -16.0 m RL
Bed load	transport of bed material, sediment, rolling and sliding along the bottom
CARP	Comisión Administradora del Río de la Plata, supervising institute of the Río de la Plata
Chine	angle in the hull of a boat or pontoon
Depositional gradient	gradient of the suspended load which sediments
Discount rate	an interest rate used to bring a series of future cash flows to their present value in order to state them in current, or today's, dollars, use of a discount rate removes the time value of money from future cash flows
DOP-pump	submersible dredging pump which is suited for small dredging work and maintenance
DHWL	design high water level
DLWL	design low water level
E/E-indicator	indicator which describes the eco-efficiency of a product or service
Eco-costs	the virtual costs applied to the amount of environmental burden of a product
EVR	Eco-costs value rate
Flocculation	formation of large sediment parts because small parts stick together
Freeboard	height of a floating element above the water level
HEA	type of H-profile, shaped like the capital letter 'H'
HZ wall	combined wall made of H-profiles and Z-shaped sheet piles
IPE	type of I-profile, shaped like the capital letter 'I'
IRR	the internal rate of return (IRR) is a rate of return used in capital budgeting to measure and compare the profitability of investments
King piles	large H-profiles which form the basis for sheet pile walls
LCA	life cycle analysis
LIMB	Uruguayan reference level which is composed to the low water levels
MCA	multi criteria analysis
MHWL	mean high water level

MLWL	mean low water level
Msheet	calculation program for the deflection of soil retaining walls
MultiCat	MultiCat work boats are versatile, multiple purpose and shallow draft vessels
NPV	a sophisticated capital budgeting technique; found by subtracting a project's initial investment from the present value of the cash inflows discounted at a rate equal to the firm's cost of capita
OCR	over consolidation ratio
Pampero	western wind which causes water level lowering in the Río de la Plata
Playa Honda formation	soft clay layer, is located at the surface till -6.0 m RL
Puelchen formation	stiff sand layer, is located at -16.0 m RL till the rock layer
RL	Cero del Riachuelo, a reference level in Argentina
Sedimentation	deposition of sediment particles carries by a fluid, under the influence of gravity
Sudestada	southeastern wind which causes water level set up in the Río de la Plata
Suspended load	sediment that is brought in the flow in suspension and transported without touching the bottom
UNP	type of U-Profile, shaped like the capital letter 'U'