Building with Nature

Creating awareness on Building with Nature in Chile

Multidisciplinary project

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by

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Preface

As part of our master program we decided to go abroad for a multidisciplinary project of 8 weeks. At the start of October we had the first meeting and soon after this the group was officially formed. There were multiple projects available in various countries, but looking at the groups potentials concerning the composition of masters, Coastal processes and Construction Management & Engineering and interests in innovative solutions the current project was a perfect fit. The project was suggested by Jan van Overeem, our supervisor and associate professor and lecturer Coastal Engineering at the Delft University of Technology. At a conference of "Ports of the Future" in Valparaíso Jan van Overeem met Mauricio Reyes Gallardo, our supervisor at the Universidad de Valparaíso, who was very enthusiastic about the Building with Nature philosophy and wanted to introduce this philosophy in Chile as it could be the solution for current coastal problems in the country.

His wish to introduce the Building with Nature philosophy in Chile formed the baseline for our project. We believe that, to introduce this philosophy, people must first be aware of the issues in the current water sector and know about the alternatives. This study has been conducted to show the current organisation of the Chilean water sector, the possibilities of Building with Nature and our findings about the potential of introducing this philosophy fitted in the Chilean culture.

We would like to thank our professor at the TU Delft, Jan van Overeem, for giving us the possibilities for getting a deeper understanding in the Building with Nature concept, for the introduction to a fascinating subject and project and for giving direction to the report where needed, but also for giving the freedom to decide otherwise. We also like to thank Marian Bosch-Rekveldt for her guidance and input throughout the project. We want to thank Patricio Winckler for the many lectures, contacts and information about the Chilean coastline processes and projects. Furthermore, we would like to thank everyone that helped us throughout the project by showing their view and providing us with the information we needed. Finally, our special thanks goes to our Chilean supervisor at the Universidad de Valparaíso, Mauricio Reyes Gallardo. We would like to thank him for the opportunity to come and study here in Valparaíso, his enthusiasm and involvement in the project, the site visits, tours and the arrangement of many of the meetings with stakeholders and above all the amazing time and experience we had in Chile.

Valparaíso, April 2019

Abstract

Growth of world population, sea level rise, land subsidence and climate change gives new challenges for the present and the future. A new innovative approach of engineers is needed to reach socio-economic development with care for the environment. In the Netherlands, an EcoShape consortium is initiated where multiple experts came together from the Dutch private and public sector. In this consortium governmental organisations, knowledge institutes and business companies are involved to search for adaptable and sustainable engineering solutions to exploit and promote the 'Building with Nature' program. The main goal is to move from building *in* nature towards building *with* nature, using the natural forces present in the system.

Chile has shown interested in the Dutch Building with Nature program and the question raised whether a similar concept could be introduced in the country. Therefore, the organisational structure of the Chilean water sector related to coastal engineering is investigated in this research, as well as several case studies are used to illustrate the potential of Building with Nature in Chilean projects. These projects are the coastal erosion in Pichilemu, a port expansion in San Antonio and coastal erosion in Los Vilos.

The Chilean coast shows in different aspects a very dynamic behavior. For the design of a coastal structure it is important to understand this dynamic behavior and the possible consequences. In addition, the study concluded that Chile is a very privatized country which is important to consider when applying Building with Nature into coastal projects. The privatization has the consequence that a substantial amount of stakeholders need to be involved in the projects also funding can be a challenge.

In general, the conclusion can be drawn that there is lack of information on the coastal characteristics in Chile. More data needs to be conducted to implement trustworthy Building with Nature designs. Additionally, one could state that there is a communication gap between the governmental parties as the Dirección de Obras Portuarias and Ministerio de Obras Públicas and the local parties involved in coastal projects. This is important to solve, as these parties needs to be involved in all coastal projects. Another outcome of the case studies is the absence of an environmental vision for most of the initiated coastal projects investigated and the absence of a long term vision of coastal management.

Meeting with various engineering consultancy firms showed the presence of a strong incentive to enlarge the consciousness on the environmental and societal aspects in Chile, and the ambition for a more co-creative and multidisciplinary design approach. Arcadis Chile has shown interest to establish a platform to introduce the Building with Nature approach in Chile. Together with the Universidad de Valparaíso, Arcadis Chile can be the initiator for the implementation of the philosophy and the increase of awareness among other important actors in the water sector.

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Introduction

In the present and future, new challenges are faced associated with a growth of world population, sea level rise, land subsidence and climate change. These challenges ask for an innovative technical approach of engineers to reach socio-economic development with care for the environment. In the Dutch private and public sector, multiple experts came together in the form of the Ecoshape consortium and initiated the 'Building with Nature' program. In this consortium governmental organisations, knowledge institutes and business companies are involved to search for adaptable and sustainable engineering solutions. The main goal is to move from building *in* nature towards building *with* nature, using the natural forces present in the system.

At this moment the Chilean economy is growing rapidly (Trading economy, 2019), cities are expanding and new infrastructure is needed. However, current projects are over budget or even fail in early stages. Therefore Chile has shown interested in the Dutch Building with Nature program and the question raised whether a similar concept could be introduced in Chile.

A project team from the Delft University of Technology has analysed the Chilean water sector related to coastal engineering and suggests recommendations on how to create awareness for a Building with Nature program in Chile. This topic is addressed in an eight-week multidisciplinary project in March and April 2019 at the Universidad de Valparaíso.

1.1. Main Question

During this research, an answer to the main question *What are the recommended actions to create awareness on the Building with Nature philosophy in the Chilean water sector related to coastal engineering?* is given. To do so, an exploratory research on the potential of Building with Nature in Chile is conducted. Along with creating awareness among various significant parties, this can be a starting point for the further development of the implementation of Building with Nature in the country. At the end, an advise is given on what could be a valuable approach to create this awareness, based on the experience gained during meetings with stakeholders.

1.2. Sub questions

Aside from investigating the organisational structure of the Chilean water sector related to coastal, case studies are used to illustrate the potential of Building with Nature in Chilean projects. Therefore a distinction in sub questions is made between questions related to the organisational level and project level.

1.2.1. Building with Nature on organisational level

After starting with a description on the Building with Nature philosophy and the Dutch network, the Chilean water sector related to coastal engineering is analysed. The cultural characteristics are an important aspect of this analysis. Finally a comparison is made between these networks and an advise is given on which parties can be involved in a future Building with Nature network in Chile. An overview on the sub questions related to the organisational structure in Chile is given below. A short explanation on each question is given to clarify the objective of this question.

1. What is the current cooperation between the different parties involved in the Dutch Building with Nature network and what are the cultural characteristics of this network?
   The start of the project is to investigate how the Dutch Building with Nature network is organised and how the cooperation between the different parties is influenced by the cultural characteristics. This helps in fully understanding the Building with Nature philosophy.

2. What is the organisational structure of the parties involved in the Chilean water sector related to the coastal engineering and what are the cultural characteristics of this network?
   A deeper understanding in the characteristics of the network in the Chilean water sector related to coastal engineering is of importance when gaining knowledge about the parties involved and the cooperation between those parties. Hereby, the project team can recognize potential interested parties for the Building with Nature philosophy. By analyzing the cultural characteristics, a strategy to approach the potential interested parties can be made.

3. What are the differences between the Chilean water sector related to networks, partnerships and cultural aspects compared to the network in the Dutch construction sector focusing on the Building with Nature cooperation characteristics?
   Building with Nature is a philosophy that is currently primarily based on the Dutch construction sector and environment. Working with Building with Nature in Chile requires knowledge on the differences and similarities between the Dutch and Chilean network.

4. Which parties in the Chilean water sector related to coastal engineering could make a valuable contribution to a potential Building with Nature network, and how can these parties be approached?
   After making the comparison between the Dutch and Chilean water sector related to coastal engineering, the Chilean parties that could be a valuable contribution to a potential Building with Nature network need to be mapped. This information will help in finding the right strategy to raise awareness on Building with Nature in Chile.

1.2.2. Building with Nature on project level

To demonstrate what Building with Nature means for projects, guidelines are described and example projects are given to illustrate this. Furthermore, the coastal characteristics of Chile, which are important for Building with Nature, are studied. To illustrate the possibilities of Building with Nature in Chile, three case studies are analysed. These projects are the coastal erosion in Pichilemu, a port expansion in San Antonio and coastal erosion in Los Vilos. An overview of the different subquestions related to building with Nature on a project level is given below, together with a short motivation.

5. What does Building with Nature mean for projects and how is it currently applied?
   Gaining insight on the Building with Nature philosophy is a cornerstone of applying the Building with Nature philosophy to new projects. This is achieved by analysing Building with Nature on existing projects and interviewing people in the field.

6. What are the coastal characteristics of Chile which are of importance when using the Building with Nature approach?
   Gaining an understanding on the general coastal characteristics of Chile functions as

basic knowledge which is needed before looking at the possibilities to apply Building with Nature on projects in Chile. This is needed because the coastal characteristics determine the kind of solutions which are possible to solve existing problems.

7. What are the physical system characteristics of the case studies: Pichilemu, San Antonio and Los Vilos?
   It is important to fully understand the current processes and situation of the case areas. The hydraulic forcing in the system is of most importance. Aspects like water levels, wave characteristics, currents and sediment transport directions are used to analyse the main hydraulic forcing present in the system. This are the boundary conditions for future Building with Nature solutions.

8. What are the socio-economic system characteristics of the case studies: Pichilemu, San Antonio and Los Vilos?
   The project team have made an inventory of the stakeholders which are involved in the different cases looking at their interests, power and attitude. Thereby a better understanding in the socio-economic system and the governance context is acquired.

9. How can Building with Nature be a solution to the problems occurring at the case studies: Pichilemu, San Antonio and Los Vilos?
   The knowledge gained on the physical, socio-economic system and the governance context of the different case studies, gives insight on the possible advantages of applying the Building with Nature philosophy. In this way the potential of Building with Nature in Chile is underlined.

1.3. The project team

The project team consist of five second-year master students on the Delft University of Technology. Boudewijn van Heijningen, Hugo Hoogendoorn and Kimberley van Batenburg are Hydraulic Engineering students specialized in coastal and river engineering. Lara Klarenbeek and Geert Ridderinkhof are both students from the master Construction Management and Engineering. Lara is specialised in the sustainable side of the construction sector, where Geert has experience with the Building with Nature philosophy during previous education.

During the eight week multidisciplinary project at the Universidad de Valparaíso, supervision is given by Jan van Overeem (Arcadis and TU Delft), Marian Bosch-Rekveldt (TU Delft) and Mauricio Reyes (Universidad de Valparaíso). A photo of the team with Mauricio Reyes can be found below.

Figure 1.1: A photo of the project team with Mauricio Reyes. From left to right: Lara Klarenbeek, Mauricio Reyes, Boudewijn van Heijningen, Hugo Hoogendoorn, Kimberley van Batenburg and Geert Ridderinkhof

1.4. Reading guide

The first chapter of this report defines the methodology used for this research. This chapter also provides the motivation for the chosen methods and case studies. Thereafter, the background study on the physical characteristics of the Chilean coastline and the organisational aspects of the Chilean water sector related to coastal engineering are presented in chapter 3. Subsequently, in chapter 4 an elaboration on the Building with Nature philosophy and the EcoShape consortium can be found. Additionally, currently applied Building with Nature projects are described. In chapter 5, the case studies of Los Vilos, Pichilemu and San Antonio are presented. This includes the physical and socio-economic aspect and possible Building with Nature examples are given. Thereafter, the current awareness in Chile on Building with Nature characteristics and education is measured with different methods. These results are presented in chapter 6. To answer the main question of this research, conclusions of the research and recommended actions are shown in chapter 7. Discussion points regarding this study are elaborated upon in chapter 8. In chapter 9, recommendations for further research are given.

2

Methodology

In this chapter the research methods are defined and the relevance of these methods are explained by describing on how they will contribute in order to answer our main research question and sub questions.

First, a research is conducted on the background of Chile. This research focuses on the physical and the socio-economic aspects of the Chilean water sector related to coastal engineering. Thereby knowledge on the context of the project scope is gained. Understanding the Chilean coastline is important as a basis of the project. The project team gained knowledge from various professors at the Universidad de Valparaíso and used related literature as resources. These findings are elaborated in **chapter 3** and thereby provide the answer to **sub questions 2 and 6** (the questions can be found chapter 1), the questions regarding the Chilean water sector and the physical characteristics on the coast.

Additional groundwork for this project is the study on the originally established Dutch Building with Nature philosophy. Understanding the roots of this new innovative design approach helps in recognizing the potential of Building with Nature. The project team has investigated the Building with Nature philosophy and its Dutch network called 'EcoShape' as a preparation for the project. This is done by interviewing different experts on the subject and doing a literature study. The outcome of this part is elaborated in **chapter 4**, whereby it answers **sub question 1, 3 and 5**. These questions cover the Building with Nature philosophy and the characteristics of the consortium. This is useful for parties interested in further research or use the Building with Nature approach in projects.

A case study approach is chosen to gain deeper insight in the Building with Nature approach on projects. This shows the possibilities of Building with Nature in Chile on various projects. In this way, interested parties will have a better understanding of the philosophy and therefore becoming more aware of its possibilities. The case studies show the variation in the possible application of the philosophy by looking at the physical system, socio-economic system and the governance context. This contributed to the creation of realistic design alternatives that use natural processes and create benefits, while at the same time, safeguard or enhance sustainability and ecological values.

Using three different cases, first of all, emphasizes the adaptability of the approach. There is no standard recipe for each case, as there are only guidelines that can be followed. Furthermore, it underlines how the approach can be applied to locations with different characteristics which shows the variety of the Building with Nature approach. The three locations of the case studies are Los Vilos, Pichilemu and San Antonio.

Los Vilos has to deal with erosion of the coast and it can be seen as a typically Chilean town concerning the involvement of multiple private companies and urban expansion. Pichilemu is another location where they have to deal with coastal erosion. This town is an example of

a fishermen's village where the coastal environment is also of great importance for touristic purposes. In San Antonio a port expansion is planned which has a lot of public attention on national level. As can be seen, these cases are all projects with their own specific characteristics.

For each case, a general system analysis on the physical and socio-economic aspects and its governance context is made. The physical aspects of the systems are gained by existing data on the coast and the historical development. The socio-economic aspects with the governance context are analysed by mapping the local stakeholders with their interest, power and attitude towards the project. This system analysis has been done by using data provided by several parties, related literature and site visits. This analysis is done on a basic level due to time restrictions, wherein the physical aspects are only based on previous studies. Modelling or performing field measurements is not within the scope of this project. Furthermore, the socio-economic aspects are analysed on a general level. Therefore the project team have had meetings with multiple parties and used related literature. At the end of each case study, Building with Nature examples are provided. The case studies are presented in **chapter 5** and thereby an answer to **sub question 4, 7, 8 and 9** are given.

In order to give an advice about how to create awareness in Chile, various methods have been tested: meetings with parties in the Chilean water sector, site visits including stakeholder meetings and site visits including a workshop. These methods are performed throughout the two months of the project. Through the cooperation with the Universidad de Valparaíso, the Dutch embassy and sponsors of the project, several meetings have been set up with parties from the Chilean water sector who showed interest in the philosophy. In these meetings the project team gained information on the current knowledge and the desire for the Building with Nature philosophy. Furthermore, the conversations contributed to the research on the organisational structure of water sector in Chile.

The site visits were performed in Pichilemu and San Antonio. In San Antonio, the port was visited and a meeting was set up with the municipality and one of the port operators. In Pichilemu, conversations with various stakeholders were arranged. At the Universidad de Valparaíso a presentation and workshop with students was performed. The results from these meetings, site visits and workshop are presented in **chapter 6**, whereby **sub question 4** was answered, that covers the possibilities of a Building with nature consortium in Chile. To measure the awareness during the various methods, a questionnaire is used that includes the variables on awareness of Building with Nature aspects. The results of a questionnaire, given during the meetings, are processed in this chapter as well. This provides insight in the current awareness on Building with Nature in Chile.

In **chapter 7** an overall advice is made on how to create awareness on the Building with Nature philosophy in Chile, which is the answer to the main research question of the project. The discussion is presented in **chapter 8** and recommendations for further research are given in chapter 9.

3

Background study

This chapter discusses the background information of Chile. This is done to sketch the context in how eventually Building with Nature in Chile has to be applied, focusing on the coastal regions. As Building with Nature handles the physical system as well as the socio-economic system, a literature study is conducted on both subjects. Therefore, in this chapter, a division is made between the socio-economic characteristics (chapter 3.1) and the physical characteristics of the coast (chapter 3.2).

3.1. Socio-economic system

In order to give advice on socio-economic level about the possibilities of Building with Nature in the Chilean water sector related to coastal engineering, it is important to understand the characteristics of Chile. In this section, a brief history of Chile is described, as well as the cultural characteristics of the country. This is followed by the organisational structure of the water sector and their important actors. To illustrate the problems in the current Chilean water sector, various example projects are presented in the last paragraph of this chapter.

3.1.1. History of Chile

Chile is a long (from 18°S to 56°S longitude), and narrow country in South America, divided into fifteen political regions, which reflect the deep-rooted differences of the socio-economic systems (Aguilera et al., 2018). It is a country with a dynamic political and cultural history. The Chilean population is a mix of various different population groups, which can be explained by the course of history of the country. Therefore, in order to understand the socio-economic structure of Chile, it is important to gain insight in the history of the country.

Traditionally, indians and fishermen nomads are the original inhabitants of Chile. The Inca civilization was living in the north and the Mapuche indians were living in the south of the county. In the sixteenth century, the Spaniards arrived in Chile. They conquered big parts of Chile, but the Mapuche people managed to preserve territory. During the sixteenth and seventeenth century, Chile was not economically interesting for the Spaniards. Only after the development of agriculture and farming in the eighteenth century, a period of economic rise started. This economic rise attracted many European immigrants.

In the first half of the nineteenth century, the battle for the independence of Chile began. The people who fought for independence were led by Bernardo O'Higgins, who had Irish roots. After winning the war, Bernardo O'Higgins became the first president of Chile. A very troubled period with many revolts and coups followed.

The development in agriculture and increasing income due to the mining industry, led to a political and economic stable period. The Guerra del Pacífico (War of the Pacific) caused a big change in the population in Chile. The Chilean conquered an important area for mining

in the north and the Eastern Islands. Although, due to their focus in the northern part of Chile, they lost territory in southern Patagonia. The Mapuche no longer held their ground. Mapuche, translated as 'people of the land', strongly feel connected with their terrain. Therefore, they were given plots of land to live on, where, till this day, they still live in poverty (Verrijp and Willems, 2019).

It became attractive to invest in Chilean industry, in particular the mining industry, as Chile offered his investors a free trade culture. Chile stayed, and partly still is, dependent on the mining industry. Due to the world wide demand for nitrate, the Chilean economy was growing fast in the first part of the twentieth century. But after the development of artificial nitrate alternatives and the opening of the Panama Canal causing ships to stop sailing around the southern point of Chile, the economy was hit hard. Various socialist parties managed to unite during this crisis and therefore the country was mainly governed by left-wing politicians in the thirties and forties (den Haan, 2013).

In the seventies the marxist president, Salvador Allende, tries to nationalize many private companies in order to distribute the wealth among the population. Unfortunately, he did not fully succeeded and Augusto Pinochet took over the leardership of the country. A heavy dictatorship prevailed under Pinochet until the end of the 1980s (Isgeschiedenis, 2013). After that a more stable democratic politic governed the country.

Over the past decade, the country has got into a process of radical economic reformation. Chile had reduced state ownership substantially and therefore their control of their domestic economies. The privatization of Chilean public services of the core sector, as electricity generation and distribution, the national airline, water and sanitation facilities and telecommunications began between 1985 and 1990. Roughly thirty state-owned organisations were sold in this period. The Chilean government had various methods to sell the shares of the privatized companies. For example, company workers were offered to buy the underpriced shares, with the guarantee that the shares will be repurchased at the age of retirement. Additionally, the Chilean government used the so-called institutional capitalism method where the shares were sold to privately run pension funds. Foreign investors were also invited to acquire shares through the international open actions and stock markets from the privatized companies. The main issue with the Chilean privatization process was that the process was so rapidly executed that there had been no time to establish regulation in which the monopolies could operate (Ramirez, 1998).

Besides the privatisation of governmental organisations, many coastal areas and inland parcels of Chile are also in private hands. This causes strong conflicts between economic activities and nature conservation priorities of the coastal systems which is expected to become even more common in future decades. Therefore, the Chilean Ministry of the Environment was created in 2010, with the protection and rehabilitation of urban coastal habitats as a goal (Aguilera et al., 2018).

The privatization has different effects on the country. The technical analysis of a research on privatization, generally has a positive outcome as profitability increases, the returns and economic efficiency are higher and welfare grows. Although, the public opinion is less positive and getting worse. In a survey conducted in 17 Latin American countries in 2001, 65 percent of people disagreed with the statement "The privatization of state companies has been beneficial...," compared to 43 percent three years earlier (Birdsall and Nellis, 2003). Reasons for the dissatisfaction against the the privatisation are, amongst others, the inequality of wealth and the lack of involvement possible of local parties (Ramirez, 1998).

The private character of Chile is important to consider when a coastal project with a Building with Nature character is aimed to be implemented. The privatization has the consequence that a substantial amount of stakeholders with different interests need to be involved in projects and funding can be a challenge.

3.1.2. Cultural differences between Chile and the Netherlands

To understand the socio-economic characteristics of the Chilean water sector related to coastal engineering, it is essential to understand the cultural differences between Chile and the Netherlands. In order to make a comparison between the Dutch and Chilean culture and later explain the socio-economic differences of the hydraulic sector, the cultural dimensions theory of the Dutch social psychologist Geert Hofstede is used. The cultural dimensions theory of Hofstede uses six cultural dimensions to define a culture. These six dimensions are: power distance, individualism, masculinity, uncertainty avoidance, long term orientation and indulgence. The dimensions can score on a index from 0-100, with 0 the absence of the dimension and 100 the full existence of the cultural dimension in the country (Hofstede et al., 2010).

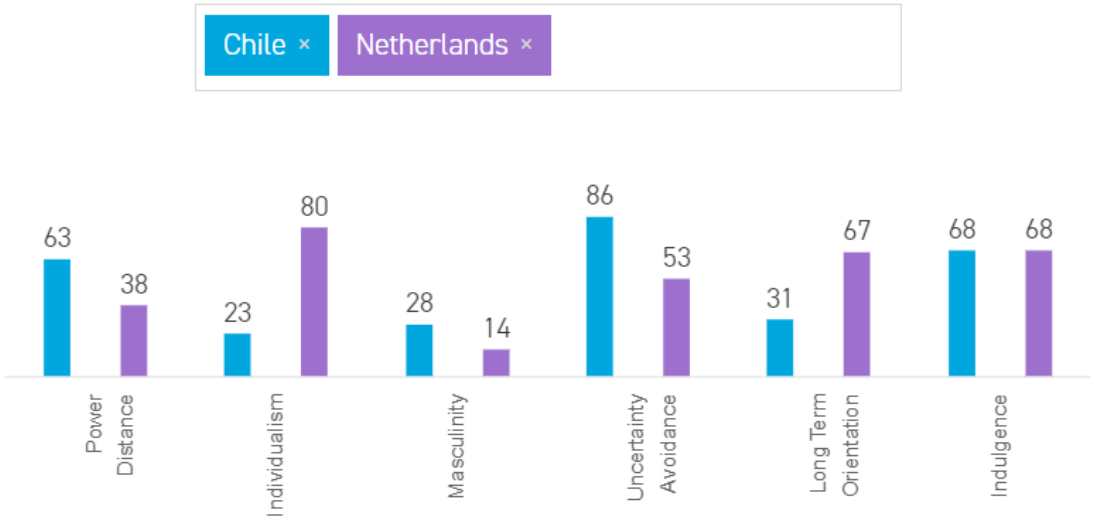

Figure 3.1: Cultural dimensions according to Hofstede of Chile and the Netherlands (Hofstede, 2019)

Chile has a high power distance of 63 relative to the Netherlands, which has an index score of 38. The cultural dimension that measures power distance is defined as 'the extent to which the less powerful members of institutions and organisations within a country expect and accept that power is distributed unequally' (Hofstede et al., 2010). Despite the fact that the index score of Chile is relatively high, it is lower than most other Latin American countries. The power distance in Chile are the remains of her authoritarian past, described in the previous paragraph, as taller power pyramids can be found in the organisational structure and power inequality is shown by status symbols. In the country, rather strict social classes and hierarchical social structures are present including power holders privileges. The Netherlands is more characterized as independent, equal, accessible and coaching leaders. Dutch communication is characterized as direct and informal and control is disfavored (Hofstede, 2019).

Individualism is a dimension that deals with the extent of interdependence within a society. This consist of the degree in which a society works in groups and take care of each other in comparison to societies where people take care of themselves and their direct family only. In these societies the self-image is more defined as 'I' instead of 'we' (Hofstede et al., 2010). As in most Latin American countries, Chile scores low on this dimension, with 23, compared to the Netherlands, that has a score of 80. This, however is variable over the different professional classes, as higher working classes are shifting to position with more autonomy and variance. This change can be the effect of Chile's increase of GDP and economic

growth. However, in areas outside the capital Santiago, a more collective society remains. The Netherlands on the other hand has a very individualistic society with loose social links and professional relationships based on mutual advantage (Hofstede, 2019).

The third dimension of Hofstede theory is masculinity. This dimension is marked by a society that is driven by competition, success and achievement. A country that has a low score on this dimension has a more feminine society, which is indicated by measuring success with quality of life and the motivation to do what you like instead of wanting to be the best (Hofstede et al., 2010). Although a little higher than the Netherlands, Chile has a relatively low score of 28 on masculinity, which means that the Chilean society has more feminine characteristics. The society has a more 'enjoying life' attitude, rather than being successful. They value personal connections with others and have the urge to belong within social groups. People strive for consensus, are team players and value quality, equality and solidarity in their professional lives instead of striving for success. With a score of 14, the Netherlands has an even more feminine society that characterizes itself with long discussions until there is a consensus reached (Hofstede, 2019).

Uncertainty avoidance is identified in the way society deals with the uncertainty of the future. The cultural dimension is defined as 'the extent to which the members of a culture feel threatened by ambiguous or unknown situation and have created beliefs and institutions that avoid these.' (Hofstede et al., 2010). Also with this dimension, the Chilean index score is similar to the rest over the Latin American countries. With a score of 86, Chile has a higher uncertainty avoidance than the Netherlands. This shows that the Chilean society has a stronger need for rules, which is, in some extent, in line with their authoritarian past. Besides this, the dimension is represented in the extensive legal system and a great dependence on experts and authorities. With a score of 53 the Netherlands has a slight preference to avoid uncertainty, but less strong than Chile (Hofstede, 2019).

The dimension that covers long term orientation describes the urge to maintain links with the past when dealing with present and future challenges. A low score on this dimension means that society prefers to maintain norms and traditions and have a suspicious perspective on social changes. A high score shows a more pragmatic approach that encourage modern and innovative changes (Hofstede et al., 2010). On this dimension, Chile and the Netherlands differ. With the Chilean score being 31, the society is more normative, as the Netherlands is more pragmatic with a score of 67. This means, the Chilean culture has great respect for traditions and is more about focusing on quick achievements than saving for the future. Where as the Dutch society adapts traditions more easy and has more the urge to save and invest (Hofstede, 2019).

The last culture dimension of Hofstede's theory is indulgence. This covers the societal aspect of controlling desires and impulses (Hofstede et al., 2010). On this dimension, Chile and the Netherlands have the same score of 68. This means both countries have a relative high indulgent orientation which is characterized by the fulfillment of desires and impulses in order to enjoy life. This results in a positive attitude and a society known for optimism (Hofstede, 2019).

The main difference between the Chilean and Dutch culture is the level of individualism, uncertainty avoidance and long term orientation. In these cases the difference between the countries is more than 30 points, with Chile scoring relative high on uncertainty avoidance and low on individualism and long term orientation compared to the Netherlands. The relatively high score on uncertainty avoidance in the Chilean culture means that the society is more conservative and want to make life as controllable and predictable as possible. This needs to be taken into account when introducing the Building with Nature philosophy as society needs to trust the new approach. The difference in individualism means that there is a more collective attitude in the Chilean society where the relation with friends and family are tight. To recognize this difference is valuable when establishing a Building with Nature

consortium. The final difference that is valuable to consider when a Building with Nature approach is aspired to be applied as the Chilean culture is short term orientated. This holds that the focus in Chile is on quick results ans short term gains, something that does not characterize the Building with Nature philosophy and which can cause challenges when implementing.

3.1.3. Organisational structure of water sector in Chile

In order to give an advice about the possibilities of a Building with Nature in the Chilean water sector, it is important to understand how the sector is organised. In this paragraph, an overview of all the national players in the water sector is given. These stakeholders are important to consider when a coastal project is executed. Among them, there are various ministries and coastal authorities. In addition, regional stakeholders, as the government of the province and the intendance of the region are included. The stakeholders listed below are the parties that will be involved in every Building with Nature project. Besides these, local stakeholders also have to be taken into account. These are, among others, fisherman unions, municipalities and local residences. The local stakeholders will be different for each case and must be studied individually for each case.

Ministerio de Obras Publicas: MOP (Ministry of Public Works)

The Ministry of Public Works (MOP) is the governmental office in charge of studying, planning, designing and constructing as well as repairing, maintaining and operating public infrastructure in Chile. Its work embraces roads, highways, bridges, tunnels, airports and airfields. Its mission considers new public building and the enhancement of existing buildings that have certain economic character. It is responsible for the management, distribution, use and conservation of all water resources within the country.

The Ministry has two main general divisions: Water and Public Works. They are divided into six departments: port works, water works, national roads, airports, architecture and permits. Besides this, there are three non-executive departments: planning, management accounting and finance. The mission of the ministry of public works is to retrieve, strengthen and advance in the provision and management of infrastructure and services to achieve the best connectivity, protect the territory and the people and get the optimum utilization of water resources (Ministry of Public Works (MOP), 2019).

Dirección de Obras Portuarias: DOP (Port Works Directorate)

The Port Works Directorate (DOP) is a part of the Ministry of Public Works. The DOP provides citizens with port and coastal, maritime, fluvial and lacustrine infrastructure services necessary for the improvement of the quality of life, the socio-economic development of the country and its physical national and international integration. Its functions are mainly:

- Planning the port infrastructure and executing the processes established in the national public investment system; develop, directly or through external consultancies, port works projects.
- Supervise and approve all projects of port works developed at the national level, both public, either direct or through external consultancies, as private.
- Establish technical standards regarding the development of port projects.
- Supervise all public port and dredging works executed at the national level, in their technical and administrative aspects; supervise and supervise the construction of port works executed by individuals, verifying compliance with the approved project.

(Ministerio de Obras Publicas, 2019).

Ministerio de Economía Fomento y Turismo (Ministry of Economic Development and Tourism)

The mission of the Ministry of Economy is to promote the modernization and competitiveness

of the country, the private initiative and the markets. Additionally, the ministry stimulates the development of innovation and strengthens the international position of the country's economy in order to achieve sustainable and impartial growth. They are achieving this by the formulation of policies, programs and instruments that facilitate the activity of the country's advantageous units (Ministerio de Economía, 2019).

Ministerio de Vivienda y Urbanismo (Ministry of Housing and Urbanism)
The Ministry of Housing and Urbanism enables access to quality housing solutions and contribute to the development of proper, integrated and sustainable neighborhoods and cities. The purpose is an increase in quality of life and well-being of individuals, families and communities (Ministerio de Vivienda y Urbanisamo, 2019a). Their goals are to reduce the housing deficit of the most vulnerable sectors, reduce the inequality and promoting social integration and recover neighborhoods areas. Additionally, they ensure the development of cities, promoting their planning, increasing investment in infrastructure for connectivity and public spaces that promote social integration. Furthermore, they provide citizens with quality products and services in the areas of housing, neighborhood and city (Ministerio de Vivienda y Urbanisamo, 2019b).

Ministerio de Bienes Nacionales (Ministry of National Assets)
Since the beginning as a nation, the state of Chile has been playing a fundamental role in matters as land tenure, property ownership and the implementation of policies and instruments aimed at increasing development and overcoming poverty. This shows in the private character of the country as described in chapter 3.1.1. Its mission is to recognize, govern and manage the fiscal estate of all Chileans, regularize the small private property, maintain the graphic cadaster of tax property and coordinate with other State entities in territorial matters, while strongly valuing the natural and historical heritage of our country (Ministerio de Bienes Nacionales, 2019).

Ministerio de Desarrollo Social (Ministry of Social Development)
The Ministry of Social Development contributes to the design and application of policies, plans and programs in the area of social development. Especially those aimed at eliminating poverty and providing social protection to vulnerable people or groups, promoting mobility and social integration. Likewise, it must ensure the coordination, consistency and coherence of the policies, plans and programs in the area of social development, at the national and regional levels and evaluate the investment studies of projects that request financing from the State to determine their social profitability. In this way, they respond to the strategies and policies of growth and economic and social development that are determined for the country (Ministerio de Desarrollo Social, 2019).

Ministerio de Medio Ambiente (Ministry of the Environment)
The ministry is involved in matters related to the conservation of biodiversity. It also generates alignment and actions for the protection, conservation, sustainable use and management of resources in both the territory and continental marine waters (Ministerio del Medio Ambiente, 2019a).

The ministry carries out the Strategic Environmental Assessment (SEA), which is an environmental management tool that facilitates the incorporation of environmental and sustainability aspects into processes for the preparation of territorial planning policies. The SEA seeks to promote and accompany the incorporation of environmental considerations in public policies and plans with a view to promote sustainable planning in the country. In this sense, this tool allows to improve, for example, the environmental approach of land management instruments, which results in a more efficient land use and to know the existing territorial limitations that must be considered in order to obtain an adequate planning (Ministerio del Medio Ambiente, 2019b).

The ministeries have for each region in Chile their own deputies. These are called SEREMI (Secretarías Regionales Ministeriales) (van de Grift, 2019).

Gobernacion Maritima Directemar (Maritime government)
The goal of the Maritime Authority is to protect the aquatic environments and ecosystems formed by the sea, rivers and lakes of national jurisdiction. The maritime government aims at safeguard them against the effects of pollution and other environmental impacts and overseeing compliance with national and international legal standards. Additionally, the government has the task to permanently assess the state and quality of the aquatic environment, in relation to the environmental impacts caused by the various uses or activities that are developed or practiced at sea, in the coastal area, or in other bodies or water (Armada de Chile Directemar, 2019a.)

The maritime government also implemented the POAL. The Coastal Environment Observation Program (POAL) was developed to monitor the annual fluctuations of the concentration levels of the main components of domestic, industrial and petroleum hydrocarbon waste in the bays, lakes and rivers. In POAL, the levels and concentrations of the main pollutants of both coastal and sweet waters are determined and evaluated. Thereby they consider the potential effects of two major factors: the discharges of the activities that take place in the surrounding environment of the body of water, such as industries and health services establishments, and in the impacts produced by the main activities that are carried out in the body of water itself such as fishing and aquaculture. (Armada de Chile Directemar, 2019b).

Government of the Province
The government of the province assist in the policy of the government and the internal administration of the State. Besides enabling a political, administrative and management platform, the government provides the population with the goods and services established by law or policies established by the Ministry of the Interior and Public Security (Gobernacion Provencial de Choapa, 2019).

Intendencia of the Region (Intendance of the Region)
The intendence is a decentralized body dependent on the Ministry of Internal Affairs and Public Security. The office of intendance represents the highest political authority in the region and is appointed by the president of the republic. As such, whoever fulfills this position is responsible for presiding over the Regional Council and the Regional Commission for the Environment. In addition, the intendance is responsible for various activities related to the proper functioning of the region, such as: the maintenance of public order, transportation and decontamination plans (Intendencia Coquimbo, 2018).

3.1.4. Comparison between Chile and the Netherlands
There is a significant difference in the involvement of private parties in coastal projects between the Netherlands and Chile. Where all coastal projects are initiated by governmental organisations in the Netherlands, is it in Chile possible to be, as a private party, the client of such a project. This makes the economical profitability of a solution a more important aspect of a tender (van de Grift, 2019).

To establish a cooperation between the different parties, the MOP and the DOP should be closely involved in every project. To develop a more sustainable approach for coastal projects, it is important that the Ministry of Environment is closely involved as well. Additionally, the regional parties as the Intendance, Provincial Government and the SEREMI of the various ministries should be consulted and stay informed. To make coastal projects more fit for the problem, the local stakeholders and municipalities should be involved and consulted more from the beginning of the project.

3.1.5. Example projects
In the past, various project in Chile failed to be executed due to resistance of local parties. In this paragraph, an overview is given of projects that were blocked due to opposition of the

community. The striking points of these failed projects are summarized, which can then be used to analyse whether a Building with Nature method can offer a solution to ensure that future projects run successfully.

HidroAysén

The HidroAysén project was a substantial plan to generate energy from water reservoirs in the Chilean Patagonia. The plan was to build five large dams in the Aysén Region and thereby flooding approximately 6000 hectares of land. The project was controlled by the consortium Hidroaysén, owned by Endesa (a subsidiary of Italian conglomerate ENEL) and Colbún S.A.. If this project would have been completed, the consortium would have owned 80 percent of the Chilean electricity market.

In first instance, the project got an official approval on May 9, 2011 under the government of President Sebastián Piñera. However, a massive campaign, Patagonia Sin Represas, arose since the first time rumors about the project reached the public. Patagonia Sin Represas managed to gather a lot of parties and organize protests against the project. The uprising against the project was both on environmental and social issues, due to the heavy and unprecedented impacts on the area. Moreover, the consortium did not discussed or even informed the public about any of their plans (Greyl and Bene, 2015).

Between the first announcement of the project in 2005 and the rejection in 2014, more and more people stood up against the project. The opponents denounced the colonial and pro-private law regulating water use. The bishop of Aysén, Luis Infanti, has repeatedly expressed himself against the project. He tried to convince the government that the decision could not only be based on economics but needs to have a broader perspective (Greyl and Bene, 2015).

Patricio Rodrigo, executive secretary of the Patagonia Defense Council, said in a statement: ”The government’s definitive rejection of the HidroAysén project is not only the greatest triumph of the environmental movement in Chile, but marks a turning point, where an empowered public demands to be heard and to participate in the decisions that affect their environment and lives.” (Howard, 2014). It could be said that Patricio Rodrigo was right, because it was one of the first projects which was stopped due to involvement of the society.

Dominga

Proyecto Dominga is an integrated mining and port project with the goal of building a new mine. When the project is completed, the mining focusses on iron and copper concentrate. According to the website, the new mine will generate over 10.000 new jobs (Minera Dominga, 2019).

This project was initiated a couple of years after the HidroAysén project, which influenced the project approach on stakeholder management and environmental management. The lessons learned from the HidroAysén project have been taking into account as the phrase of Proyecto Dominga translates in: ”We are a port mining project, which proposes to develop a ‘New Mine’, responsible, inclusive and transparent, in partnership with the community and respecting the environmental and historical heritage of the environment that welcomes us.” (Minera Dominga, 2019).

However, the public is divided about this project. Punta de Choros, the coastal town on the northern coast of Chile, is an unique spot for a fishing community. The three islands that make up the Humboldt National Penguin Reserve are nourished by the Humboldt Current, the current that brings nutrients and various species from Antarctica to Ecuador. The coastal population, where the new port is planned to build, claim that it will destroy their livelihoods because they depends on fishing and the tourists visiting the town. On the other hand, the poorer inhabitants of the inland region see the project as an opportunity to raise

their standard of living (Ansede and Rivas, 2018).

This project has similarities to the pilot project and case study in Los Vilos, due to the involvement of private companies.

Pelambres - El Mauro

In 1997 the Luksic Group started a project to expand the Los Palambres mine. Due to the expansion of this mine, the three tailings dams that were earlier approved by the environmental authorities, would no longer be sufficient enough. Instead, they planned to build one big dam. This dam, called El Mauro, would cut trough the most important water slope of the valley. According to multiple actors, the social and environmental impact of this dam was not properly considered (Fahrenkrog and Boily, 2015).

Farmers, residents and other users of the water of the valley, were opposed to the project, because their water rights would be affected. Despite of the civil society, the Luksic Group went on with their plan and presented an Environmental Impact Declaration (DIA) but did not consider most of the observations made by the public services. Opponents went to the Appeal Court of Santiago against the project. After a long process of hearings at the Court, the decision was made that the Luksic Group had to compensate the farmers in different ways (Fima, 2019).

Port expansion Valparaíso

The ”Mall Puerto Barón” was the project created through by a public and private partnership between the private company Mall Plaza and the state-owned Empresa Portuaria Valparaíso (EPV). The Mall would be constructed at the Baron dock, on the coastline of Valparaíso. This was the reason for a large opposition to arise as the Mall would block the ocean view of the city and interfere with the local heritage of Valparaíso. This intervention generated a lot of controversy (Wikipedia, 2018b).

After months, irregularities in the contract between Mall Plaza and the Port Company of Valparaíso, that worries about congestion problems around the port area, are not solved. Additionally, there are difficulties regarding the limited access to the coastal border, the maximum height of the mall, the interference with the port area, heritage at risk and more (P., 2012). At this point, the local public had the perception they are not being heard and that there was insufficient respect towards their opinion, which caused more friction between the different parties (Bustos, 2016). At the beginning of 2018, the Supreme Court declared its construction illegal, so the project was banned from being executed (Wikipedia, 2018b).

President Sebastián Piñera, within a new investment plan since 2019 for the coastal border of Valparaíso, has announced the construction of a Great Park in the Baron sector, called Paseo del Mar. This includes the restoration of Simon Bolivar cellar, the construction of a pier for Cruises, the elimination of the Baron Viaduct and the adjustments for Avenida Argentina to turn it into a boulevard. The end of the project is estimated for 2021 (Wikipedia 2018b).

Additionally, the Port Authority of Valparaíso planned the expansion for the Port of Valparaíso and developing it as the most important port of Chile. The project ”Terminal 2 Cerros de Valparaíso”, whose owner is the company Cerros Terminal of Valparaíso S.A. (TCVAL) consists of the construction and operation of a new container terminal, which will increase the number of berthing sites and thereby expanding the cargo transfer capacity of the Port of Valparaíso. The new terminal will be formed by a pier of 725 meters in length created by reclaiming land at sea through the use of fill material. This shifts the coastal border 185 meters west of the current coastline. Thereby a new berth is created, capable of serving two Post Panamax ships simultaneously and has an operational surface of approximately 13.6

hectares (GSI ingenieria and TCVAL, nd).

The port expansion plan, additionally to the Mall Baron project, experienced a lot of opposition of the local public as they argued that the effects of the expansion will cause a pollution of to the city and decrease in well being of the inhabitants. They appeal that the well being of people and the heritage of the city is the most important thing to take care of, and this project damages those irreversibly. The amount of pollution that will occur, also in terms of noise for the city, makes it an irresponsible project for them. The opposition furthermore argues that the expansion is an unfavorable project, because it does not have 100% sheltered waters, nor does it have two berths for ships of the latest generation and does not grand the accesses that every port of the 21st century requires (El Mercurio de Valparaíso, 2018).

The decision taken by port operator TCVAL to terminate the expansion concession contract for "Terminal 2 Cerros de Valparaíso" was announced in a press release in March 2019. TCVAL argued as the main reason for its decision the successive delays in the environmental processing of the project, which had been extended beyond reasonable time (Patricio Rozas, 2019).

While the Puerto Barón Project was totally discarded in Valparaíso, in the port of San Antonio, the Matte group inaugurated its Puerto Central terminal (PCE), a concession that was awarded in 2011 and that has demanded investments of US $ 450 million. This makes it the largest private port work in the country (Barberis, 2018).

In a more recent statement by the current president of Chile, Sebastián Piñera, the announcement was made that the expansion of the San Antonio harbour gets state support. Piñera said that he is planning to start the construction of the San Antonio harbour expansion within his current term of office. This negatively influences the state support of the Valparaíso harbour expansionn. The reason for this is the close connection between the harbour of Valparaíso and San Antonio in terms of location, cargo transfer and inland connection (Redacción PortalPortuario.cl, 2018). Specifics on the port expansion project in San Antonio can be found in chapter 5.2.

Striking points of the projects

The investigation of four projects in Chile has shown various striking points. The most obvious finding to emerge from these projects is the power of the public. In each of the projects the public stood up against the plans (mostly because of environmental reasons) and made the project difficult to proceed. In the HidroAysén project and Valparaíso the environmental protests even lead to a rejection of the project.

All of these projects took place during the last decade. It is possible therefore, that Patricio Rodrigo is right about the turning point where an empowered public demands to be heard and to participate in the decisions that affect their environment and lives (Howard, 2014). It appears that there is a shift in society going on were transparency is becoming more common and the public opinion is getting more power.

3.2. Physical characteristics of the coast

Chile is one of the most diverse countries worldwide looking at climate and nature, due to its unique shape with a length of 4200 km and an average width of 172 km (see figure 3.2). The coastline stretches over the entire country, however large differences are visible: deserts are located in the northern regions, while fjords can be found in the south. This variability makes Chile a complex country to describe.

The following section describes the most important characteristic aspects concerning the coastline of Chile. It is of importance to know the larger system to understand the origin and the changes in the local system.

Figure 3.2: Map of the whole of Chile (MetService, nd)

3.2.1. Geological properties

The geophysical properties of Chile are highly determined by the two tectonic plates that form a convergent boundary about 150km off the coast of Chile. The two plates are called the South American plate and the Nazca plate. The eastern edge of the Nazca plate is being slowly subducted beneath the South American plate. This process is very important when looking at the geophysics of Chile. This plate subduction causes tsunamis and earthquakes which are one of the most aggressive and important nature phenomena in Chile (Fisher and Raitt, 1962).

At the convergent edge of the plates there is a deep underwater trench which is called the Peru-Chilean trench or Atacama trench (see figure 3.3). This trench has a length of approximately 5900 km and runs from the south of Ecuador to central Chile, the maximum depth is about 8000 meters (Fisher and Raitt, 1962).

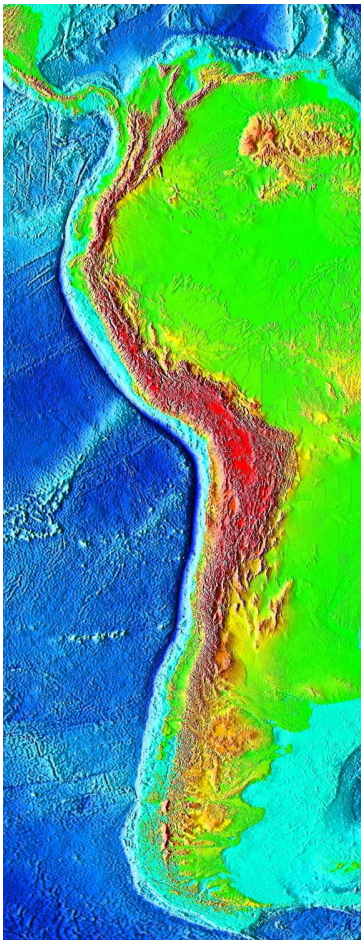

Figure 3.3: The dark blue part points out the Peru Chile trench. The plate east to the trench is the Nazca plate, the plate west to the trench is the South American plate (Interiot commonswiki, 2006).

The continental shelf in the north is short and expands more to the south. This is the reason why the Peru-Chilean trench which is very deep in the north of Chile and less deep in the south. The presence of the trench furthermore results in a steep and rocky coast. In figure 3.4 a cross section of Chile at approximately 33°S, from far offshore to about 150km inland, can be found. Several conclusions can be drawn from this figure. At first the Peru-Chilean trench can be seen at about 120 km offshore with a depth of 6000 meters. This is the location of the interface between the two converging plates. It is recognised that Chile has one of the narrowest continental shelves on the earth (Paris et al., 2016). In the inland

of Chile a pattern can be observed which is similar in most of central Chile. The first 50km measured inland off the coast is a more flat part. Then a lower stretch of mountains (the Cordillera de la Costa) can be found. After that there is a more flat area again (called an intermediate depression in which Santiago is located as well) and at about 100km inland the Andes mountains start. The Andes mountains are also a result of the convergence of the Nazca and the South American plate. This information is obtained from a visual analysis of figure 3.4.

Figure 3.4: Depth map at approximately 33°S, with on the horizontal axis the horizontal position and on the vertical axis the vertical position (Google Earth, 2015).

3.2.2. Climate

Chile knows a large variety in landscape and climate. In order to describe the climate, the country is divided into three different zones:

- North (18°S-30°S)
- Central (31°S-35°S)
- South (36°S-56°S)

The climate in central Chile is elaborated upon in more detail as this is the main region of interest in this report. At first the El Niño–Southern Oscillation (ENSO-circulation) is explained as this circulation has a large influence on the Chilean climate.

ENSO Circulation

The ENSO circulation is an important circulation in the south Pacific Ocean. This describes the periodic irregularity in winds and sea surface temperature over the tropical eastern Pacific Ocean. During normal conditions, easterly trade winds blow warm surface waters to the western side of the Pacific Ocean. Subsequently, cooler deep water upwelling can be found at the eastern side. The warmer surface water at the western side (Australia) result in a low pressure area (and strong precipitation) due to the evaporation of the water. The cooled air is then returned to the eastern side (South-America), where a high pressure area (with little precipitation) can be found. This circulation is known as the Walker-circulation, and is displayed in the upper picture in figure 3.5 (Lau and Yang, 2003).

Once every five to seven years a weakening of the trade winds takes place. Therefore the water near South-America gets warmer, and the water at the western side gets cooler. This results in a high pressure area in this regions and a low pressure area at the eastern side of

the Pacific Ocean. This event, in which the Walker-circulation is weakened, is called an 'El Ninõ' (see lower picture in figure 3.5). During 'La Nina', the reverse process takes place: at the eastern side the water is even cooler than normal, and at the western side even warmer surface waters can be found. This periodic fluctuations in sea surface temperature and winds over the tropical eastern Pacific Ocean are known as the ENSO-circulation (Pietrzak and Katsman, 2018).

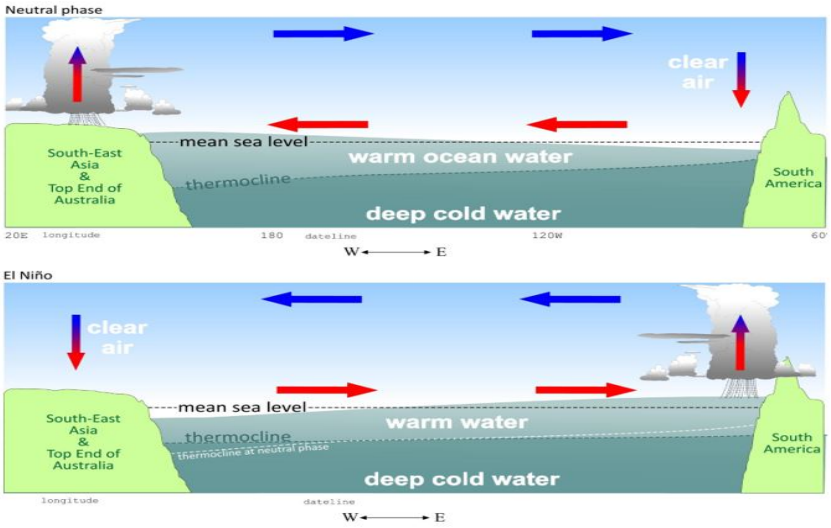

Figure 3.5: ENSO Circulation (MetService, nd)

North

In the south-east Pacific Ocean a high pressure area, named the South Pacific Anticyclone (SPA), is located. The SPA results in trade winds above the Southern Pacific which are directed towards the north in the summer and to the east in the winter. Due to friction with the surface water, in combination with the Coriolis effect that directs the surface waters towards the left, coastal upwelling occurs (see figure 3.6), mainly in the summer. This causes the arid and dry climate in the north of Chile (Aguilera et al., 2018).

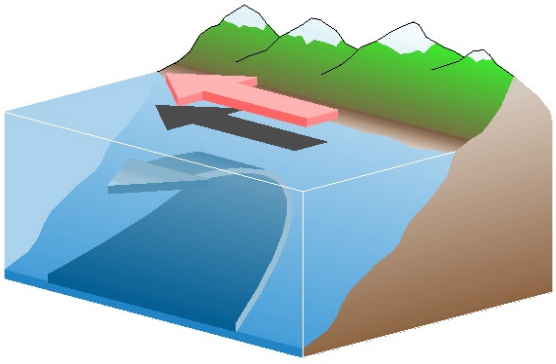

Figure 3.6: Coastal upwelling (Washington, nd)

Central

The climate in central Chile (31°S-35°S) can be described as a so called snow dominated Mediterranean-climate. This climate is characterized by a strong seasonality with temperatures just above zero in the winter, and rainfall concentrated in the autumn. and winter. In the spring, summer and the early autumn intense direct solar radiation occur with a small probability of precipitation (Meza et al., 2012).

Seasonal variations are strengthened by the direction of the SPA. The equator-ward winds are directed towards the north in the summer and in the winter they are directed towards the coast (so to the east). Due to this change in direction in the winter the upwelling will be weaker. This leads to more rainfall and a warmer water temperature in the winter (Aguilera et al., 2018).

The places of upwelling, with a width of 50-100 km, are dominated by south/south-west winds which strengthen towards the north. Around 30°S the coastal upwelling reaches a maximum, where low level jets, nutrient rich and (sub)surface waters can be found. Above land, especially in the afternoon, the air temperature is a lot higher. In combination with the cooled air above the sea this result in strong, cool coastal winds (Aguilera et al., 2018).

South

The climate in the south of Chile ranges from cool to cold. The more south, the more cold the climate becomes. Furthermore the rainfall amount is high (2000 - 4000mm per year). In the most southwards parts of the country, perennial snow can be found on low altitudes (Cecchini, 2019).

3.2.3. Climate change

Global warming

A temperature change of around 4°C can be expected in the subtropical Andes region following the mean of the climate models used by the Intergovernmental Panel on Climate Change (IPCC). According to these predictions the mean annual precipitation in Chile can be reduced with about 20%, in central Chile this reduction can be up to 40%. Furthermore, on higher elevated areas the impact is expected to be larger as well (Meza et al., 2012).

A temperature change of this magnitude has a large influence on the hydraulic cycle. The climate becomes warmer and dryer which result in a higher rate of evaporation. The river peak flow will shift from the summer towards winter or early spring due rapidly melting snow, which can lead to critical situations at the foot of the mountains if the winter peak flow cannot be fully stored by the rivers (Barnett et al., 2005). Due to the expected rise in temperature, the glacier margins are exposed more often to rain rather than snow, so even less glacier water storage will be available, shifting the discharge peak even more to the beginning of the year (Meza et al., 2012).

Sea level rise

Over the whole world a sea level rise has been detected due to thermal expansion of the water and loss of ice. Locally, the amount of sea level rise is affected by the gravity distribution of the earth and the level of salinity of the ocean. Along a coast as long as Chile's those changes can be noticed. The sea level rise can be defined in two ways: absolute sea level rise (figure 3.8), or relative sea level rise, compared to a fixed point at the coast (figure 3.7). As can be observed, at some places along the Chilean coast, a relative sea level drop is measured in the period from 1944 to 2016.

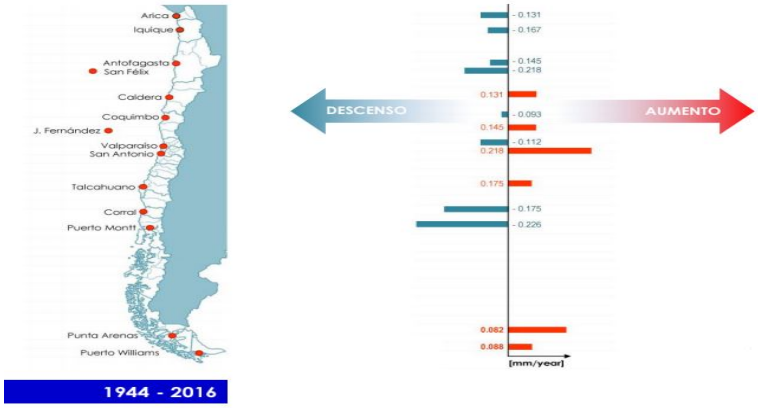

Figure 3.7: Relative sea level rise (Winckler, 2019b)

In the research of Fraukje Albrecht and Gary Shaffer (2016) two emission scenarios (representative concentration pathways 4.5 and 8.5) are considered. In figure 3.8 the expected sea level rise along the Chilean coast in the period 2081-2100 compared to 1986-2005 is shown. The 25th/75th percentiles are shown by the dashed lines. The crosses represents the outliners. From those results a sea level rise can be expected in the coming years, but is not necessary the case due to the range in the results. Furthermore, seismic effects, which are discussed in chapter 3.2.6, can cause significant uplift of subsidence of the coast, influencing the relative sea level rise. Those effects can play a more important role for coastal engineers than the sea level rise itself and can explain the heterogeneity observed in figure 3.7.

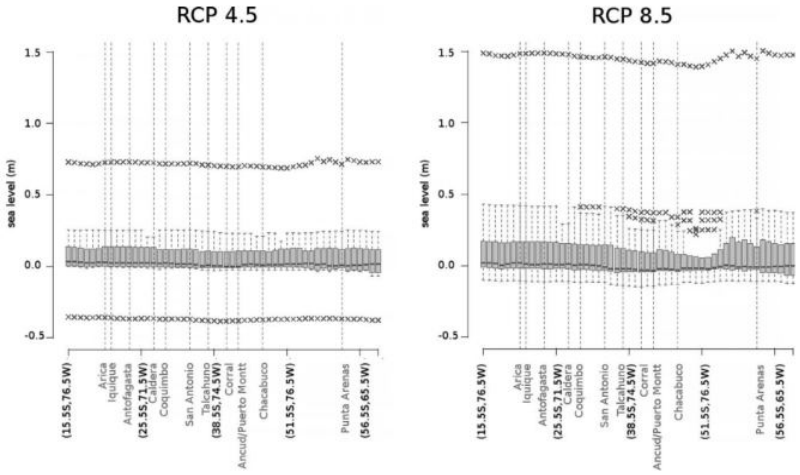

Figure 3.8: Sea level rise along the Chilean Coast for the period 2081 - 2100 compared to 1986 - 2005 (Albrecht and Shaffer, 2016).

Wave climate

Climate change does not only affect temperature change and sea level rise. A recent study of Patricio Winckler (2018) shows also a change in extreme wave events in central Chile. The occurrence of extreme wave events has increased from 5 to 20 per year in the 21 century. Furthermore, a change in wave direction of about 20 degrees to the south have been observed. Lastly, an increase in monthly maximum significant wave height was discovered, however no seasonal distinction could be proven. In the figure below, the results of the study are shown. As Patricio Winckler states, this may have caused recent erosion problems in Chile. Therefore

this is an important event to consider.

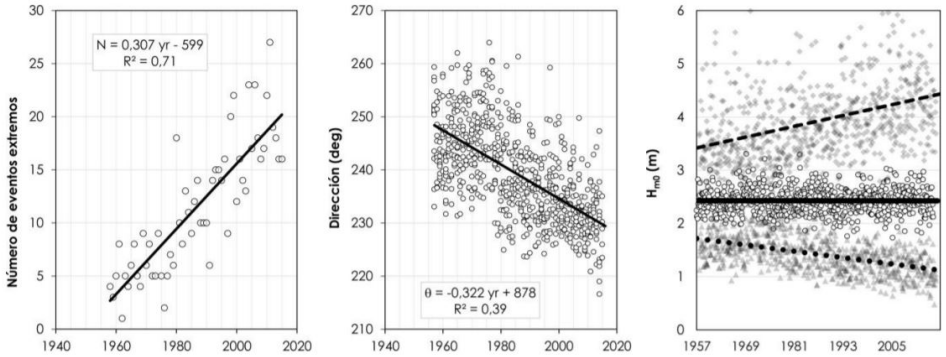

Figure 3.9: Wave evaluations from 1958 to 2015 near Valparaíso. The left figure shows the number of extremes, the middle figure shows the directional evolution over time and at the right the monthly significant wave heights are shown (Patricio Winckler, 2018).

3.2.4. Oceanography

The west wind drift reaches Chile at the height of Chiloé Island and deflects towards the north into the Humboldt Current (HCS) and to the South into the Cape Horn Current. The HCS ends at the surface at the equator and at the subsurface at the pole. In the north of Chile (18 - 40 °C) the coast is exposed to a dominating continues wave climate. Between 40 and 45 °C the HCS is dominating, below the 45 °C the Magellan Current dominates (Aguilera et al., 2018), see figure 3.10.

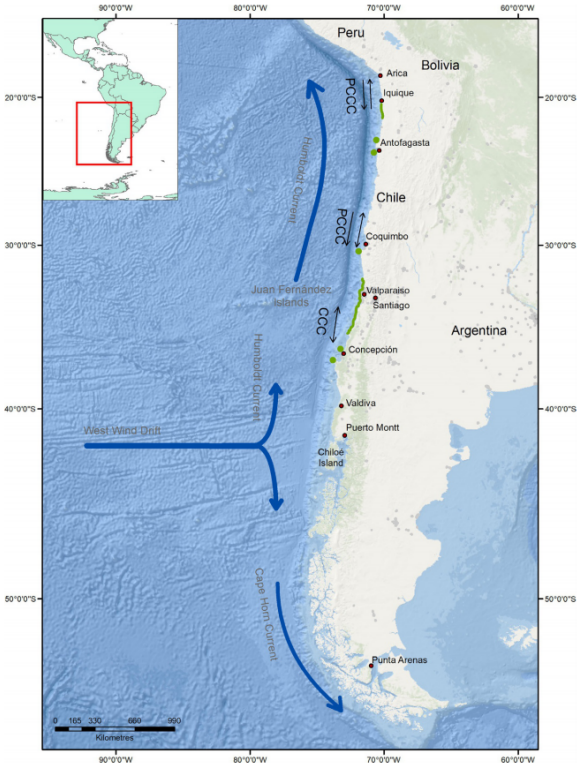

Figure 3.10: Large Sea Current (Aguilera et al., 2018)

3.2.5. Activities in the coastal zone

About 75% of the Chilean population is located in the south and central zones of the country. In these regions most of the heavy productive activities take place, which impacts the coastal

environment, for example in large coastal cities as Valparaíso of San Antonio. According to Alvial and Reculé (1999) a further increase of inhabitants of the coastal cities can be expected. Moreover, the increasing amount of (foreign) tourists has led to the construction of hotels and other recreational facilities. Lastly, almost 94% of international trade is carried out over the sea. All these activities can heavily impact the Chilean coastal environment and asks for proper coastal management.

3.2.6. Earthquakes in Chile

Chile is a country which is very prone to earthquakes. In central and northern Chile there is a lot of seismic activity, also illustrated in figure A.1 in the Appendix. This is due to the existence of a convergent plate boundary about 150km off the coast of Chile. This boundary runs all the way from the north to the south of Chile as discussed in chapter 3.2.1. Chile therefore mainly deals with so called interplate earthquakes that occur close to the plate convergence which are most of the times located underwater (Reyes, 2019).

The slow subduction of the Nazca plate under the South American plate, which is visualised in figure 3.11, causes the earthquakes in Chile. Due to this movement there will be pressure build up at the interface of the two different plates. This pressure build up can occur due to the roughness of the interfaces. These pressures lead to deformation of mainly the South America plate. In case of an earthquake the pressure build up is too large and at a sudden moment the plates will start moving, causing an earthquake with its hypocenter (which is variable in depth) somewhere along the interface of the plates (Reyes, 2019).

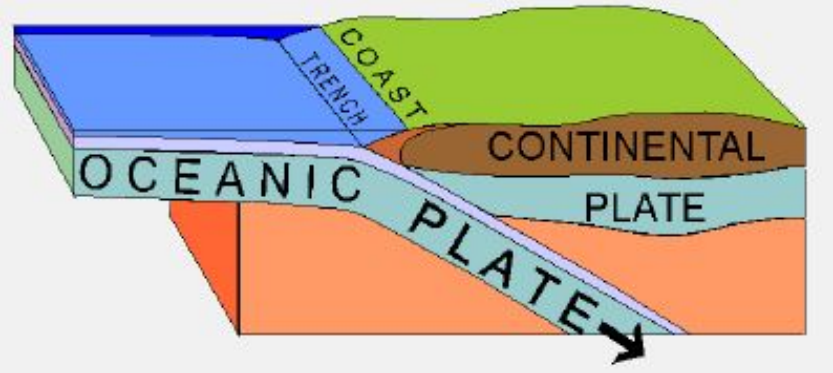

Figure 3.11: Convergence of two component plates of the earth (Reyes, 2019)

In figure 3.12 all the recorded earthquakes with a magnitude of 7 or higher in the history of Chile can be seen (only in the last 100 years almost all the earthquakes that actually occurred are recorded). This confirms the frequent occurrence of high magnitude earthquakes in Chile. The biggest earthquake ever recorded with a magnitude of 9.5 occurred in Chile in 1960. A more recent high impact earthquake was the earthquake in 2010. With a magnitude of 8.8 and a large rupture zone this earthquake had a profound impact in central Chile (Reyes, 2019). More information on this specific event can be found in Appendix A.3.

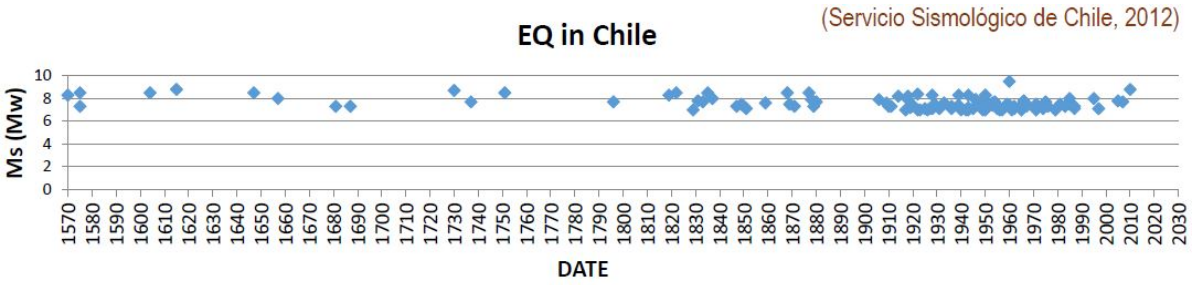

Figure 3.12: The recorded earthquakes with a magnitude of 7 or more in Chile in the last 500 years (Reyes, 2019)

Earthquakes not only cause damage to the infrastructure, but also whole landmasses can permanently be moved vertically or horizontally. This is something to keep in mind when looking at things like relative sea level rise. For example in the 2010 earthquake in Chile it came to light that some landmasses had risen relative to the sea level about 1 to 2 meters vertically and up to 10 meters horizontally (Edge, 2013). As can be noticed, this effect can be orders of magnitude larger than sea level rise.

For information on terminology and overall characteristics of earthquakes, see Appendix A.1.

3.2.7. Tsunamis in Chile

In Chile tsunamis are caused mainly by the three following processes: earthquakes, meteorological reasons and landslides.

Earthquakes:

Earthquakes are by far the most important cause of tsunamis in Chile because of the extreme displacements of water masses that can occur due to earthquakes. In Chile most of the earthquakes occur around the Peru-Chilean trench in front of the coast. This makes it that any displacement of the seabed due to an earthquake displaces the water column located above, causing a tsunami wave (Winckler, 2019a).

The specific location of the earthquake is very important for the amount of energy the tsunami contains. In Chile the place of generation of the tsunami is not more than 150km off the coast in most cases. When earthquakes occur in deeper regions of the Chilean coastline, the tsunami contains more energy (because more water is moved). Therefore, when earthquakes occur close to the deepest part of the Peru-Chilean trench, the energy of the tsunami will be higher compared to a tsunami due to an earthquake that occurred closer to the coast. Most of the tsunamis in Chile arrive at the coast within about 10 to 30 minutes depending on the place of generation (Winckler, 2019a).

Meteorological cause:

Meteorological tsunamis, also called meteotsunamis, are caused by fast changes in barometric pressure or wind gusts above the sea. This causes a displacement of the water body and creating a tsunami-like wave, with a typical timescale between 5 minutes and 2 hours (Winckler, 2018). The relative importance of meteotsunamis in Chile compared to seismic tsunamis is minor. For comparison, the largest recorded meteotsunami wave in Chile is about 1.5 meters. However, it still needs to be considered because in case of other extreme events, the meteotsunamis can cause significant damage (water level variation due to a meteotsunami will add up to for example wave height or storm set up) (Winckler, 2019a).

Landslides

Tsunamis due to landslides occur mostly in the southern part of Chile. This is due to the steep slopes of the fjords around mean sea level. In big rain events the soil on these slopes

can become unstable and landslides can occur. These landslides displace water and create a tsunami wave. In comparison to a tsunami due to earthquakes this type of tsunami contain less energy and only has an impact on local scale (Winckler, 2019a).

For information on overall characteristics of tsunamis see Appendix A.2.

3.2.8. Coastal characteristics

The Chilean coastline is dominated by a hard, rocky coastline with a few steep, small beaches in between. The larger cities close to the sea have protected their borders with primarily hard solutions (figure 3.13 A, E). The beaches are mainly located inside a bay where the beach is protected for the more aggressive waves (figure 3.13 B, C, E), the smaller villages are located near those beaches. As the bay is naturally protected a hard sea defence is not necessary.

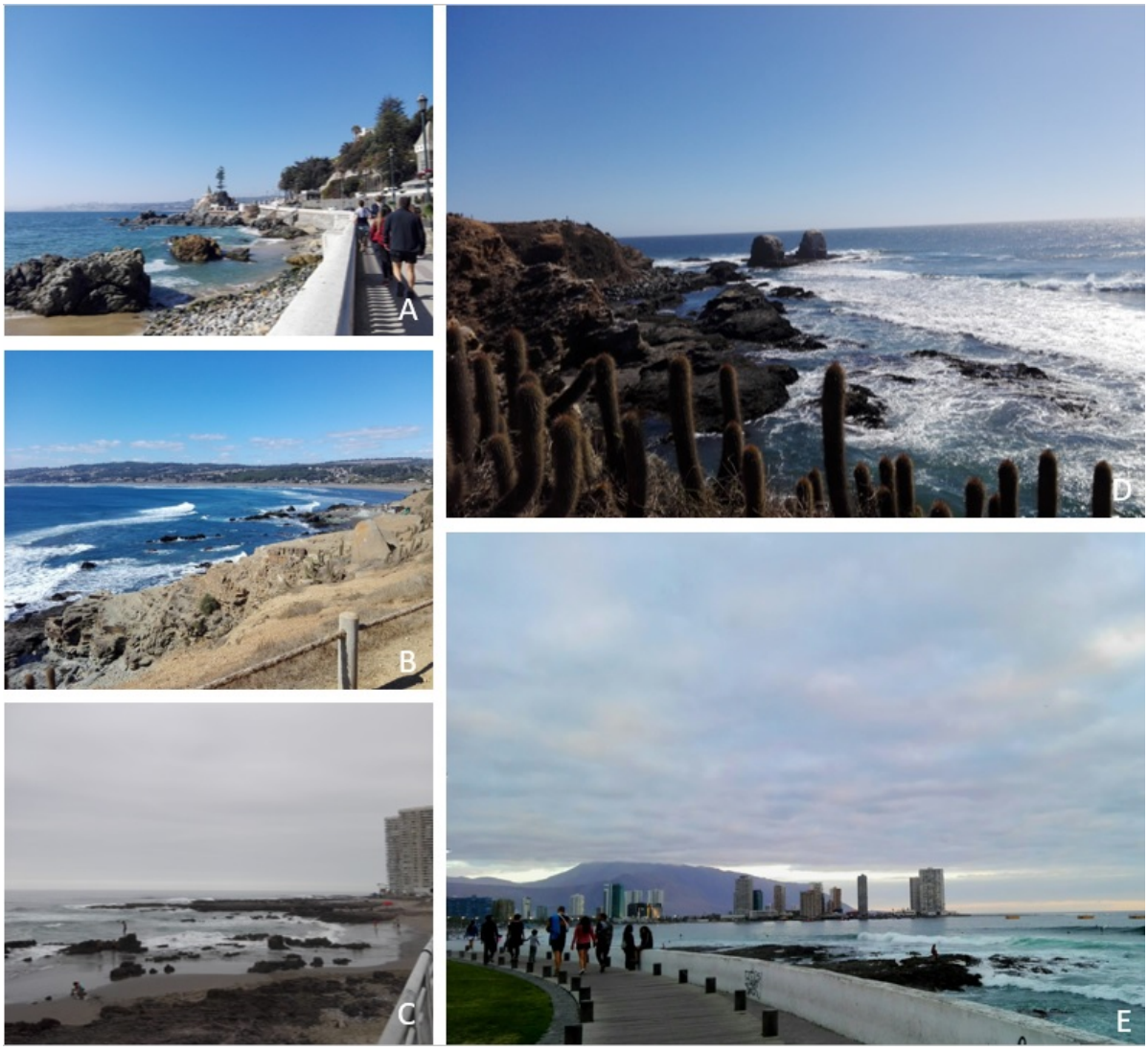

Figure 3.13: Coastline of Chile, Iquique (C, E), Viña del Mar (A), Pichilemu(B, D)

3.2.9. Overview

The Chilean coast shows in different aspects a very dynamic behavior. For the design of coastal structures it is important to understand this dynamic behavior and the possible consequences. A overview of the most important findings is given below.

- Mainly due to the presence of the Peru Chile trench close to the coastline of Chile, rocky and steep coastline can be found. With a hard, rocky and steep coastlines it is harder to apply soft solutions, as used often in the Netherlands were the coast exists of a flat sloping beach with more availability of sand.
- The concentrated rain fall in autumn and winter is also an important point to consider, especially to understand the behavior of the rivers and its sediment transport towards the coast. Rivers can be dry in the summer and transport a large amount of water in the winter, which is a lot more dynamic than the more steady river flow's in the Netherlands. Furthermore, the ENSO-circulation strongly influences the precipitation affecting river discharges as well.
- Through the influences of earthquakes, tsunamis and the snow dominated Mediterranean climate, Chile has a very dynamic coastline with a lot of different extreme events that can take place. The effect of the relatively slow sea level rise, is less than the sudden change in surface elevation which can occur during an earthquake event.

On every location along the Chilean coast those aspects need to be taken into account, but also the local conditions need to be studied in detail.

4

The origin of Building with Nature

A study into the origin of Building with Nature is conducted to have a deeper understanding of the philosophy. This chapter describes the core of Building with Nature and how it has been applied to date.

4.1. The philosophy

Building with Nature is a philosophy based on the analyses of a system as a whole. By including all the aspects of a system, it becomes clear where shortage or disruptions occur and what the consequences are. The philosophy encourages a design approach that moves from building *in* nature to building *with* nature (De Vriend and Van Koningsveld, 2012).

As coastal areas, rivers and deltas are densely concentrated urban areas, the demand for water safety increases. Additionally, stakeholder involvement is a present-day trend that puts a higher demand on the management of a project (De Vriend et al., 2015). This considering, the population of the world growing and the rise of the sea level, adaptation is necessary. For our hydraulic infrastructure this means the need for adaptable designs that are not at the expense of public areas and recreation (De Vriend and Van Koningsveld, 2012). This makes a hydraulic engineering project no longer an exclusive domain for hydraulic engineers. Social, economical, ecological and administrative sciences need to be involved in a design to realize an acceptable solution. For engineers this means that the design process becomes more than being right according to the law of physics and the decision making process becomes more complex (De Vriend et al., 2015). At the same time, the needed developments are often in fragile environments that are dynamic and under constant pressure. Through the Building with Nature philosophy, the balance between development and the sustainable functioning of ecosystems is aimed to be found (De Vriend and Van Koningsveld, 2012).

To design with the Building with Nature philosophy it is important to keep in mind that a design must cope with changing conditions like climate change, can fulfill more than one purpose, and most importantly it does not work against the natural ecosystem but is harmonized with it. Focusing on minimizing the negative effect and compensating for remaining downside effects of the designed infrastructure, the Building with Nature approach aims to utilize natural ecosystems and providing the involvement of nature in the development of infrastructure. Besides nature, the approach provides more involvement of other stakeholders into the design process (De Vriend and Van Koningsveld, 2012). During the development of a Building with Nature project, the aim is to realize a product out of co-creation between problem owners, stakeholders and experts with different backgrounds. This makes a different attitude of all actors involved in the decision making and development necessary and asks for a interdisciplinary and collaborative process (De Vriend et al., 2015). The alignment of engagement of nature and stakeholders and the main function of the infrastructure is the basis needed to create a socially accepted and sustainable infrastructure design (De Vriend

and Van Koningsveld, 2012).

The Building with Nature philosophy has three cornerstones to reach a design of an hydraulic infrastructure (De Vriend and Van Koningsveld, 2012):

- Adaptable solutions
- Active stakeholder involvement
- Governance processes

The Building with Nature program adopted and further developed the idea of using the dynamics of natural systems to create new opportunities for nature and recreation (De Vriend and Van Koningsveld, 2012). Additionally, the philosophy is about meeting the infrastructures demands of society (De Vriend et al., 2015). Changing circumstances as climate change and the consequential sea level rise, are uncertain and relative slow processes (De Vriend and Van Koningsveld, 2012). As are possible changes in societal demands (De Vriend et al., 2015). The use of adaptable solutions allows flexibility in the design in a later stage and gives society time to respond gradually to changing conditions. For this reason, the Building with Nature approach promotes the application of more gradually developing solutions instead of the direct application of a hydraulic structure. When this approach is used in combination with traditional, proven technologies, it can lead to more aesthetically appealing and cheaper solutions whom adjust or can be adjusted to changing circumstances (De Vriend and Van Koningsveld, 2012).

Stakeholder management is an important part of the development of an infrastructure project, but often underestimated. As water-related infrastructure projects are likely to affect the interests of a numerous of stakeholders, especially in densely populated areas. Building with Nature also includes the development together with society. Therefore, stakeholder management is important for numerous reasons (De Vriend and Van Koningsveld, 2012). The philosophy is centered around the societal demands on the infrastructure with the characteristics of the social and natural systems as a starting point. The ambition is not to only deal with these systems, but make optimal use of them and create new possibilities for both (De Vriend et al., 2015). First, project developers should be aware that they are interfering with the social areas and habits of people when a project is located in a populated area. When the stakeholder management is poorly done in a nontransparent way, projects can find themselves with resistance of the local residents (De Vriend and Van Koningsveld, 2012). This often causes cost and schedule overruns and negative publicity in infrastructure projects, which can, in some extent lead to court cases (De Vriend et al., 2015). Besides this, the local population also have a lot of knowledge about the area they live in, which can be helpful for the awareness of the local conditions. Public involvement can in this way lead to a better understanding of the natural ecosystem and can also give beneficial insight in the local processes. The involvement of stakeholders is likely to result in a solution that is respected and supported by the local population. In that end, it is crucial to explore and evaluate the options together with the stakeholders, only then a Building with Nature solution can be found (De Vriend and Van Koningsveld, 2012).

As a final cornerstone of the Building with Nature philosophy, governance processes has to be taken into account. Like all projects, Building with Nature project also have to be inline with the legislation, regulations and procedures to be able to obtain all necessary permits. Building with Nature is also building with society, governance is an important aspect of every project. Governance needs to be approached the same way as we approach an ecosystem. Therefore it is necessary to know how the governance system functions and map the important players (De Vriend and Van Koningsveld, 2012). When this is poorly done and actors are holding a negative attitude towards the project, they can undertake legal steps to block the project. This can be avoided by sufficient stakeholder involvement and complying with the governance processes (De Vriend et al., 2015).

4.2. Organisation in the Netherlands: EcoShape

To prove and demonstrate that the Building with Nature approach can bring substantial added value to a project and enhance the development of the approach, the two major dredging companies in the Netherlands, Royal Boskalis Westminster and Van Oord, initiated the creation of the EcoShape consortium (De Vriend and Van Koningsveld, 2012).

In the EcoShape consortium, parties from three different sectors are working together:

- Private sector (Business parties)
- Public sector (Governance)
- Research institutes (Knowledge)

Within the consortium all sectors have their own role. Where research institutes are the base of the education of the engineers, private parties are executing the project. This, of course, has to be in line with the legislation made by the government, as discussed in the previous section. However, it has to be stressed out that this is not an absolute division. Business parties also gain knowledge based on the execution of projects, which can be used by research institutes for further research. The other way around, new knowledge obtained by research institutions can be used by the private sector during the execution of projects. Also the government can play an active role by giving business parties opportunities to implement innovative solutions. In this way a bridge has been created between the different parties involved, to implement smart and innovative solutions faster. Therefore, it can be said that those three sectors form the triangle of cooperation for Building with Nature, showed in figure 4.1.

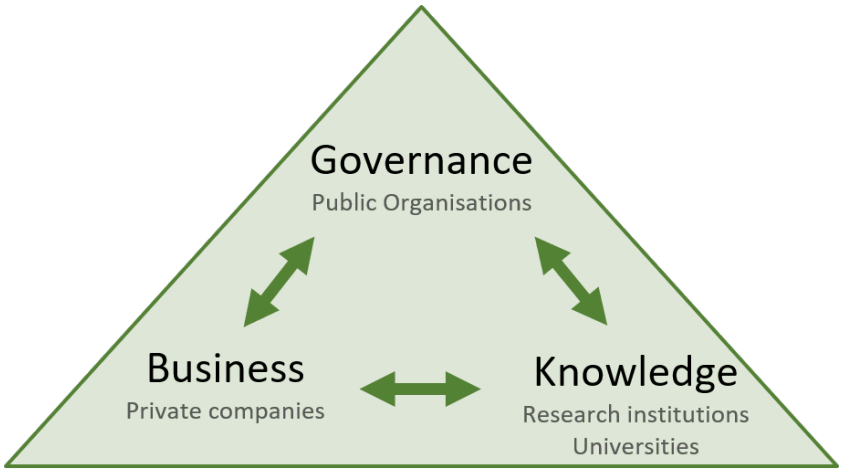

Figure 4.1: Cooperation triangle

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The EcoShape foundation carries out the Building with Nature program mainly in the Netherlands and develops knowledge on this subject. With the wide variety of backgrounds, disciplines and reference frames from the different partners, the consortium has a lot of knowledge and experience. The consortium has enabled a common language, culture and communication across disciplines and organisations, although some are competitors in the market. As the partners operate from one common office, a culture of transparency, trust and respect has been established (De Vriend and Van Koningsveld, 2012).

By operating in this way several objectives are set. Firstly, enabling water-related Building with Nature by gathering and developing knowledge of ecosystems. The aim is to close the knowledge gaps about the dynamic interactions between biotic and abiotic ecosystem

components, ecosystem responses to human activities, ways to deal with uncertainties and multi-stakeholder decision-making processes. A second objective is to develop scientifically based, location-specific design rules and environmental norms that are inline with responsible authorities. Additionally, developing expertise by applying the Building with Nature concept is another ambition of the program. Through various applications of the Building with Nature philosophy in pilot projects, knowledge can be acquired to improve the practical use of the philosophy. This includes the demonstration and validation of Building with Nature solutions with practical examples. Therefore, a portfolio is created of Building with Nature solutions in hydraulic engineering projects that can inspire for future designs. A final objective is researching and developing how it can be ensured that the Building with Nature concept is adopted by society. This enhances the likelihood that Building with Nature alternatives are considered in the development of projects (De Vriend and Van Koningsveld, 2012).

There is no standard handbook available on how to apply Building with Nature on every project because the approach differs for each of them as local conditions form the base for the design. However, guidelines, which can be followed for every project are given. The Building with Nature program is set up according to the learning-by-doing approach, in which all parties (from governance, knowledge and business) are closely involved. These experiences are used to update the Building with Nature guidelines. Building with Nature is specialised in projects in five environments: sandy shores, estuaries, tropical coastal seas, shallow shelf seas and deltas lakes (Deltares, 2018).

4.3. Building with Nature guidelines

To apply the Building with Nature to projects, guidelines are given containing five steps that can be followed (Deltares, 2018). The first two steps are elaborated upon in more detail as these steps make up the largest part of the approach to Building with Nature in this report.

- **Step 1: Understand the system (including ecosystem services, values and interests).**

This step is the most important step in a Building with Nature design. Before you can start thinking about realistic alternatives there needs to be a clear understanding of the system. The system that has to be considered is the physical system and socio-economical system with its governance context. The system is highly dependent on the main objectives of the project. When first having clearly defined these objectives, the system boundaries can be defined.

When looking for user functions and ecosystem services one has to look further than only the values directly related to the main objective. This includes gathering information on the system from different resources and perspectives. This can be in the form of interviewing people with local knowledge or research in historical files to better understand the origin of the system. These steps help in arriving to a multipurpose solution (Deltares, 2018).

Ecosystem services are used in determining the main values of a system. Ecosystem services are defined as: ”the benefits natural ecosystems provide to people” (The Nature Conservancy, 2019). They can be categorized in the following three broad groups: provisioning services, regulating services and cultural services. In figure 4.2 an overview of different ecosystem services that can exist within a system are depicted. This image can be used as a guidance in finding all the ecosystem services of the project specific system (The Nature Conservancy, 2019).

- **Step 2: Identify realistic alternatives that use and/or provide ecosystem services**

Moving from the traditional reactive perspective (focusing on solving the problem) to a more proactive perspective (where problems are turned into opportunities) is essential in this step of the overall Building with Nature concept. Answering some of the following important questions, also indicated in the guidelines, can be helpful for coming up with realistic alternatives (Deltares, 2018)

Figure 4.2: Overview of different ecosystem services that can exist within a natural system (The Nature Conservancy, 2019)

- How can we strengthen the functioning of the receiving system (ecology, recreation, landscape)?
- Larger scale: how can a project deliver benefits to the overall system in which it resides?
- Smaller scale: how can the project (with small adaptations) be more eco-friendly?
- How can better use be made of locally active (natural) resources: tide, waves, gradients, sediment availability, flora, fauna, economy, cultural values, etc?

- **Step 3: Evaluate the qualities of each alternative and preselect an integral solution**

In this step the alternatives need to be selected and combined to come to an integral solution. Important aspects in this process are:
- A higher value does not always imply higher costs of construction
- Dare to be creative and innovative
- Have a clear identification of all the uncertainties and handle them well
- Involvement of the stakeholders in the selection of alternatives.
- Perform a cost-benefit analysis including the valuation of nature.

- **Step 4: Fine-tune the selected solution (practical restrictions and the governance context)**

- **Step 5: Prepare the solution for implementation in the next project phase**

These five design guidelines are a basic process that can be applied to every phase of the project cycle. It is best to apply the Building with Nature steps as early as possible in the project cycle. Additionally, for every project the application of Building with Nature is different and no standard recipe of the implementation of Building with Nature on cases exists.

Building with Nature can be applied to every project as long as there is enough available information on the natural ecosystem. This does however not imply that this leads to a fully Building with Nature solution. In some cases it may be that a hard structure (not specifically a natural solution) like a breakwater or a dike serves the project best. In this case the Building with Nature process still makes one conscious about the certain impact of an intervention on its surroundings and in particular on the ecosystem (IADC, 2017).

4.4. Example projects

To give a better illustration of Building with Nature projects, three different example projects are discussed. The projects are the oyster reefs in the Eastern Scheldt (the Netherlands), mangrove forests in Indonesia, and the sand engine at the Dutch coast. This clearly shows the variety of Building with Nature solutions.

4.4.1. Oyster reefs, the Netherlands

The tidal flats in the Eastern Scheldt, an estuary located in the South-West of the Netherlands are prone to erosion. This is caused by the Eastern Scheldt barrier (build in 1986), located at the seaside of the estuary. This storm surge barrier, reduces the tidal prism and the current speeds. Therefore, the tidal channels are too large and started gaining sediment from the tidal flats, since no sediment import is available from the North Sea. The tidal flats offer a good habitat for birds and other species, which means the biodiversity is in danger (Smaal and Nienhuis, 1992). Furthermore the flats serve as wave reduction to protect the coast (De Vriend and Van Koningsveld, 2012). This means the disappearance of the tidal flats not only negatively influences biodiversity, but also water safety is compromised.

In order to stop this, oyster reefs are planted on the tidal flats (see figure 4.3) in order to trap the sediment and reverse the erosion into accretion. The first results are positive and in line with the expectations: sedimentation of the tidal flats occurs. In one of the cases however, more sedimentation than expected is taking place, which can also damage the established oyster reefs (De Vriend and Van Koningsveld, 2012).

Apart from the technical part of this Building with Nature solution, also the stakeholder involvement following the guidelines is visible. A good example is the involvement of the shellfish growers, which were concerned that the oysters might compete for food with the shellfishes. After research it was shown this was not the case. Furthermore different ecosystem services can be recognized: coastal protection, cultural identities (the existence of biodiversity) and food production. This underlines the Building with Nature approach of this case.

Figure 4.3: Oyster reefs, Easter Scheldt (WUR Marine, 2018)

4.4.2. Mangrove forest, Indonesia

In northern Java (Indonesia), coastal erosion effects a large part of the coastline. This is caused by the removal of mangrove belts because of the placement of hard coastal defence structures (which did not function well, as the erosion problems clearly shows). The natural system was disturbed by these interventions preventing the capture of sediment along the coast. Also groundwater extraction resulted in land subsidence (Ecoshape, 2019). In figure 4.4 the location of the coastline over the years is visible. At some points along the coast the coastline moved land inwards more than 1 km within 10 years.

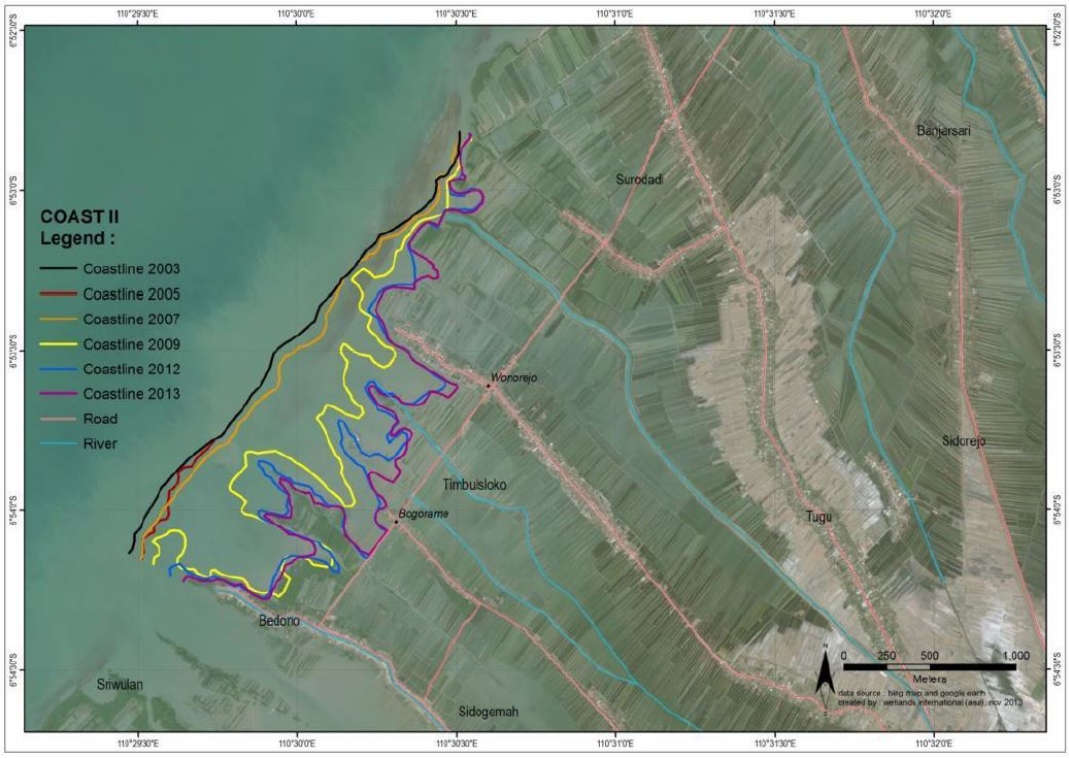

Figure 4.4: Erosion along the Indonesian coast near the town of Demak (Wetlands International, 2017).

To solve the erosion problem, a Building with Nature solution has been found. Semi-permeable barriers are built for the damping of the waves and caption of the sediment. These barriers consist of poles and brushwood. Over time, if the sediment capture is increased to a sufficient level, nearshore mangrove starts to grow again, which helped in protecting the coastline from eroding. On the other hand dialogues were started with local communities to reduce groundwater extraction to reduce land subsidence (Ecoshape, 2019). Not only local communities are involved in this process: also the government, private sector and students play a role. Educational lectures given to these target groups address technical, socio-economical (improved aquaculture), and institutional (integrated Coastal Zone management) matters (Wetlands International, 2017).

This project is clearly in line with the Building with Nature philosophy. It involves a nature based solution for restoration of the mangrove forest. The new forest furthermore protects the coast from erosion in a natural way. On the other hand, different kinds of stakeholders are involved from the start of the project. And also different Ecosystem services (described in step 1 of this chapter) can be recognized within this project: coastal protection due to the mangroves, food production (by means of introduction of sustainable aquaculture) and cultural identities. Therefore this is a good example of a Building with Nature project.

4.4.3. Sand engine, the Netherlands

The coast of the Netherlands exists of a mildly sloping sandy beach. The beach fulfills multiple purposes. On one hand it is important for recreational purposes, but on the other hand the beach (and the dunes) play an important role in the coastal protection. Erosion of the beach is therefore considered to be a problem.

From 1979 onward this maintenance of the beaches has been done by Rijkswaterstaat (part of the ministry of Infrastructure and Water management) by compensating the eroded sand in the form of beach nourishments (Atlas, 2019). To cancel the structural erosion along the dutch coast 6 million m^3 of sand per year was needed. This amount increased to 12

million m^3 per year in 2001 due see level. According to current predictions a further increase to 40-85 million m^3 sand per year in 2100 is needed. Moreover, the frequent (one every 4 years) nourishments disturbed the ecosystem close to the seabed. Therefore, the question was raised whether other solutions to reduce beach erosion were possible (De Vriend and Van Koningsveld, 2012).

A new, innovative approach was chosen to replace those small, frequent nourishments by a single large amount of sand (21.5 million m^3), located in the south, covering a area of 100 hectares. The northward directed sediment transport distributes the sand along the Dutch coast. In this way erosion is prevented for the next 20 years according to present predictions (De Vriend and Van Koningsveld, 2012).

Not only coastal safety was considered, but also other aspects were of importance by designing the sand engine. To give space to nature, the sand engine is a hook-shaped peninsula with a shallow lagoon to offer place to different kinds of species. Furthermore, recreational purposes are met in the form of a visitor centre, observation tower and a place for wind, wave and kite surfers. This project has been finished mid 2011 and is functioning as expected. (De Vriend and Van Koningsveld, 2012)

Figure 4.5: Sand Engine (Landschap, 2019) (kitesurfschoolbest, 2019) (Anantis, 2019), (Google Earth, 2018e)

5

Case Studies

5.1. Introduction

In the previous chapters the background of Chile and the Building with Nature philosophy with the EcoShape consortium are explained. In this chapter three Chilean case studies are used to show the potential of Building with Nature in coastal projects. In this way, the wide applicability of Building with Nature is underlined.

Each case is located in a different coastal town in Chile. The case studies are all focused on a specific project or problem in the area. The three cases which are elaborated upon in this chapter are listed below:

- **San Antonio**: Harbour expansion project
- **Pichilemu**: Beach and dune erosion problem
- **Los Vilos**: Beach erosion problem

During each of the cases, the first two steps of the Building with Nature guidelines are carried out. A full overview of the guidelines is shown in the previous chapter in section 4.3. Whereby, the first step is to understand the system and the second step is create Building with Nature design alternatives. The alternatives are elaborated upon in the form of a first example on how to use Building with Nature in a possible solution. This is a first example which needs more research in later stages to really technically validate the given examples. In this report this functions as a first local Chilean example of Building with Nature on different case studies, and to also get a first idea on how Building with Nature can possibly be applied in Chile.

The structure within the report of the three different case studies is aligned and corresponds to the following: After a short introduction about the location of the case study, the problem is described. After knowing the problem and objective of the case study, the system boundaries are defined. To understand the full system, the system analysis is divided in two parts: the natural system and the socio-economic system. The natural system describes the physical characteristics of the system with all the relevant components. Within the socio-economic system description, the land use plan of the area is made and all the relevant stakeholders within the area are mapped. After a conclusion of the integral system analysis, a first Building with Nature example is shown for each case study to possibly solve the problem.

5.2. San Antonio

San Antonio is a city located about 180 kilometers west from Santiago at the Pacific coast. The city was founded in 1894 and currently has around 90,000 inhabitants (Wikipedia, 2019).

Puerto San Antonio is the main port of Chile, located in the central zone of Chile, being the port terminal closest to Santiago, the capital of the country. The area of influence of the port stretches out in the central zone of Chile and the province of Mendoza, in Argentina. Puerto San Antonio has competitive advantages over other terminals in the region because of the strategic location, excellent road and rail connection with the inland, favorable topographic conditions and a large number of support areas to project growth and integration to port infrastructure (EPSA, 2019). The current capacity of the port is 3 million TEU (Invest Chile, 2018). However, it is not fully used: according to Horacio Moggia and Hartwig (2019) around 2.3 million TEU is shipped every year. Two pictures of the port area can be found in figure 5.1.

In 2012, an ambitious investment plan was initiated, which includes the construction of a new berthing front of 700 meters. This plan is the largest project in the country in order to provide efficient and flexible services to fulfill the needs of customers in a more globalized and competitive market (MundoMarítimo, 2019). To give the local stakeholders a positive perception on the port and emphasize that the project will not interfere with the city, the name was changed from Puerto Gran Escala (Large scale port) to Puerto Exterior (Exterior port) (Bartelink, 2019).

Figure 5.1: Two photos of the San Antonio port, taken during a site visit to the port. At the left a photo of the terminals in the main port can be seen. An image of the fishery port is visible in the right photo.

On the 10th of April 2019, a site visit to San Antonio has been performed by the project team. During this visit also a short boat trip was made to see the port from the waterside. Hereby Loreto Denisse Trigo, a master student performing her thesis on the San Antonio port and a local resident, assisted the project team and provided additional information. Moreover, two meetings were arranged with the municipality and the terminal operator PCE.

Besides the use of the information gathered during the site visit, a literature study is done to analyse the San Antonio case.

5.2.1. Problem statement

The international trade is an important contributor to the Chilean Economy. Most of the trade is handled in the ports. According to projections, the demand will grow in the future, especially in the Valparaíso region (EPSA, 2019). Therefore the capacity is expected to be exceeded between the year 2025 and 2030. In order to cope with the growing demand, a port expansion of 9 million TEU is planned for the port of San Antonio, increasing the total port capacity to 12 million TEU. Due to the limited space on the land, a seaward expansion of the port is proposed. The name of this project is: 'Puerto Exterior de San Antonio' (Puerto San Antonio, 2018).

As mentioned in section 3.1.5, where project plans in Valparaíso regarding a port expansion are discussed, the president of Chile, Michelle Bachelet, awarded the port of San Antonio with state support for the port expansion. This also had an influence on the development of the Valparaíso port. For more information on the Valparaíso case, see chapter 3.1.5.

In the current design of the port expansion, a Building with Nature approach seems not to be followed. Therefore, the aim of this section is to come up with a Building with Nature alternative for the Puerto Exterior.

5.2.2. System boundaries

In the figure 5.2 a map of San Antonio is shown. Everything within this map is considered when analysing the system. For the natural system the main focus is on the port area. At the south of San Antonio, the Maipo river is located, which is expected to bring sediment into the coastal system. Also the inflow of sediment at the southern boundary is taken into account. Furthermore, the wetlands which are of natural value are pointed out. The small coastal town of Santo Domingo, located south of San Antonio, is important to consider because of the possible influences of the port expansion.

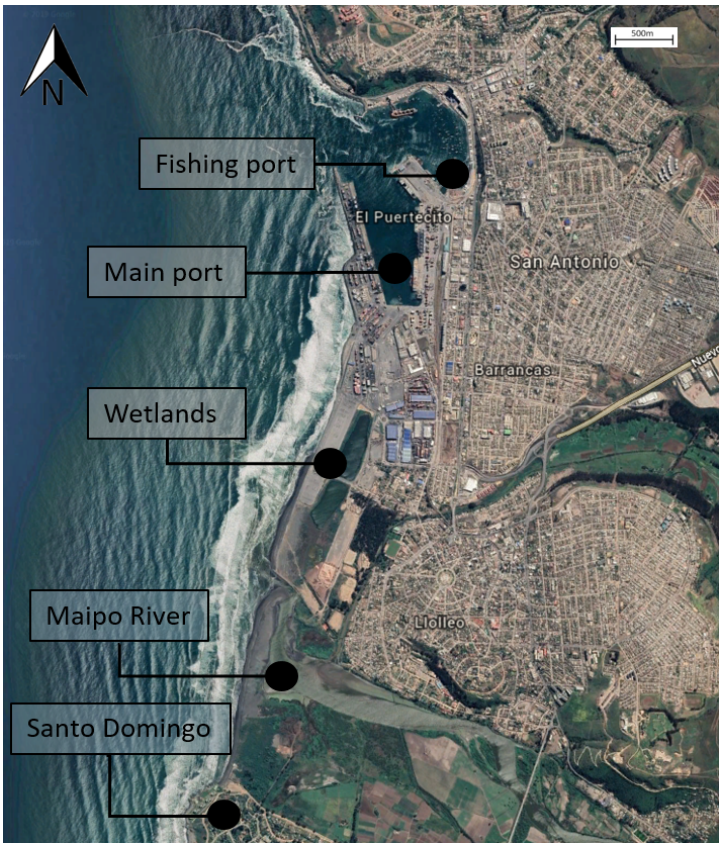

Figure 5.2: The system overview of San Antonio (Google Earth, 2018c).

5.2.3. Natural System

To be able to come up with a Buiding with Nature design for the port expansion in San Antonio, first the natural system is analysed. The main focus is on the morphological aspects, since the sediment could play an important role in the expansion of the port.

Bathymetry

In figure 5.3 the bathymetry near the San Antonio port can be found. As can be seen a deep canyon is located at the north side of the port, reaching depths of over 50 meters in the vicinity of the port. The unique presence of the canyon in the north also affects the wave behaviour which is explained in the next part of this section. Further to the south, the water is more shallow and the contour lines are more parallel to the coast. Around 400 meters offshore, a water depth of ten meters can be found. The water depth in the sheltered port area is in between ten and twenty meters, this depth needs to be maintained by dredging works (International Dredging Review, 2019).

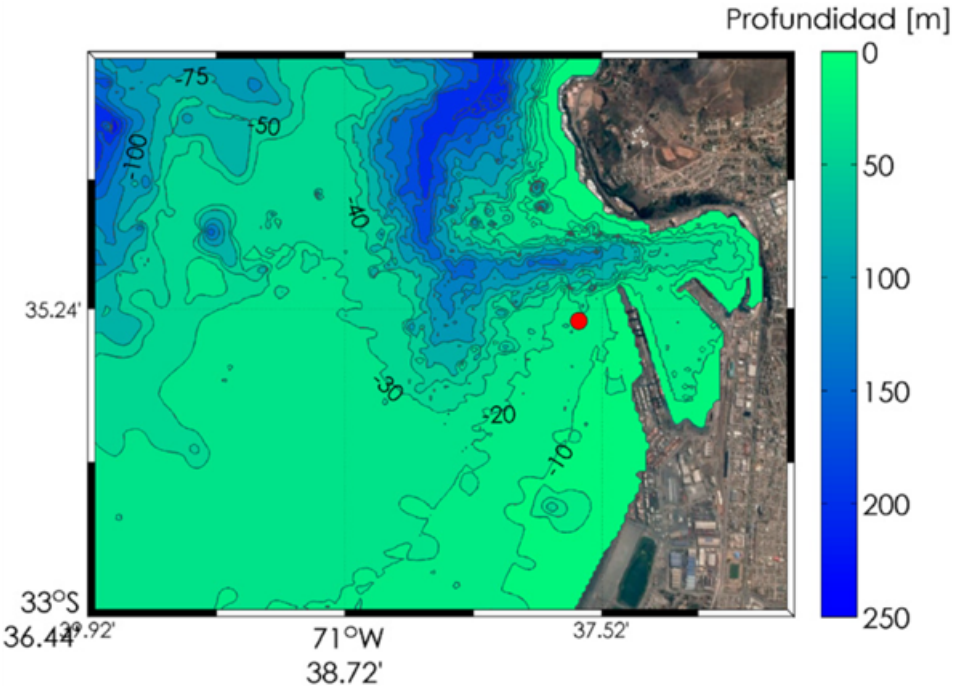

Figure 5.3: Bathymetry near San Antonio (M. José Beyá, 2016)

Waves

To describe the offshore wave characteristics, wave data from Valparaíso, located 75 kilometers northward of San Antonio, is used. This is the offshore data point closest to San Antonio. It is assumed that these offshore wave characteristics are similar in San Antonio This assumption can be made because in the part of the coastline from the data-point to San Antonio, the coast is very steep, so offshore wave date in both locations is not influenced by bathymetry and considered to be similar. As can be seen, the main wave direction is from the southwest. However, extreme wave events are also coming from the northwest, as indicated in the right of figure 5.4.

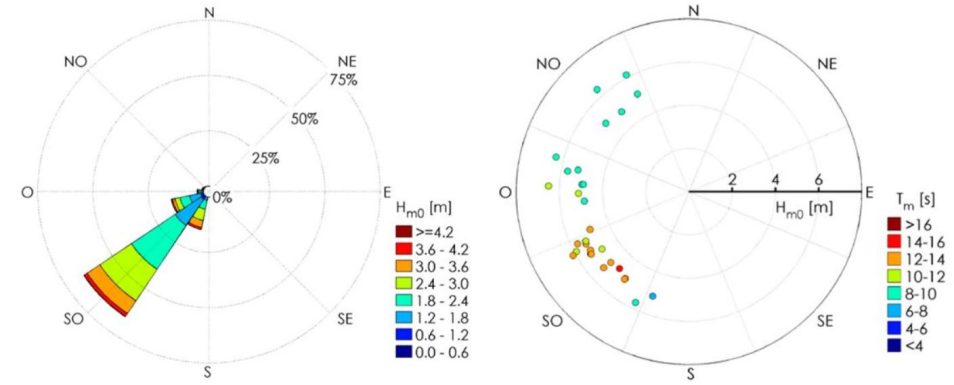

Figure 5.4: In the left the offshore wave rose near Valparaíso is shown. In the right figure the extreme wave events with direction are shown (M. José Beyá,2016).

More nearshore, a different wave pattern can be found. The location of the considered point is indicated by the red dot in figure 5.3. As can be seen in figure 5.5, the main wave direction in this point is from the northwest. This nearshore wave transformation was done using a numerical model. This change of direction occurs due to the presence of the canyon in the north. When offshore waves from the southwest direction propagate to the nearshore they refract due to the underwater canyon. Depth contours of the canyon are visible in figure 5.6. When looking at the extreme wave rose event, all extreme wave events also refract due to the canyon and come from the northwest, which should be taken into account when designing the lay-out of the new port.

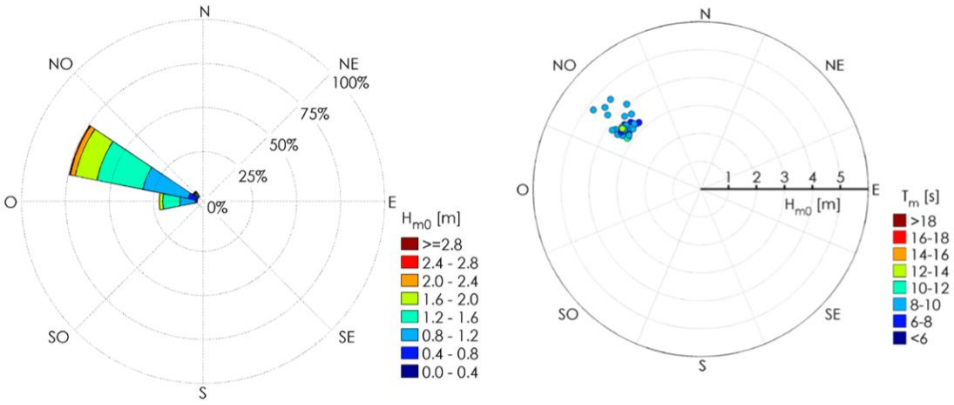

Figure 5.5: In the left the nearshore wave rose at San Antonio is shown. In the right figure the extreme wave events are depicted with nearshore direction (M. José Beyá, 2016).

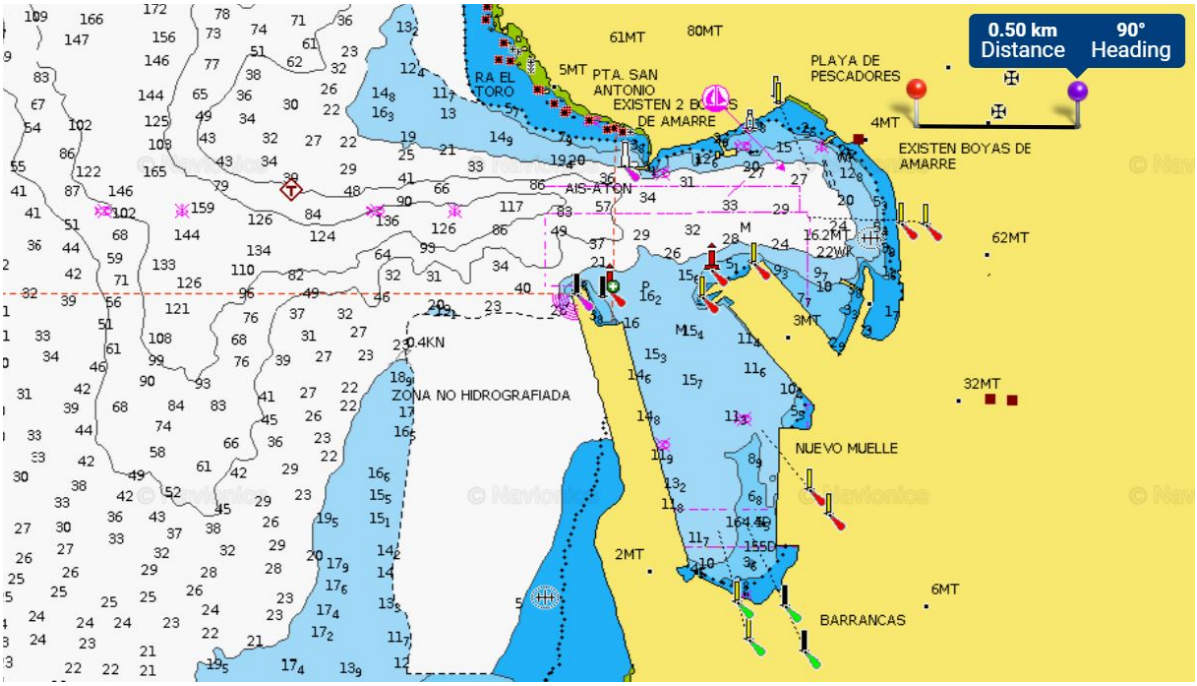

Figure 5.6: Depth contours in front of the San Antonio harbour where the underwater canyon is visible (Navionics, 2018).

Sediment transport

The sediment transport direction is from south to north near San Antonio, which corresponds to the wave characteristics discussed in the section above. Due to the presence of the canyon (which the sediment is not able to pass), there is no influence of the sediment transport north of the port, and thus it can be concluded that the sediment near San Antonio has to origin from the south. Evidence of the northward directed sediment transport can also be found when looking at pictures before and after the construction of the present port of San Antonio. In figure 5.7, major accretion at the southern side of the breakwater can be seen over a period of 100 years.

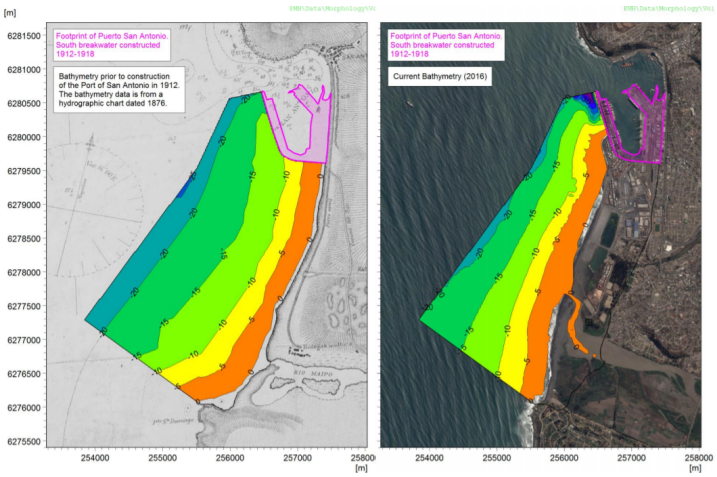

Figure 5.7: The visualisation of the accretion after the construction of the current port of San Antonio (Puerto San Antonio, 2018).

A more recent example also shows the large amounts of sediment transport on the coast of San Antonio. This is illustrated using Google earth satellite images. The first image in figure 5.8 shows a stranded ship in front of the San Antonio coast near the outflow of the

Maipo river at 28/01/2013. The second image shows the same situation on 19/04/2013. As can be seen, a lot of accretion has occurred between the coast and the ship forming a tombolo-like shape. This evolution of the coast in less than 3 months time, indicates the large amount of sediment present in the system.

Figure 5.8: Two Google earth satellite images on a stranded ship. The left image is an areal photograph on 28/01/2013, the right image is from 19/04/2013 (Google earth, 2013).

River Maipo

As pointed out earlier, the Maipo river is located south of the port. The main water source of this river is melting water from the Andes mountains in spring. During spring the highest river discharges can be found. During the other seasons of the year the river discharge is rather low. A unique characteristic is that the river is not interrupted by dams or other structures which can trap sediment. However, in the last years the discharge at the mouth of the Maipo river has been very low, and less sediment is being transported. A possible reason for this is the water (and sediment) extraction for irrigation in the upstream part of the river (Roja, 2019). Therefore also the sediment contribution of the Maipo river to the coastal system is likely lower than in the past. However, not much data on sediment and water discharges exist, so no hard conclusions can be drawn.

Wetlands

South of the port, two wetlands are located. Those wetlands originate from around 1940 when the port decided to redirect the Maipo river. From this, a wetland with three different lagoons was created. However, one of them disappeared after the earthquake and tsunami in 2010 (Roja, 2019). At the moment, the wetlands are functioning as a nature area which is of large importance to the local community, therefore the preservation of these wetlands is also important (Trigo, 2019).

Tsunamis

Since San Antonio is a relatively low lying city near the coast with frequent occurrence of earthquakes, the city (and port) are also tsunami hazard zones. A map of the tsunami inundation zone can be found in appendix B.1.1. This stresses out the importance of taking into account the tsunami effects during the design of the new port.

5.2.4. Socio-economic system: land use

Figure 5.9: Land use San Antonio (EPSA, 2013)

San Antonio is a port city, where most of the inhabitants are directly or indirectly earning money from the port business (Trigo, 2019). Therefore, the port is of high importance to the city. As can be seen in figure 5.9, the residential areas surround the port area. Fisheries are located in the north part of the port and the nature areas are mainly concentrated around the river mouth, at the south of San Antonio (EPSA, 2013).

5.2.5. Socio-economic system: stakeholders

To understand the socio-economic system in San Antonio, the stakeholders in the area are considered. This will give a clear view about the general opinion on the port expansion and the wishes of the various parties involved.

Municipality of San Antonio

'Our commitment is to improve the benefits of municipal services, financial efficiency, incorporating to municipal management the improvement of human resources, citizen participation, particularly in the formulation of projects and/or programs' (I. Municipalidad de San Antonio, 2019a). During the meeting with the Chief Economic Development of the municipality of San Antonio, Oscar Tapia Rojas (2019), it appeared that the municipality of San Antonio has a different relation with the port than most Chilean port cities. The municipality is closely involved in the port expansion plan as, among other things, they are in charge over the land use of the area.

The state works on a new law that obligates EPSA to have the mayor of San Antonio in the board of the port authority and to introduce taxes on port transport in order to compensate for the strain that the port puts on the city. Due to accretion at the south side of the port, new wetlands were created, which are municipal property. The municipality agreed to give these wetlands to the port authority EPSA in return for the conservation and creation of new ecological areas at the north side of the city. In general, the municipality has a positive attitude towards the port expansion project, but is worried that the port will suffocate the city by expanding around it. This is why they are strict on the planification of the land use in San Antonio. To enhance the knowledge of port technologies in the city, the municipality

works together with STC Rotterdam in the Netherlands to establish a national knowledge institute on port technology in the city. They arrange this by organizing courses for the port employees and including port technologies in the high school program.

Local residents
In general, the local residents are positive about the port expansion. After a survey that Loreto Benisse Trigo (2019), conducted among 150 residents, it appeared that 68% of the local residents were in favor of the port expansion. Around 50% of the residents work in relation to the port, directly or indirectly. As the port expansion will be onshore and not inshore, the expansion will not be to much interfering with the city, like it will be with the port expansion in Valparaíso. The expansion of the port will be located onshore near the current industrial area, which causes less impact on the residents as it would in Valparaíso (Bartelink, 2019).

Illegal inhabitants of the wetlands
Due to the accretion on the south side of the existing harbour, new land is created. The land is confiscated by inhabitants, lead by Juan Aspee, that build their houses (called 'Toma') on the new wetlands illegally. The wetlands also created new environmental value for the area (Trigo, 2019). The municipality changed the land use of the wetlands in the possible use for the port area. EPSA therefore bought most of the land and houses from the owners. There are four families left in the wetland area. The prediction is that they will also sell their house to EPSA on short term. EPSA is responsible for the preservation of the nature area (Roja, 2019).

Fishermen's Associations
El Sindicato de Pescadores Buzos Embarcados de San Antonio is the Fishermen's Associations of San Antonio (I. Municipalidad de San Antonio, 2019b). The area of the fisheries belongs to the EPSA due to an outdated law. This is why the fisherman now have a contract with EPSA that they can stay in the port for 30 years (Roja, 2019). The Fishermen do, in general, not oppose against the port expansion project but are concerned about the Hake population in the area due to the dredging of the port. They want EPSA to include this in the EIA (Galdames, 2019).

Port Authorities: Empresa Portuaria de San Antonio (EPSA)
EPSA is the responsible and financial power of the port expansion project. EPSA, as the port authority of San Antonio, must ensure to comply with the rules established by law by maintaining competition within and between ports to ensure the continuity of the development and growth in benefit of the country's economy and the community of San Antonio (EPSA, 2019). EPSA invests in the development of new projects and businesses that generates value to the company and community and that allow the differentiation and improvement of competitiveness, promoting the efficient use of resources and the use of the best available technologies in the value chain of the port operation. EPSA is obligated to invest in the development of the area that is indirectly used by the port, as warehouse and logistic areas. Besides this, EPSA is responsible to conduct a Environmental Impact Assessment (EIA) (Roja, 2019).

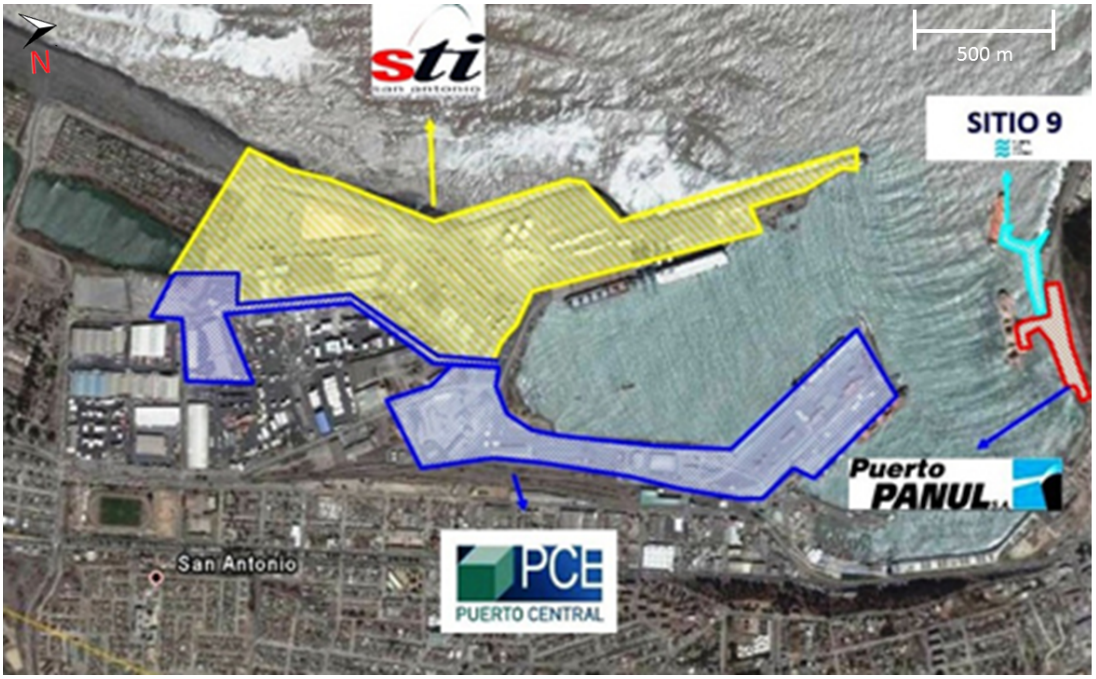

Figure 5.10: Terminal use of the San Antonio port, (Google Earth, 2018d).

Terminal Operators

As can be seen in figure 5.10, there are three terminals in the port of San Antonio, operated by different companies. For the port expansion project, these terminal operators are not considered as stakeholders by EPSA (Horacio Moggia and Hartwig, 2019).

- *San Antonio International Terminal (STI)*: STI is the most modern and efficient port terminal in South America and has three berths. It is located on the west coast of Chile and operates the concession of the Molo Sur Berth Front of the Port of San Antonio. It has the largest Gantry cranes in the country and the west coast of South America. This equipment, together with the very high levels of efficiency achieved by its operations, contribute to positioning itself as the terminal with the highest yields in container transfer in this part of the continent. The investors in STI are SSA Marine and SAAM (EPSA, 2019).

- *Terminal Puerto Central (PCE)*: In May 2011, Puerto de Lirquén S.A., the 20-year concession of the west terminal of the San Antonio Port was awarded to the Costanera-Espigón, carried out by the San Antonio Port Company (EPSA). In July 2011, Puerto Central S.A was incorporated with the purpose of constructing, developing, maintaining, repairing and exploiting the Costanera-Espigón terminal of the San Antonio Port (EPSA, 2019). In the course of these years PCE has managed to gain a foothold in the car transfer market, were the other two main terminals in the Valparaíso region have their focus on container transport. PCE exploits as a multipurpose terminal and has 4 berths in the port of San Antonio (Horacio Moggia and Hartwig, 2019).

- *Puerto Panul Terminal*: The Puerto Panul terminal has one berth and is the largest solid grains operator in Puerto San Antonio. Its main business area is to exploit the dock front, where the wharf services, cargo transfer and other services inherent to the port activity are provided. The bulk ships are served by a Level Luffing crane, which can discharge 700 tons per hour (EPSA, 2019).

- *Terminal Sitio 9:* Sitio 9 operates under a multi-operator system, managed by EPSA, specialized in the transfer of liquid bulk and has one berth (EPSA, 2019).

Tourism: Cruise terminal
As it is the main port of Chile, the San Antonio port has a cruise terminal. The cruise terminal was moved from Valparaíso to San Antonio in 2017 and is operated by PCE (Horacio Moggia and Hartwig, 2019).

State Railway Company (EFE).
Puerto San Antonio also has a railway station. The lines that provide transportation service belong to the State Railroad Company (EFE), whose railway expansion connects Santiago with San Antonio and is for the exclusive use of cargo. Its network makes it possible for the railroad to reach all terminals in San Antonio Port (EPSA, 2019).

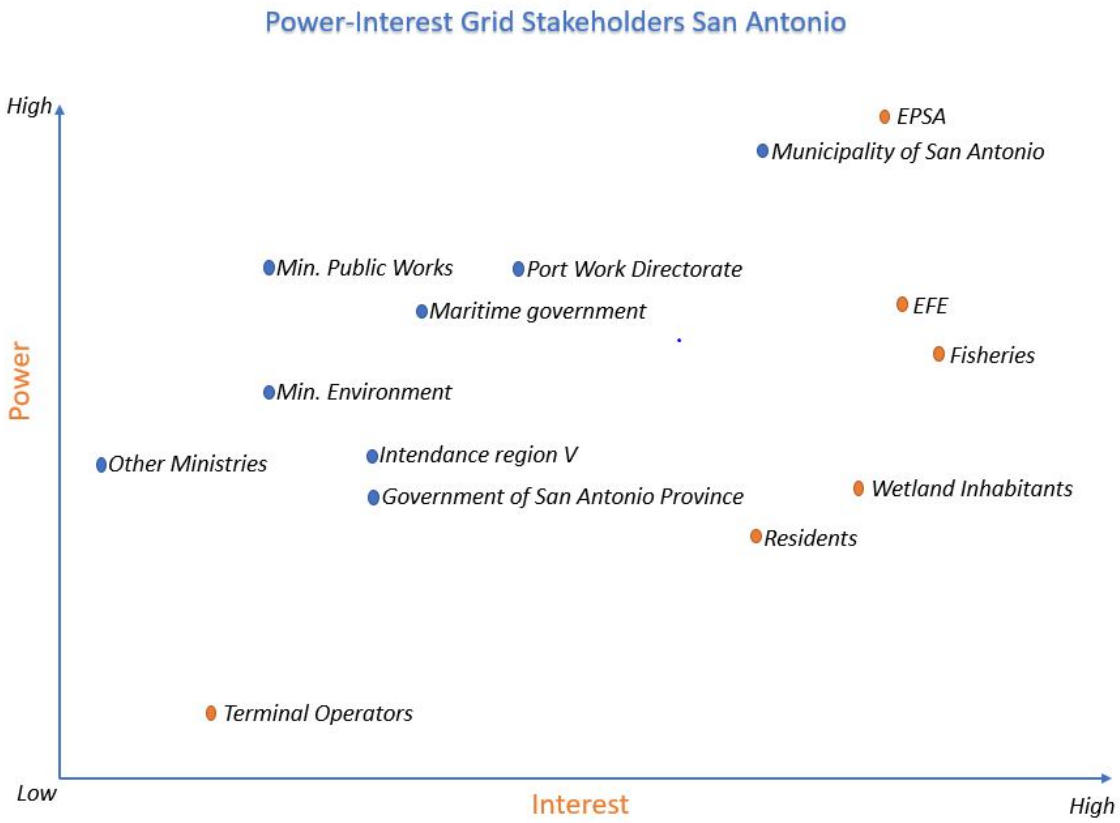

Figure 5.11: Power-Interest grid San Antonio

To get insight on the stakeholders position, a power-interest grid is made. This can be seen in figure 5.11. Local stakeholders are identified in orange and the regional and national stakeholders in blue. The PI-grid shows the level of interest and the level of power of all stakeholders in the San Antonio port expansion project. The stakeholder with high power and high interest needs to be managed closely. In this case this is EPSA as a port authority and the municipality of San Antonio. The fisheries, local residents and the railway company EFE have a high interest in the project but have less power.

5.2.6. Conclusion system analysis

During analysis of the physical system it is shown that the unique presence of the canyon north of San Antonio, greatly influences the wave characteristics. The main wave direction is from the southwest, however due to the canyon refraction takes place. Therefore near the port, the main wave direction is from the northwest. Important to notice are the northwest storms during winter. A recent study indicates a more frequently occurrence of storms, how-

ever, more from south-westerly directions (see chapter 3.2.3).

The sediment transport near San Antonio in front of the coast is northerly directed. The sediment originates from both the river Maipo as well as from the southern system boundary. More recent, the input from the Maipo river has decreased. However, there is enough evidence to say that a lot of sediment transport is still present within the system. The sediment transport is blocked north of the port due to the canyon. For the future port, it is important to incorporate the wetlands in the design, because those are of environmental value for the city.

For the socio-economic system in the area of San Antonio, it is possible to say that the general opinion towards the port expansion is positive. There will be new employment opportunities for the city of San Antonio and more income can be generated. The fisheries are worried about the impact that the new port will have on fish population. They want this to be a part of the Environmental Impact Assessment. In the current plans of the port expansion, the terminal operators of the existing port are not considered as stakeholders. It could be valuable to acknowledge them as stakeholders and take their points of view into account.

5.2.7. Building with Nature example

After investigation of the physical and socio-economical system, a Building with Nature example is given in this section for the port expansion of San Antonio. The location of the new port is located in front of the already existing port. A more northerly located port is not possible because of the presence of the underwater canyon. Placement of the port expansion south of the current port is not desirable due to the interference with the natural river outflow of the river Maipo and the preservation of the coastline near Santo Domingo. Therefore a seaward expansion of the already existing port is considered to be the best solution. For the dimensions of the port, the current design by EPSA (port authority in San Antonio) is used as a guideline.

For a seaward expansion of the port a lot of sediment is needed. Dredging of this sediment is most of the times a more costly and environmental unfriendly solution. Therefore, the northward directed sediment transport along the coast could be used as a sediment supply for the land reclamation of the new port expansion.

To do so, the port expansion could be constructed in different phases, to create more opportunities to use the Building with Nature principles during construction. It must be stressed out that this is just an example of how the construction could be done. For the most optimal way of constructing the port, and to validate the effectiveness, more studies and research needs to be done. In the first stage of construction, groynes are placed (indicated in blue in figure 5.12). The goal of this first construction step is to block the sediment transport along the coast and make sure the sediment is captured between the groynes. This causes the most landward part of the land reclamation (number one in figure 5.12) to be filled up with sand making use of the natural sediment transport processes. With this way of constructing the dredging activities during this part of the construction process are limited. The exact orientation of the groins is something that needs to be decided by doing an in depth analysis, also focusing on financial feasibility. Another possible option could for example be to construct breakwaters parallel to the coastline.

Figure 5.12: Building with Nature construction of the port expansion

After that, the perpendicular port breakwater (orange line in figure 5.12) is advised to be constructed. Due to the south to north sediment transport, accretion is likely to occur on the south side of this breakwater. The time scale of this sedimentation process is hard to predict. Further research on sediment transport quantities is advised before starting to make approximations about volumes of accumulated sand. Starting as early as possible with the construction of this breakwater is important to have the highest amount of accretion. This captured sediment can be used in later construction steps, mainly for reclaiming the land of parts two and three of the future port (see figure 5.12).

To use this sediment for construction of the new port, it needs to be transported to the correct location by means of local dredging activities. However, the wave impact in this area will be too high to keep the sediment in place. Therefore, the outer breakwater needs to be constructed first (red line in figure 5.12) to lower the wave height in the port area. After this, part two and three of the new port can be reclaimed using the sand from the sand accretion as described before.

Other available sediment sources within the San Antonio area that can be used for land reclamation are listed below:

- Dredged sediment from the current port of San Antonio can be re-used and function as fill material for the port expansion.
- The current water depth at the location of the future entrance channel of the new port (indicated with number four in figure 5.12) is about fifteen meters on average (see figure 5.7). As big cargo ships need to be able to enter the harbour there needs to be a deepening in this part of the port expansion. The sediment that results from this deepening can be re-used for land reclamation.

After full construction of the port expansion, more accretion on the south side of the breakwater can be expected due to the blocking of northward sediment transport (see figure 5.12). This accretion occurs in front of the river mouth of the Maipo and most probably causes the river mouth to move more offshore. The risks of this change in river mouth dynamics is an

increase in water level of the river in the inland part of the river. This can cause the river to overflow and potentially damage the local environment. Therefore, before the construction there needs to be an extensive study on the morphological processes and the influence of these processes on the Maipo river. Besides this, after the port construction there needs to be active management and monitoring of the river mouth dynamics.

This new area of accretion can also create opportunities for nature and tourism. For example, the new natural accretion that likely occurs can be used as a recreational beach. Moreover, this area can give opportunities for the fisheries to extend their business. Another interesting additional value of the accretion can be a possible recovery of the beach in Santo Domingo. After the earthquake and tsunami of 2010 this beach changed a lot, the main difference is the change from a sandy beach to a rocky beach. This made the beach less interesting for recreational purposes. Possibly, the sand accretion due to the new port construction can provide the Santo Domingo beach with sand. It must be said that this is a very uncertain added value and a more extensive research on this is advised.

5.3. Pichilemu

Pichilemu is a fisherman city southwest of Santiago, located in the central zone of Chile in the O'Higgins region. It is the capital of the Cardenal Caro province. The first settlements of the city were founded at 1544. At first it was established as a sub delegation in 1867, and later as an autonomous commune. At the moment, Pichilemu has about 14000 inhabitants.

Pichilemu is known as a world famous surf spot, in particular the beach of Punta de Lobos is well known. The point breaks of Punta de Lobos has caused the involvement of Pichilemu as the World Surf Capital with championships of international relevance. Therefore tourism is the most important industry of the city. However, forestry and handicrafts are also of importance (Wikipedia, 2019).

A site visit has been done to Pichilemu to see the environment and talk with different local stakeholders. On the 4th and 5th of April 2019 meetings have been conducted with the following local stakeholders:

- Flor Ilic: Director Culture center Pichilemu
- Andres Margozzini and Sophia Claro: Fundacion Punta de Lobos
- Genaro Guerrero: President of Fishery federation Pichilemu
- Daniela Paz González Cordero and Macarena Cornejo: Municipality of Pichilemu
- Nicolás Recordón: Surf community

For the analysis of the Pichilemu case, both the input from the meetings and the findings of the literature study are used.

5.3.1. Problem statement

As mentioned in the introduction, Pichilemu is economically dependent on tourism. Since the tourism particularly focuses on surf related activities, the state of the beach is very important. However, over time erosion has occurred at the beach north of the Punta de Lobos. The location of the Punta de Lobos is visible in the next section in figure 5.15. To illustrate the erosion, in figure (5.13), pictures of June 2010 and July 2011 are shown of the same part of the beach. It is clearly visible that the beach has eroded significantly in one year. Behind the beach there is a dune area, which is visible behind the steep incline in figure 5.13. This dune area is being damaged and also partly lost due to the erosion.

Figure 5.13: A picture of the beach in 2010 and 2011 with reference point (Recordon, 2018)

Not only tourism is affected by the loss of beach area, also the local residents suffer from the erosion, as their houses are threatened. This is illustrated in figure 5.14. Due to the erosion of the last ten years, a house was lost in the near vicinity of the beach (Ilic, 2019).

Figure 5.14: Erosion which threatens houses (Recordon, 2018)

5.3.2. System boundaries

The system that is considered in this case study is shown in figure 5.15. Punta de Lobos is at the south of the system. The area south of Punta de Lobos is not taken into account, only possible sediment input into the system from the south is considered. For stakeholder purposes the whole town of Pichilemu is included within the system boundaries to cover the full range of land users and stakeholders.

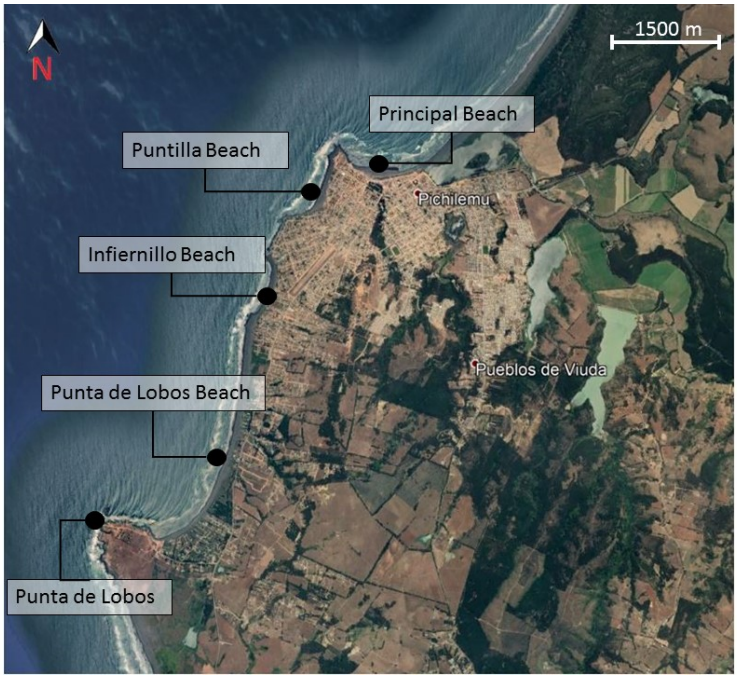

Figure 5.15: The system overview of Pichilemu (Google Earth, 2018b)

5.3.3. Natural system

The natural system consists of information on the necessary forces, characteristics and processes. Within the natural system, the focus is on the Punta de Lobos beach. As said in the problem statement, the main problem of this beach is erosion. The natural system analysis will look at the main morphological processes that influence the beach and the historical evolution of the beach erosion. After that, possible reasons for the erosion are elaborated, using the perspectives gained from the different local stakeholders.

The area where the erosion occurred over the last years, is located at the beach north of the Punta de Lobos. The area behind the beach is primarily dune area. This dune area has natural value for the Pichilemu system and also functions as coastal defense (Soto,2005). In a conversation with Nicolás Recordón (2019), a local surfer in Pichilemu, it came forward that for the surf community the conservation of the dunes is of high value. This is due to the undisturbed winds that blow over the dunes that create perfect conditions for, for example, wind surfing. Also Flor Ilic (2019), the director of the cultural center of Pichilemu, pointed out the value of the dunes.

For the study of the erosion of the beach a study is used by Patricio Winckler (2018). The conclusions in this study are drawn from historic Google Earth data.

In 2004, the beach at Punta de Lobos had a length of 50 to 100 meters and with the presence of vegetation in the higher beach area. As mentioned before, a sand dune is located behind the vegetation. In 2010 an increase in erosion occurred. In 2013 this erosion increased even more and a steep slope can be seen on the border between the beach and the dune area (see figure 5.14). Furthermore, the vegetation in the upper zone of the beach has disappeared. In 2014, more erosion is observed but it can be concluded that the erosion process is slower compared to the period of 2007 to 2010. From 2004 onwards the more northern part of the beach is concluded to be stable (Patricio Winckler, 2018).

In figure 5.16, two images are shown of the same fence in 2003 and 2009 on the beach of Punta the Lobos. It is clearly visible that within those six years large amounts of sediment has

disappeared from the beach. Figure 5.13 shows the erosion with the reference point marked with a red circle. Extreme erosion occurred in 2010 and the first half of 2011. In figure 5.13, shown in chapter 5.3.1 there is a big difference in the time span of one year. A high amount of erosion is observed and the development of a very steep profile on the border of the beach and the dunes is visible on the 2011 image. The reason for this erosion could be the occurrence of an extreme storm event but also the earthquake and tsunami that occurred in February 2010 could be a reason. The influence of the earthquake and tsunami is discussed in more detail later in this section. In appendix B.2.1 beach profile cross sections are visible and from this study related to historic beach profiles it can be concluded that in the period of 2009 to 2018 a total cross sectional beach area of 511 square meters has been lost (Recordon, 2018).

Figure 5.16: A picture of the beach with a reference point in 2003 and 2009 (Recordon, 2018)

Waves

There is no local wave climate study available in Pichilemu. Therefore offshore wave measurements in Valparaíso are used which are assumed to be similar to the offshore wave climate in Pichilemu. This data point is located about 200 kilometers north of Pichilemu. This assumption can be made because in the part of the coastline from the data-point to Pichilemu, the coast is very steep, so offshore wave date in both locations is not influenced by bathymetry and considered to be similar. The wave climate is visible in the left in figure 5.17 below. The main wave direction in Pichilemu is from the southwest. Extreme waves are arriving from the north (see the right side of figure 5.17). Nowadays, extreme wave events occur more frequently (as discussed in chapter 3.2.3), which can also be a cause of erosion.

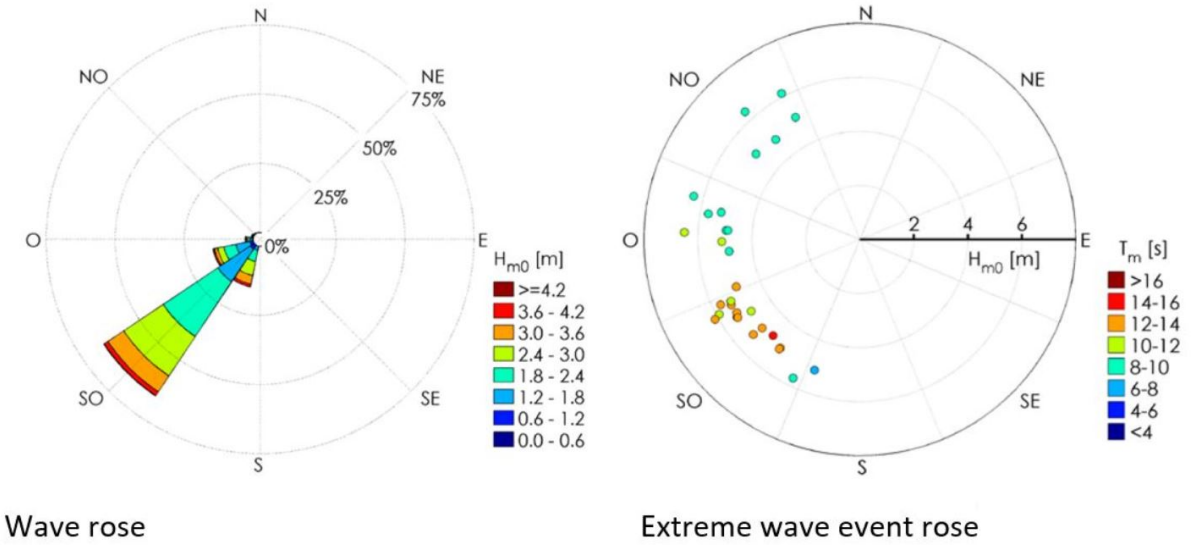

Figure 5.17: In the left an Offshore wave rose near Valparaíso is shown and on the right an extreme event wave rose at the same location is shown (M. José Beyá, 2016).

The southwest waves diffract around the Punta de Lobos and arrive at the beach parallel to the coast. In figure 5.18 the wave propagation is shown with waves arriving from a southwest direction. This wave direction is a possible reason for the existence of the south to north longshore current that transports the sediment along the coast.

Figure 5.18: Overview picture of the waves arriving at the Punta de Lobos beach (Recordon, 2018)

Beach dynamics (on a yearly timescale)

The Punta de Lobos beach is very dynamic and undergoes a lot of changes during the year. The coast is characterised by a south to north sediment transport with strong currents around the Punta de Lobos. The sediment origins from different river outlets to the south of Punta de Lobos. The closest outlet is located near the city of Cahuil, see figure 5.19 for the location of this outlet with respect to the Punta de Lobos. This outlet is manually opened during summer period. In the conversation with Fundacíon Punta de Lobos (2019), it came forward that the opening of the outlet in the summer could be a reason for the beaches to accrete around this time due to the increase in sediment transport.

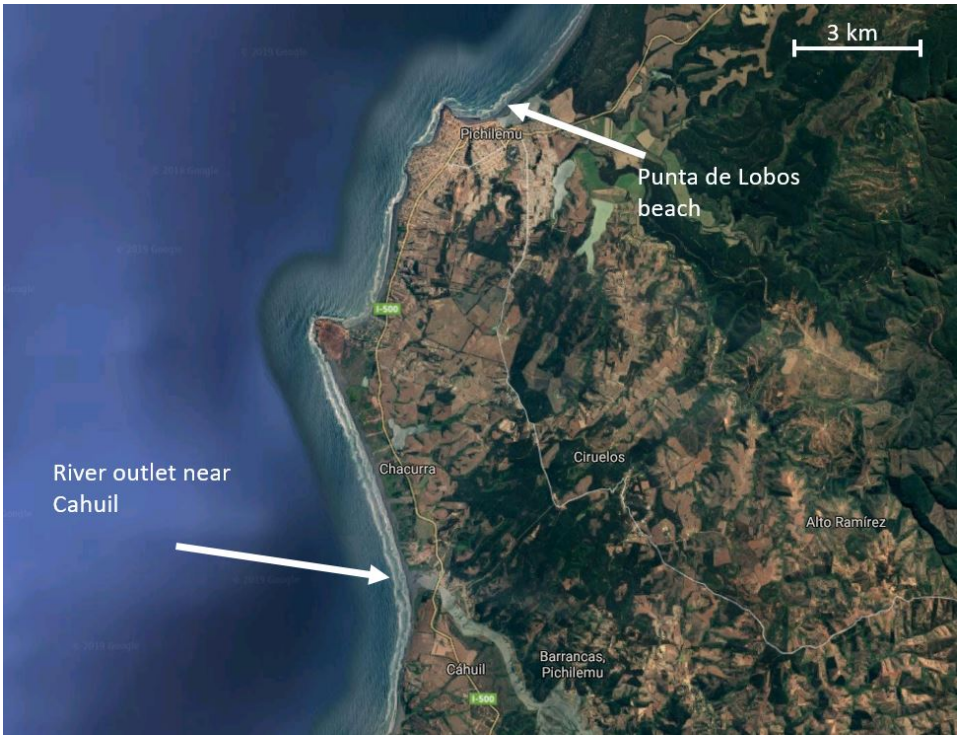

Figure 5.19: Location of the river outlet near Cahuil (Google Earth, 2018b)

In winter time, there is a more frequent occurrence of storms, compared to the summer, that produce big waves. Referring back to figure 5.17, it was concluded that part of these storms arrived from the northwest. When waves arrive from the northwest in Punta de Lobos beach there is a more direct impact of the waves on the shore because there is no sheltering behind the Punta de Lobos. The big wave impact and storm set up due to the more frequent occurrence of storms in the winter causes more erosion of the beach (Margozzini,2019).

In the conversation with Nicolás Recordón (2019) about the influence of the northwest storms on the surf conditions around Punta de Lobos, he said that due to the storms the longshore current is temporarily stopped or reversed, which causes sediment to settle near the Punta de Lobos. This increases the quality of surfing near the Punta de Lobos during this period.

When studying the erosion at the Punta de Lobos beach it is important to take this yearly variation in beach morphodynamics into account.

Tsunami and earthquake in 2010

The tsunami and earthquake in 2010 could be a reason for the erosion of the beach at Punta de Lobos. Nicolás Recordón (2019) mentioned the influence of this event on the state of the beach. He said that the land subsidence due to the earthquake is a reason for the erosion of the beach. A rough guess of the land subsidence in Pichilemu was made at about 60 centimeters. This land subsidence causes relative sea rise and thus is a possible reason for erosion. The influence of the 2010 tsunami on the morphology was limited .

It is expected that due to the convergence of the Nazca plate and the South American plate eventually the Chilean coast is uplifted (for more information on the geological properties of Chile see section 3.2.1). So the Nazca plate is on the long term pushing up the South American plate. This is a long term process with lots of uncertainties. So with this future uplift, Nicolás Recordón expects that the erosion will stop and eventually can even be

reversed (Recordón, 2019).

For overall information about the 2010 tsunami and earthquake see appendix A.3.

5.3.4. Socio-economic system: land use

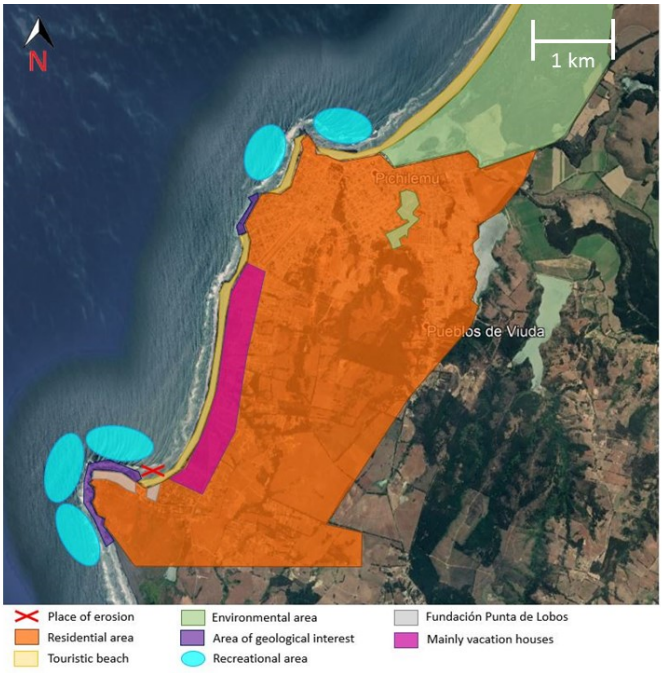

Figure 5.20: Land use of Pichilemu (Google Earth, 2018b).

Figure 5.20 shows the land use plan which is made by using documents of the Ministry of Public Works, CRUBC (CRUBC and Gobierno Regional Del Libertador Bernardo O'Higgins, 2018) and Google Earth and information gained from conversations in Pichilemu.

Pichilemu is a town with a high touristic focus. Along the coast there are mainly vacation houses and there are a lot of recreational activities on the beach and in the water. Besides of the recreational activities, which are pointed out in figure 5.20, the president of Fishery Federation Pichilemu stressed out that fishermen are fishing on algae all along the whole coast (Guerrero, 2019). There are several environmental areas, but they are not protected.

Punta de Lobos is an internationally known surfbreak, with different surf spots. Furthermore, the rocks around Punta de Lobos have a geological interest. Fundacion Punta de Lobos, land owner of a part of the area, is planning to build a park and has a hotel close to Punta de Lobos (Margozzini, 2019).

5.3.5. Socio-economic system: stakeholders

To understand the whole system in Pichilemu, the stakeholders in the area are considered. This will give a clear view about the general opinion on the coastal erosion and the wishes of the various parties involved.

Municipality

The project team spoke to two persons from the municipality of Pichilemu who are responsible for the forest and environmental management (Cordero and Cornejo, 2019). One of the tasks of the municipality is to design the land use plan of the town, thereby they organize citizens participation evenings in order to fulfill the wishes of the inhabitants. The Ministry

of Housing and Urbanization is the ministry which has to accept the land use plan, thereby they conduct a strategic environmental assessment. One of the objectives of the municipality is to build a walking path on the beach of Punta de Lobos.

The coastal management is done by the municipality and the Dirección de Obras Portuarias (DOP), a department of the Ministerio de Obras Públicas. The municipality is responsible for coastal projects with a small scope. Projects with a larger scope require funding from different ministries, whereby the DOP is responsible. The DOP is responsible to organize citizens participation evenings when carrying out a project. According to the municipality, the attendance of the citizens during these evenings is very low (Cordero and Cornejo, 2019). The cause of this is not clear. One of the projects that the DOP tried to execute, has been stopped by the inhabitants. They planned to construct a pipeline for waste water into the ocean, but the inhabitants were afraid that the project would cause a pollution of the wetlands in the north of Pichilemu. The municipality emphasized that they were glad that the project had been stopped. Therefore it can be concluded that the relationship between the DOP and the inhabitants and municipality of Pichilemu is not perfect.

The municipality mentioned a number of other environmental challenges and explained that they hired their first environmental expert. As a result, it can be concluded that steps are being taken to consider and protect the environmental values.

According to the interviewees, the problems at Punta de Lobos related to erosion are mainly caused by private companies. The problem is that private companies demolished parts of the dune area to construct their buildings. The municipality is not able to prevent this from happening, as they can only give restrictions to certain areas (Cordero and Cornejo, 2019). In Pichilemu many areas are in private hands, for example dunes and lagunes, so the municipality has no influence on these areas.

Local Residents

The municipality of Pichilemu has a population of around 1 000 people. From the population, 24 percent corresponds to rural population and 76 percent to urban population.

Both the director of the cultural center and the representative of the surf community states that there is a lack of recognition among the original inhabitants of Pichilemu about the environmental value of the coast. During the last decades, many tourists who visited Pichilemu regularly, moved to Pichilemu. According to Flor Ilic (2019), most of these 'new' inhabitants were attracted to the environmental value of the coast and therefore respect the coast more, this is also confirmed by Nicolás Recordón (2019). The overall local community is known for not being receptive to interventions that imply the stiffening of the coast, for example: levees, breakwaters or retaining walls, or the movement of dredged sands from the same bay or brought from other sites (Patricio Winckler, 2018)

Fishermen's Associations

In Pichilemu, fishermen attach great value to fishing in a traditional way. This means that a lot of fishermen are operating on and around the coastline. Shellfish farming, algae divers and seaweed industry is an important way of earning their income. According to Genaro Gverrero (2019), president of fishery federation Pichilemu, 92 percent of the fishing industry is on algae. Algae are mainly located on the intertidal areas of the coastline. The fishermen are cutting only the upper parts of the algae so that they can easily grow on. The algae are sold as food or as a product for the cosmetic industry, see figure 5.21.

Figure 5.21: Algae

Due to the fact that the main activities of the fisheries are in the coastline, they have a strong opinion about the way the coast is managed. The fisheries of Pichilemu are united as a trade union, Federación de Pescadores de Pichilemu. This federation consists of seven unions with more than 210 members operating in Pichilemu and Cáhuil (Anansa, 2019). According to their representative, Luis Gómez, the conservation of artisanal fisheries will act as a basis for development of the coastal areas. As an argument, the representative states that an economical and social growth of the fisheries will contribute to the maintenance of infrastructure and a positive effect on the quality of the commercial activities of the city (AQUA, 2018).

Fisheries in Pichilemu has come together often to defend their interest with regard to the coast. For example when private companies prohibited fishermen access to the coast at several beaches (Santa Marta, Monaco, Panilonco and Alto Colorado), the fisheries stood up together and eventually the mayor has put sanctions against the private companies. (El Tipógrafo, 2019b), (El Tipógrafo, 2019a), (Gobierno Regional, 2019). It can be concluded that the fishing association and private companies on the coast do not have a good relationship with each other and their interest are conflicting.

Genaro Guerrero (2019) also mentioned the cooperation between the surfers and the fisheries, as they were the first two groups who stood up against a project of the planned pipeline into the ocean. Therefore it can be assumed that the surfers and the fisheries have a good relationship. Added to this, Genardo Gverrero stated that the fishermen are interested in the involvement of stakeholders into coastal projects. The interests of the fisheries are of importance in the region.

Surfers

Pichilemu is known as the surf capital of Chile. Surfing in Pichilemu has become increasingly popular in recent decades and even became internationally known for the surf spots the town has to offer. One of those spots is Punta de Lobos, which is considered the cultural center of surfing in Chile (Justin P. Wright and Sadrpour, 2014).

In order to ensure that the interests of the surfing community are considered important, Save the Waves coalition has conducted a study into the economic impact of surfing on the local economy of Pichilemu (Save the Waves, 2015). The study showed that surfers contribute between 1,6 to 6,4 million US dollars of revenue to the town every year. This displays that surfing contributes significantly to the local economy of Pichilemu and therefore the economy is dependent on a high quality of wave and pristine coastal environment (Justin P. Wright and Sadrpour, 2014).

This study also emphasizes the unique set of environmental characteristics of the area.

The reef on where the waves break is recognized as a significant geological site that is estimated to be more than 300 million years old (Willner and Ring, 2009). Upwelling currents provides a nutrient-rich feeding ground to a number of species. Among these oceanic species are black, fin and sperm whales, orcas, sea lions, sea turtles, Humboldt and Magellanic penguins, oystercatchers, cormorants, pelicans and boobies. A threatened endemic cactus species, Echinopsis bolligeriana, is located at the point of Los Morros (International Union of the Conservation of Nature, 2014).

There are multiple surfing organisations which protect the interests of the surfing community. Save the Waves coalition is a organisation from California with the mission to protect and preserve the coastal environment with the focus on the surf zone (Save the Waves, 2015). Surf and Nature alliance is an international non-profit organisation devoted to the conservation of the marine environment, with a special interest in surf areas. In Pichilemu the organisation worked together with coastal community groups and local government and took the first steps on the process of conservation and coastal management (Surf & Nature alliance, 2017).

Tourism

The most valuable touristic attractions with national and international context of the O'Higgins region are the Sewell Mining Camp, the Colchagua Valley Wine Route and the tourism facilities in the coastal areas of Pichilemu, Navidad and Matanzas. In Pichilemu the touristic activities are mostly related to surfing.

Pichilemu is one of the coastal cities which was heavily hit by the tsunami in 2011. Besides the physical damages in the city, a strong decrease in number of tourists caused large economic damages. For reconstruction of the city and projects for tourist development, economic resources have been made available. In fact, a plan has been established to make Pichilemu one of the most important surfing destinations in the world.

The tourism development plan is primarily aimed at attracting surfers. Within the plan they strive for a better connection between the center and the coast. The director of the cultural center mentioned that many tourists who visited Pichilemu regularly, moved to Pichilemu in the last few decades. These 'new' inhabitants became competitors of the original inhabitants which has led to some conflicts in the tourism sector (Ilic, 2019).

Fundación Punta de Lobos

Fundación Punta de Lobos, launched and managed by several locals, wants to use Punta de Lobos as a conservation prototype project to protect landscape and biodiversity. They want to achieve this while working together with the community to safeguard their traditional activities like fishing and surfing.

Their vision statement is: "To create value awareness to an otherwise undervalued ecosystem all along Chile, aiming to move conservation interests towards spaces which are constantly under threats and can still be rescued, north of Patagonia". According to FPL, Punta de Lobos needs to be protected in accordance to a certain set of restrictions which are:

- The coastline need to have public access and a regulation of touristic activities.
- Allow artisanal fishing and surfing
- Make sure that the value of the coast will be preserved regardless of the land owner in place.

Within their master plan FPL is in a process of understanding the needs of the land in relation to erosion reduction of the coast. The foundation have purchased a part of Punta de Lobos and want to turn it into a park. Thereby they want to protect the cacti which are located in the area (Margozzini, 2019). Although it seems that the foundation is protecting the environmental value of the area, opinions differ among the population of Pichilemu

about the foundation. According to Andres Margozzini (2019), 60 percent of the population is positive and 40 percent is negative about the foundation. The foundation is founded by a wealthy business man who owns a hotel in Pichilemu, therefore the population is afraid that the foundation has different plans with Punta de Lobos. The foundation is trying change the overall opinion of the population by inviting them to work sessions (Margozzini, 2019).

The opinion of the municipality of Pichilemu about the foundation is positive. According to them, there is a good cooperation with each other (Cordero and Cornejo, 2019). Nicolás Recordón is less convinced by the foundation, he declared that the foundation is not totally protecting the heritage of Punta de Lobos (Recordón, 2019).

Andres Margozzini states that the erosion of the beach at Punta de Lobos mainly has to do with the construction of buildings on the dunes behind the beach by private landowners (Recordón, 2019).

Overview

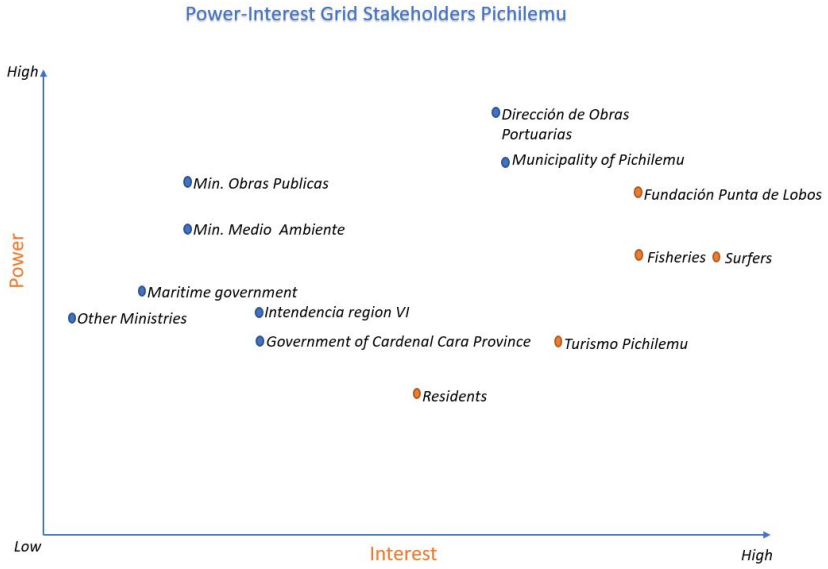

Figure 5.22: Power interest grid stakeholders Pichilemu

In order to understand how the stakeholders are related to the project, a power interest grid is made, see figure 5.22. Local stakeholders are identified in orange and the regional and national stakeholders in blue. In this PI grid, the regional stakeholders related to Pichilemu which are described in chapter 3.1.3. Due to the fact that Punta the Lobos is an international known surfbreak, the surfers have the highest interest in the project. Dirección de Obras Portuarías have the highest power in the project, cause they are responsible for coastal projects. A conclusion from the power interest grid is that the local stakeholders have a way higher interest than the regional stakeholders. This is mainly based on the meetings that the project team had with local stakeholders, they clearly described their interest in the area and stated that the regional organisations did not had a big affinity with the area.

5.3.6. Conclusion system analysis

The physical system analysis shows that the erosion of the Punta de Lobos beach is concentrated at the south part of the beach. The north part is considered stable. The erosion in the south part is very dynamic and has yearly variations due to changes in sediment supply from the south in summer and the occurrence of northwest storms in winter. Besides the yearly variations, there is also net erosion occurring in the last twenty years that primarily

influences the dunes. The dune areas are eroding and this can be dangerous for the houses located on top of the dunes. So the problem is not only in beach erosion but also in dune erosion. There is no available evidence that beach activities as swimming and surfing are influenced by the erosion.

The cause of the erosion is not exactly known. Possible reasons are the earthquake in 2010 that caused subsidence of the town of Pichilemu. Also the occurrence of extreme storms from the northwest is a possible reason. Forecasts of the expected erosion in the future are very unsure and very much depend on the local conditions. A possible future perspective is the stopping of erosion due to the general uplift of Chile related to the plate tectonics. The problems related to the erosion of the dunes seems to be mainly the cause by private companies. The problem is that private companies demolished parts of the dune area to construct their buildings.

The socio-economic system analysis has clearly shown the importance of surfing at the coast of Pichilemu. The economy of the town is highly dependent on their touristic character and most of the touristic activities are related to the surfing industry. Specifically Punta de Lobos is the most attractive location for surfing activities. Near the erosion of the beach of Punta de Lobos the surfers attach a lot of value to the natural behaviour of the morphological system. This morphological behaviour makes it that Punta de Lobos is such a good surf spot.

Furthermore, Pichilemu attaches great value to their traditional way of fishing. Meaning that the activities of the fisheries are mostly on and around the coastline. The fisheries have come together as Federación de Pescadores de Pichilemu, this organisation has managed to show their importance in the area.

Therefore, the conclusion can be drawn that it is of importance to include the surfing and fishing community in the Building with Nature process which is elaborated upon in the next section.

5.3.7. Building with Nature example

An example of a solution with Building with Nature can be the stabilisation of the steep interface between the beach and the dunes which is visible in figure 5.14. This steep slope looks to be unstable and prone to erosion due to wave impact. It must be stressed out that this is just one example to show how Building with Nature can be possibly implemented in the Pichilemu case study.

After talking to the surfers, fisheries and the Fundación de Punta de Lobos the importance of the natural preservation of the Punta de Lobos territory became very clear. This preservation needs can focus on the offshore part of the Punta de Lobos beach. Because the offshore area near the beach is very important for the surf community and the fishery, this Building with Nature example focuses on solution on the shore. Because of the lack of hydrodyanamic data in the area of Punta de Lobos, more studies and research need to be done if a solution under the waterline needs to be proposed. For example an in depth morphological study can be performed. In this case a possible solution can be to make use of, for example, seaweeds as algaes and kelps, to reduce wave energy and trap the sediment near the beach in a natural way. According to the fisheries in Pichilemu there is great availability of algaes in the area and these algae can function as a sediment trap (Guerrero, 2019). With this kind of solution there are also opportunities for food production and an increase in marine biodiversity. The increase of marine life has great potential in Chile as is currently studied on the Universidad de Valparaíso (Muñoz, 2019).

Conserving the natural state of the dunes is important in stimulating dune growth and vegetation growth. The construction of buildings or other infrastructure on top of the dunes should be prevented as much as possible. This is not easy as most of the dune area is in private ownership (Margozzini, 2019). A first step in this process could be to raise aware-

ness among the local residents by telling them about the natural and functional values of the dunes and strive towards a change in the land-use plan of the area.

Enhancing the vegetation growth on the dunes can provide more stability and offer more resistance to erosion. Besides a gain in stability of the dunes, the vegetation can prevent erosion due to wind and can even trap sediment resulting in dune growth. In the current situation there is some vegetation on the top side of the dunes. But as said before, the private ownership of the dunes limits the vegetation growth. On the steep border between the beach and the dunes, there is less vegetation present. Below in figure 5.23 this lack of vegetation is shown. Planting more robust vegetation on the steep surface could possibly withhold the erosion. More studies on dune vegetation need to be performed to get more details on the specific types of vegetation that can be planted and grown in the Punta de Lobos dune area. The use of vegetation for coastal protection is a typical Building with Nature solution. Besides functioning as a coastal defense it creates more natural value within the system and therefore is a multipurpose solution. An example project on using vegetation to prevent erosion can be found in chapter 4.4.2

Figure 5.23: Picture of the steep interface between the beach and the dunes taken by the project team during the site visit of Pichilemu

In order to prevent the dune erosion and possibly trap sediment, it could be a possibility to place screens (for example wind screens or a semi-permeable wooden screen) in front of the dune interface visible in figure 5.23. The screens can be placed at the base of the steep border on the most landward end of the beach. The screens can protect the dune border from direct wave impact in case of extreme storm events and with this prevent erosion. On the other hand this makes it possible for sediment to pass through the screens which in the ideal case leads to accretion. This measure can provide calmer conditions for the dunes and creates a more suitable environment for the growth of vegetation. The screens must be able to resist direct wave impact and needs a deep foundation. The exact placement location and behaviour of the sediment around these interventions needs further research to come with more exact solutions.

In figure 5.24 the possible Building with Nature solution is summarized and visualised.

Figure 5.24: Summarizing picture of the possible Building with Nature solution of the beach north of Punta de Lobos

5.4. Los Vilos

Los Vilos is a small coastal town located in the central zone of Chile in the province of Choapa, which is part of the region of Coquimbo, the fifth region of the country. It is located 246 kilometers to the northwest of Santiago. Los Vilos started as a small settlement at the coast in 1830. On the 3rd of January 1855, Los Vilos was assigned as a small port for the transfer of goods by the means of an agreement signed by the 'Ministerio de Hacienda'. In the same year the harbour was expanded with the construction of a wharf, warehouses and buildings for commercial activity. In December 1857 it was decided that a small town needed to be built. The city of Los Vilos has nowadays a little over 9000 inhabitants (Wikipedia, 2018a).

Figure 5.25: A photo of the main beach of Los Vilos with the Caleta San Pedro in the back (GHD, 2017b.)

Los Vilos can be seen as a location with a typically Chilean character concerning the involvement of multiple private companies that are linked to the coastline (for more information on the privatization within Chile see section 3.1.1). This is one of the reasons which makes Los Vilos a good location for the case-study. The main focus of this coastal town is seafood production and tourism. Currently, the most important activities of the population are directly or indirectly linked to the coastal area, both in the extraction of marine products and in the services associated with tourism. Every year in the summer months, January and February, around 15 000 to 20 000 people visit Los Vilos, which shows that the economic influence of tourism reaches considerable levels. The main tourist attractions are focused

around the main beach La Principal.

The main fishing centers of the community are the coves ”San Pedro” and ”Las Conchas”, both within the urban boundaries of Los Vilos and located on its coastal edge. Las Conchas is one of the first areas where infrastructure related to artisanal fishing is carried out by the Port Works Directorate. Caleta San Pedro is a larger cove that is staged at the double dock (GHD, 2017b).

The mining company Antofagasta PLC with the mine Pelambres, is an important actor in the town, it is one of the biggest mining companies in Chile. The company ships their mined products from a harbour in the north of Los Vilos. Due to their activities, some environmental discussion arose among the inhabitants of the city (BNAmericas, 2013).

All the information used in this section is from a report of GHD which analyses the coastal demands of the area of Los Vilos (GHD, 2017b).

5.4.1. Problem statement

As said before, Los Vilos is economically dependent on touristic activities. These activities are dependent on the state of the touristic facilities which is primarily focused on the coastline. Over the last years there has been a significant change in this area, caused by erosion processes. In figure 5.26 the change of the coastline can be seen from 1978 up to 2016. It is clearly visible that there has been a decrease in beach area over the years.

The beaches, the tranquility of its waters and the impressive landscape, together with the easy access to the resources of the sea, have made the town an attractive place for the development of recreational activities and holiday retreats. Although, infrastructural shortcomings has caused hindrance against the expected growth of the touristic sector. Over time, the lack of tourism policy and the quick and easy efforts of the commercial working class have become the main problems that the sector has had to face, problems that even today causes obstacles for further development.

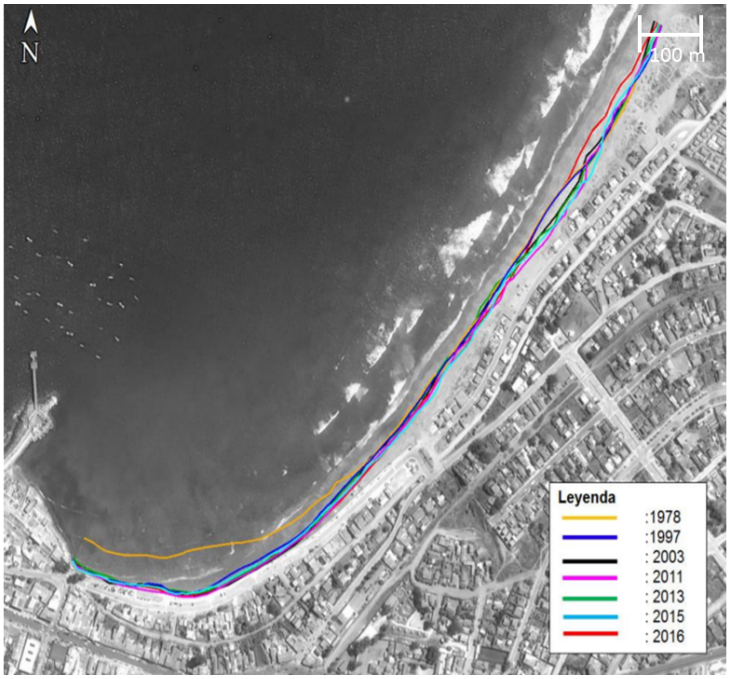

Figure 5.26: Erosion of the bay over time (GHD, 2017b.)

Due to the erosion, the beach cannot fulfill its main functions for the town of Los Vilos.

The beach functions as a coastal defense which can reduce wave energy and prevent damage to the coastline in case of big storms and tsunamis. Besides this, the beach is used by tourists and local people for recreation and social activities. This is of big value for the future development of Los Vilos as a touristic spot. In figure 5.27 the beach is shown during high and low tide. Looking at the image from a recreational perspective, one can conclude that there are minor possibilities for recreation with the current state of the beach. Besides the human interest in the beach, it is also an habitat for flora and fauna which is affected by the erosion (GHD, 2017b).

Figure 5.27: The Los Vilos coast at low and high tide (GHD, 2017a)

5.4.2. System boundaries

The system that is considered in this chapter is shown in figure 5.28 below. Everything within the boundaries of this figure is part of the system which is elaborated in the first step of the Building with Nature approach. In the figure of the system boundaries some important locations are pointed out. The system is limited to the bay of Los Vilos because this preliminary study the external influences, for example of the rivers that influence morphology in the north, are not taken into account.

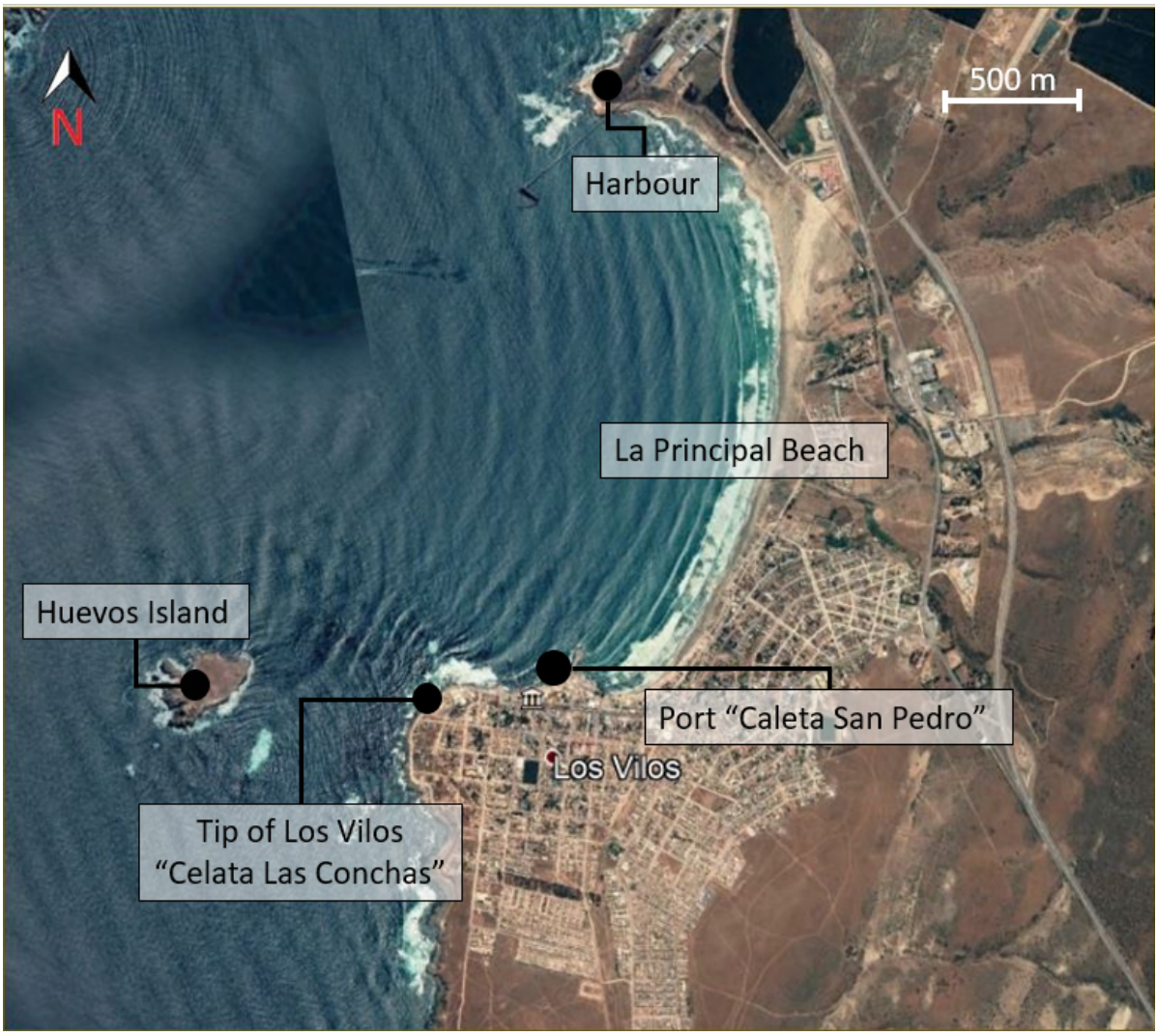

Figure 5.28: Everything shown within the boundaries of this map is considered as the system which is described in the following chapters (Google Earth, 2018a).

5.4.3. Natural system

The natural system description in this section consists of information on the forces, characteristics and processes within the natural system. Within the natural system the focus is on the main beach "La Principal". As mentioned in the problem statement, the main problem within the natural system is the lack of beach area in the southern part of the main beach. The focus of this natural system analysis is on the important morphological processes near the principal beach and the external factors that can influence this morphology.

First, the problems in the main bay of Los Vilos are analysed. To research the erosion of the main beach over the last years, historical aerial pictures are used. From these images, the location of the coastline is derived for different years. By comparing these images the change of the coastline over the last years can be found. The specific part of the coast that is used in this coastline study is shown in the figure 5.29.

Figure 5.29: Overview of the beach area that is considered in this morphology part (GHD, 2016b)

The year 1978 is taken as a base year and is compared with the more recent overview pictures. The comparison of coastlines is shown in figure 5.30. The images are from both Google Earth (for the years 2002, 2011, 2013, 2015 and 2016) and Servicio Aéreo Fotogramétrico (for the years 1978 and 1997). The following conclusions can be drawn from these images:

- It is clearly visible that most of the coastline change occurred on the south side of the beach primarily in the period 1978 to 1997.
- There are some small changes in the coastline in the period 1997 to 2016 but these differences are small and could be related to measurement errors or a difference in tidal elevation. Therefore, after 1997, the coastline is considered to be stable.
- Over the whole period (1978 to 2016) it can be concluded that the northern part of the coast is stable and has not changed considerably.

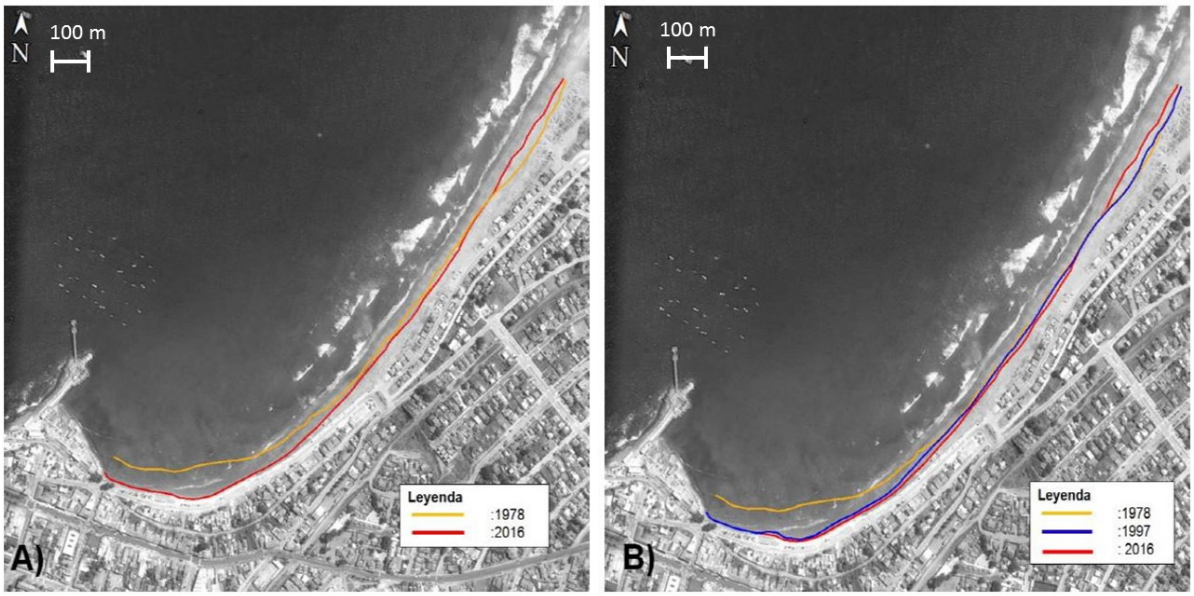

Figure 5.30: The coastline change is shown with respect 1978 (GHD, 2016b)

Two other pictures of the coastline of Los Vilos, obtained from the local community, shown in figure 5.31, provide more evidence of coastline change. Picture B is known to be taken around 1965. The year in which picture A is taken is unknown, however, due to the fact that there are less houses visible in the background, it is concluded that this is earlier than 1965.

After identification of similar features in the pictures, it can be concluded that there was a decrease in coastline that occurred somewhere before the year of 1965 (GHD, 2016b).

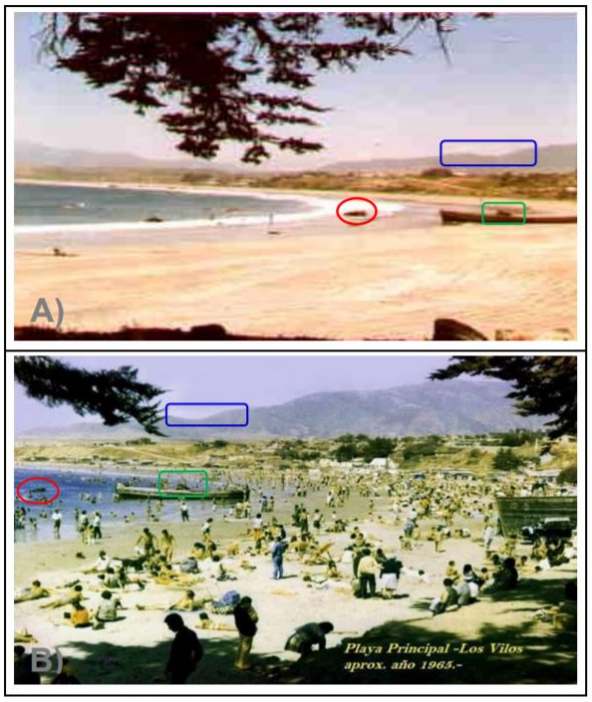

Figure 5.31: Historical pictures of the south part of the main beach in Los Vilos, taken around the year of 1965 (GHD, 2016b)

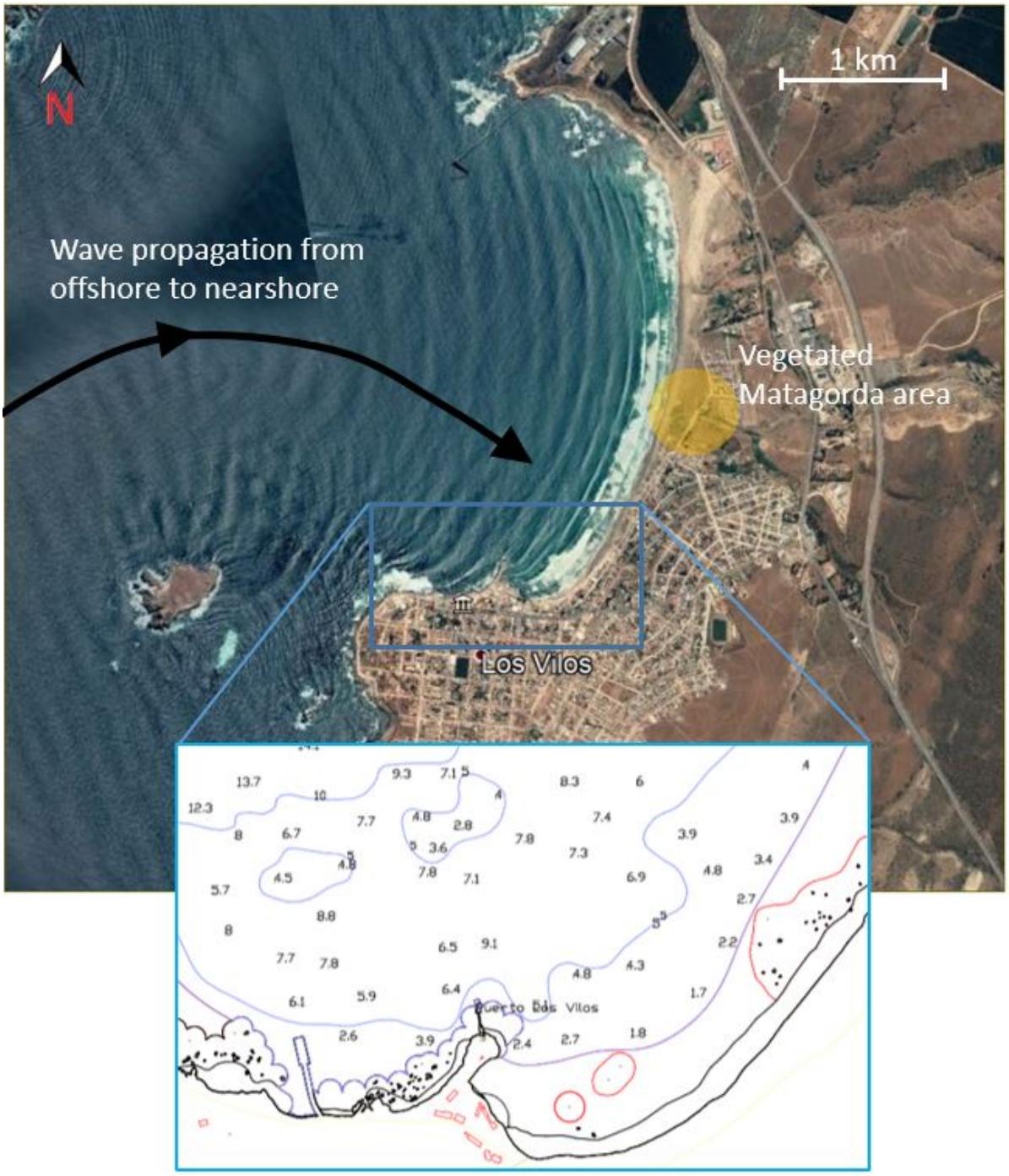

Figure 5.32: An overview of the system characteristics (Google Earth, 2018a) (GHD, 2017b)

Waves

Wave processes dominate the morphodynamics around the main beach. The wave climate in Los Vilos is analysed using an offshore data point and nearshore data point one (visible in image 5.32). Furthermore the propagation of the waves from offshore to nearshore is indicated by the black arrows. This is derived from the information of the two wind roses shown in figure 5.33. The main direction of the offshore waves are from the southwest. During the wave propagation to the nearshore, the waves refract around the Huevos island into the Los Vilos bay. Due to this refraction, the main direction of the nearshore waves is from the northwest. The refraction also causes a reduction in wave height when propagating nearshore (DOP, 2016). More information on the wave statistics of Los Vilos can be found in appendix B.3.1.

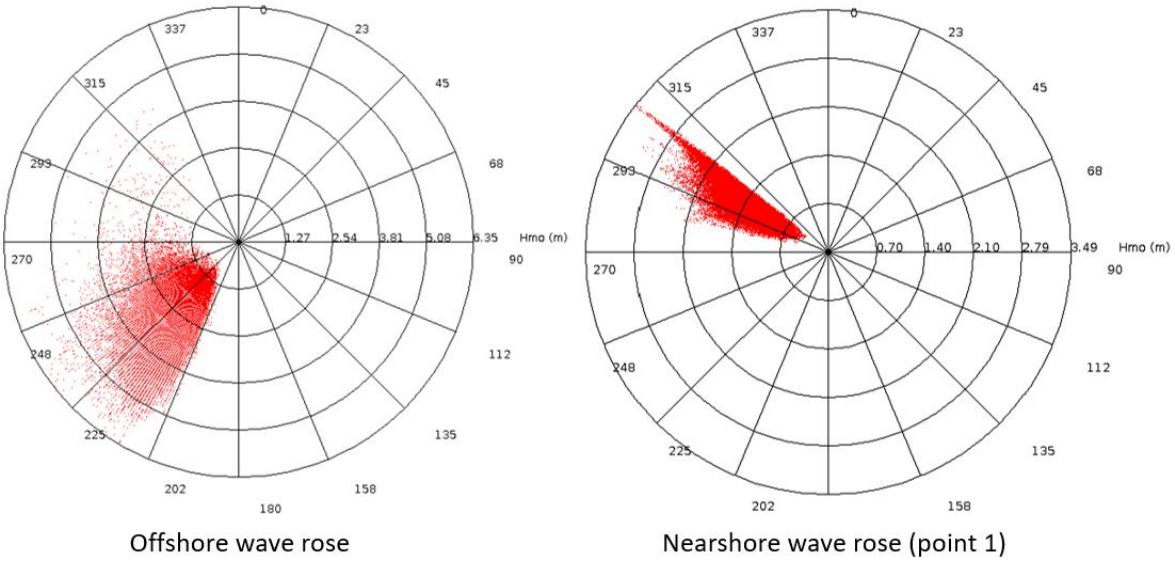

Figure 5.33: Directional spreading of the waves with wave heights for both the offshore and nearshore waves (DOP, 2016)

Bathymetry

The bathymetry of a part of the Los Vilos bay is shown in the overview in figure 5.32. This part of the bathymetry is interesting because of the nearby historic erosion. The coast of the Los Vilos bay is not extremely steep, for example near the tip of the Caleta San Pedro the water depth is five meters. Part of the bathymetry is visible in figure 5.32. Also there are two shallow areas in the bay northwest of the Caleta San Pedro with a depth of about three meters. These shallow areas could possibly influence the wave energy and wave direction (GHD, 2017b). The full bathymetry of the Los Vilos bay can be found in appendix B.3.2.

Tsunamis

Tsunamis can occur in front of the Chilean coast. In Los Vilos the area that is of most danger to tsunami flooding is the Matagorda nature area (visible in the overview map in figure 5.32). Besides the flooding of the land, tsunamis can cause a very sudden change in morphology and hereby easily damage coastal structures, especially for soft coastal structures (for example sandy structures near the coast) (SHOA, 2017). A tsunami inundation map of Los Vilos can be seen in appendix B.3.3 and more information on tsunamis in Chile can be found in chapter 3.2.7.

Other characteristics

The sediment within the Los Vilos bay is fine sediment with a grain size in the range of 0.125 to 0.250 mm. After research on the chemical deposition of the sediment it can be concluded that the sediment is not contaminated and can thus function as a building material for new design (GHD, 2017d). More information on the sediment characteristics can be found in appendix B.3.4.

The vegetation and nature along the coast of the Los Vilos bay is primarily located around the Matagorda nature area. This is visible in the overview picture 5.32 (GHD, 2016a). More information on the vegetation types can be found in appendix B.3.5.

Earthquake 1971

An earthquake occurred very close to Los Vilos in 1971 with 7.75 on the Richter Scale. This earthquake damaged Los Vilos and damaged for example the Caleta San Pedro. According to a resident of Los Vilos there was a land subsidence that occurred in Los Vilos due to this earthquake. This background is important to take into account because this land subsidence could have influenced morphological processes and part of the coastline change.

Caleta San Pedro

The construction of the Caleta San Pedro on the left side of the main beach could have influenced the change in coastline. Historical images of the Caleta San Pedro are visible in the image 5.34 below. The first image is approximately from 1940. It is visible that a first rock inforced shelter was made to accommodate a small fishers port. In the picture of 1967 the Caleta San Pedro is clearly visible and has a similar shape as the present Caleta San Pedro. With the historic images, the assumption is made that a large part of the Caleta San Pedro was constructed somewhere between 1940 and 1970 (GHD, 2017a).

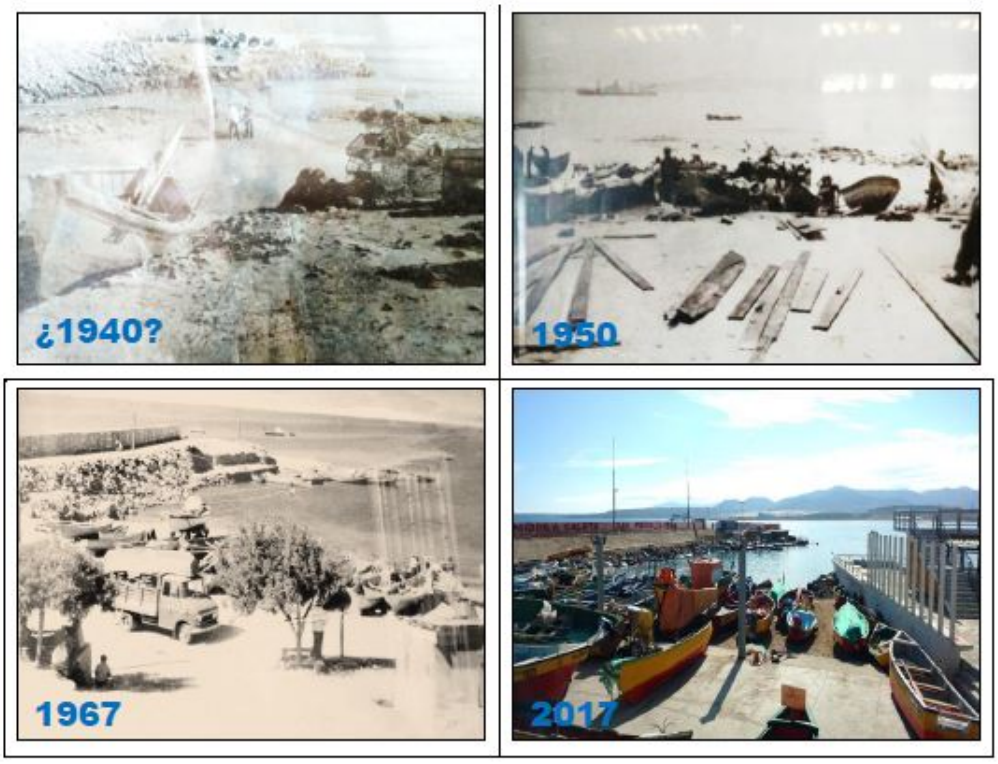

Figure 5.34: Historical pictures of the Caleta San Pedro (GHD, 2017a)

To look at the possible influence of the Caleta San Pedro on the morphology, research has been done on the currents near this structure. Currents have been measured in two spots (sector one and two, visible in image 5.35 below) (GHD, 2016c). From this study on currents it was found that in every case (rising or falling tide) the current levels nearest to the Caleta san Pedro were more intense. The difference was in the order of 0.04 m/s and with a directional tendency to north and northeast. This intensification of the currents confirms the influence of the Caleta San Pedro on flow patterns and most probably on the sediment transport in the Los Vilos bay area (GHD, 2017c.).

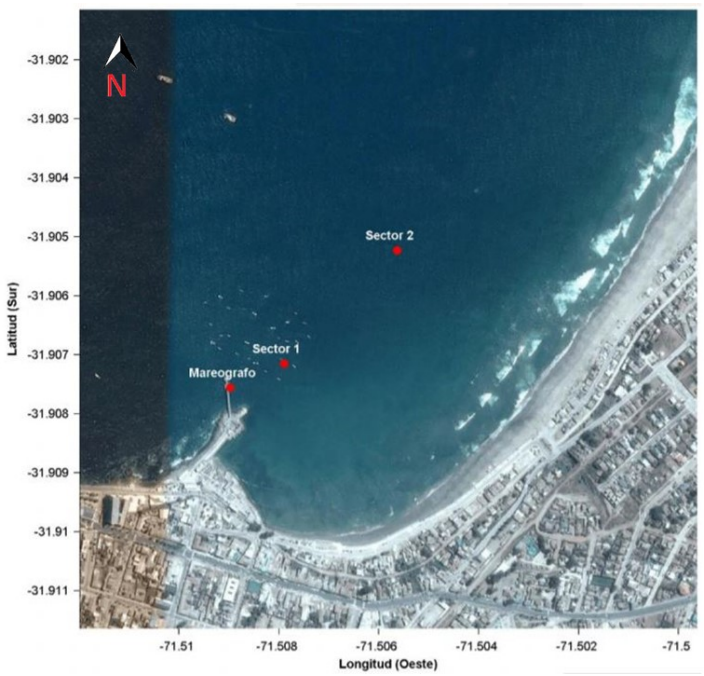

Figure 5.35: Location of the current measurements (GHD, 2016c)

The Caleta San Pedro influences the wave patterns. An overview picture of the influence of the Caleta San Pedro on the wave patterns and currents is shown in image 5.36. The change in wave and current climate cannot be shown in detail with the current resources but is approximated in a very basic way. This wave pattern has to be researched in more detail before a conclusion can be drawn about the influence of waves and currents on the erosion of the beach.

Figure 5.36: Influence of the Caleta San Pedro on the waves and currents (GHD, 2016c)

Tides

The maximum tidal range is around 1.50m. Furthermore, the tide can be characterised as a predominantly semidiurnal type, indicating two high and low waters a day. It is assumed that the tides do not have a significant influence on the morphology within the bay. This is concluded because of the relatively low tidal range and the negligibly low tidal currents (GHD, 2016b). A tidal record at Los Vilos is shown in appendix B.3.6.

5.4.4. Socio-economic system: land use

With the use of documents of the Ministry of Public Works, GHD and Google Earth a land use map has been made, see figure 5.37 (GHD and de Obras Publicas, 2016). There is a difference between the purposes of the two ports, Port Caleta San Pedro and Port Puntachungo. Port Caleta San Pedro is a port which is used by fisheries and touristic companies. Port Puntachungo is port with a more industrial character, used by the mining company to ship their mined materials and some other industries. Looking at the map, the place where coastal erosion takes place is a recreational spot for several watersports. A little bit to the north there is a protected nature reserve which is the rivermouth of Quebrada Matagorda.

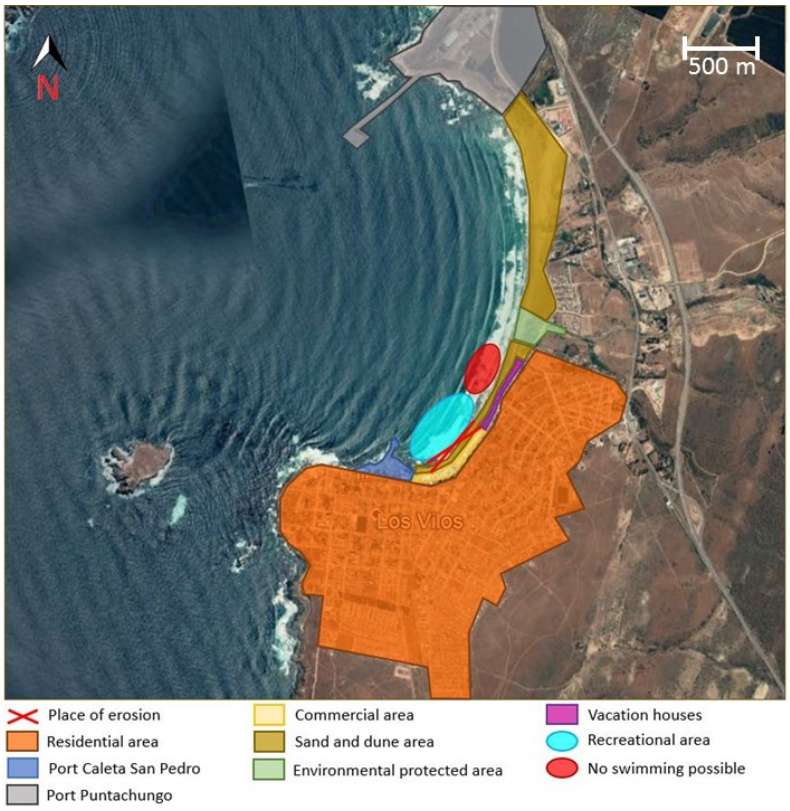

Figure 5.37: Land use of Los Vilos, (Google Earth, 2018a)

5.4.5. Socio-economic system: stakeholders

To understand the whole system in Los Vilos, the stakeholders in the area are considered. This will give a clear view about the general opinion on the coastal erosion and the wishes of the various parties involved.

Municipality of Los Vilos

The municipality of Los Vilos' governmental plan has the main goal of accommodating development of the community by the establishing urban and building regulations, which safeguards livability while balancing safety and environmental balance. In this way increase the quality of life of the inhabitants of the community. Los Vilos is a coastal community, an identity that is necessary to protect. This includes the sea related neighborhoods, its landscape values, its cultural heritage and typical constructions. The municipality will seek to protect the heritage and cultural identity of the population by safeguarding heritage elements and cultural assets. Besides this the municipality wants to use the potential for exploitation of the existing tourism and enhance it by the regulation of land use and various activities present in the territory. On the other hand, the productive activities are mainly related to mining, which contributes to the welfare in the community. For the environmental dimension, the policy includes the presence of natural elements of high environmental and landscape value, and the establishment of urban regulations that can minimize the occupation of such areas.

The environmental objectives of the policy of the municipality include safeguarding the coastal edges and the natural water courses, including channels and estuaries, from human activities that deteriorates the landscape and contaminates the waters. Additionally, the municipality wants to avoid contamination of groundwater and shallow water that are threatened by the infiltration and runoff of sewage water from individual sewerage systems (Municipalidad de Los Vilos, 2017). The municipality of Los Vilos is the problem holder of the coastal erosion of the main beach of the town (van de Grift, 2019).

Local residents

During a citizen participation night, the community pointed out the main and most valued activities at the coast of Los Vilos. These occured to be maritime activities as surfing, hiking and fishing, recreation activities on land like sporting, playing and commercial recreation as restaurants and accommodations. Additionally, the requirements of the public services were elaborated on by the local community. The most important were:

- Beach recovery area, whereby the aim is to promote tourism, which is why it is proposed to allocate the first line of the coastal border as a beach recovery. The requirement is justified to the extent that it would be cheaper than the construction of an artificial beach, that it would allow the construction of a wide waterfront and that it is a risk zone in the face of storm surges.
- To establish standards in the coastal border, to manage the tourist purpose. The aim is to promote tourism, which is why it is proposed to generate standards for the management of the coastal zone, focusing its purpose towards tourism.
- Construction of a new coastal walkway. Generate a new coastal walk with tourist facilities that complements the waterfront. It is expected to have high standards and incorporate lighting, bike path, shaders and universal access.
- Construction of a waterfront: Generate a new coastal road with a tourist facilities, that complements the coastal walk.
- Generate constructions or interventions specifically aimed beach recovering: It is considered necessary to recover the beach, although it is indicated that it should be a complement to the other requirements since without them, it would not be a contribution to the tourism of the city.(GHD, 2017b)

Fishermen's Associations

To come up for the rights of the fisherman, there are various unions in Los Vilos. The four are:

- A.G. Pescadores Artesanales
- S.T.I. de Pescadores Artesanales y Buzos Mariscadores de Productos Marinos - Caleta San Pedro
- S.T.I. Mujeres, Pescadores Artesanales, Mariscadores Buzos y Recolectores de Orilla, Labores Afines Lord Wilow
- S.T.I. de Pescadores Artesanales Extractores de Productos del Mar - Caleta Las Conchas
- Cooperativa de Pescadores Artesanales de Los Vilos Ltda. - Caleta San Pedro

The fisherman want an extension of the pier to enhance tourism and the possibilities for the fisheries. They are also concerned about the expansion of the port of PLC, as this could block their access route to the harbour (van de Grift, 2019)

Antofagasta PLC: Minera Los Pelambres

The mine Los Pelambres is one of the mines from the Antofagasta PLC copper companies. Antofagasta PLC belongs to the major international copper producers of the world, which mainly operates in Chile. They are operating four mines in Chile, namely: Los Pelambres, Centinela, Antucoya and Zaldivar (Wikipedia, 2019). Antofagasta PLC wants to expand the ore processing capacity through the installation of a new milling line and a new flotation line at the Piuquenes Plant, located within the production facilities of Minera Los Pelambres (Antofagasta minerals, 2019a). They want to do this according to the maximum environmentally friendly approved processing rate. During the construction and exploitation phase, they plan to use the public roads of Los Vilos to transport goods, materials and people. In

addition, the project in Los Vilos includes installing a reverse osmosis desalination plant in the Los Vilos community. The desalination plant will have a production capacity of 400 liters per second of desalinated water of industrial quality. The plant can be used as a backup in periods of drought (Antofagasta minerals, 2019b).

CRDP: Corporación Regional de Desarrollo Productivo

The CRDP works on the achievement of sustainable economic and social growth by the strengthening of the quality of life and sustainability, energy, water resources and internationalization of the Coquimbo Region (Gobernacion Regional de Coquimbo, 2019). The CRDP is a non-profit organisation that works closely together with the private sector. The miner companies, as MLP, are obligated to invest in the CRDP to compensate for the impact they have on their surroundings. The development of Los Vilos is one of the projects were CRPD invest in (van de Grift, 2019).

CORE Région de Coquimbo (CORE Region of Coquimbo)

The Regional Council of Coquimbo is a collegiate body with the purpose to make effective participation of the regional community. The Regional Council - also known by the CORE acronym - is the body that represents the interests of the community in making decisions that directly affect the Administration of the Region. Its main objective is to promote social, cultural and economic development, approving projects, programs or studies aimed primarily at improving the quality of life of its inhabitants. The CORE, together with the Mayor, make up the Regional Government (CORE, 2019).

Overview

To map the stakeholders of the Los Vilos case study, a power interest grid is made. This can be seen in figure 5.38. Local stakeholders are identified in orange and the regional and national stakeholders in blue. The PI-grid shows the level of interest and the level of power of all stakeholders in the Los Vilos project, the governmental organisations have blue dots and the local stakeholders have orange dots. The stakeholder with high power and high interest needs to be managed closely. In this case this is the municipality of Los Vilos. The fisheries and local residents have a high interest in the project but have less power, these stakeholders need to be listened to and kept informed. The other stakeholders need to be monitored and kept satisfied during the development of the project.

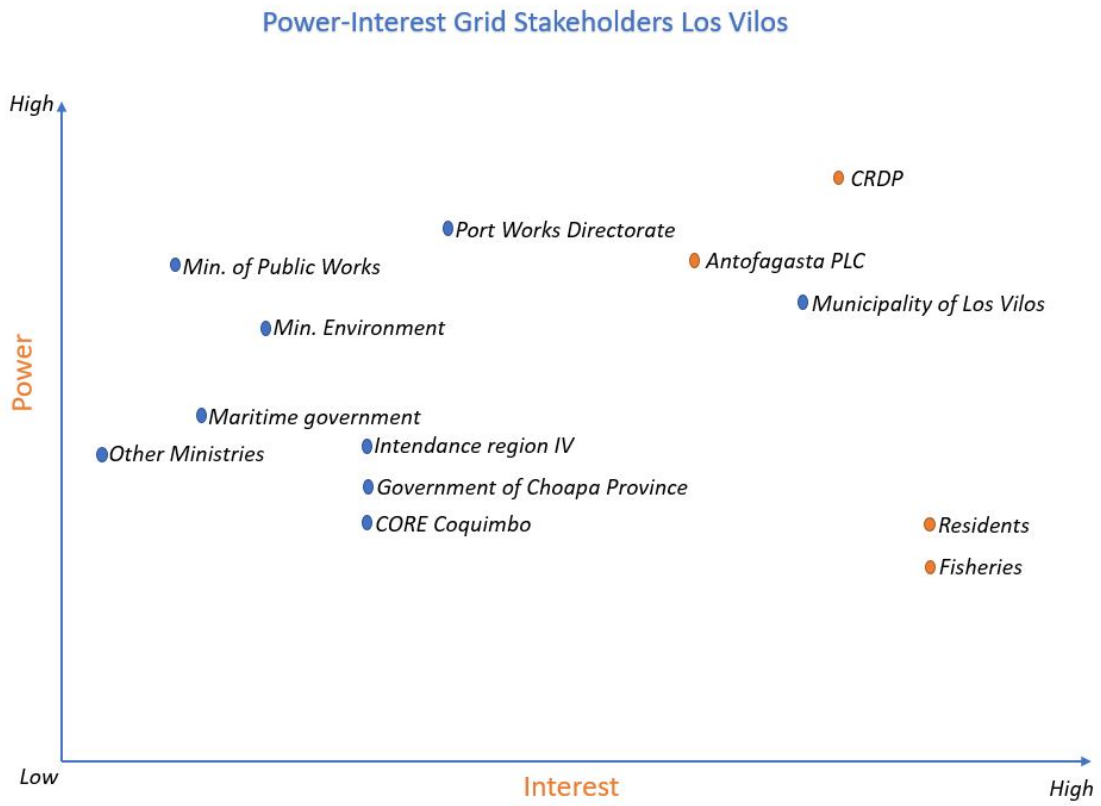

Figure 5.38: Power Interest grid stakeholders Los Vilos

5.4.6. Conclusion system analysis

The results of the system analysis show that there is a problem with coastal erosion in the south side of the Los Vilos bay. This part of the bay functions as an important touristic area for the city. The importance of this area for the local stakeholders was also found during the stakeholder analyses. The beach of the northern part of the bay appeared to have a more stable coastline with negligible erosion and a bigger beach area compared to the south. However, this area is not suitable for recreational purposes because of the partly protected nature reserves and the rocks located in the sea. The southern part of the bay is more attractive to point out as a touristic area due to its close connection to the city. Therefore, the Building with Nature advice focuses on the southern area of the principal beach.

In conclusion of the stakeholder analysis, the important requirements of the stakeholders are the preservation of maritime activities like surfing, hiking and fishing. Furthermore, recreational activities on land like sporting, playing and commercial recreation as restaurants and hotels are of high value to the local residents. Additionally, the public service requirements are the recovery of the beach area with necessary interventions and establishment of standards in the coastal border to manage the tourist purpose and construct a new coastal walkway and waterfront. An extension of the current pier to, among other things, enhance tourism facilities, is a wish of the residents and local fisheries.

The mining company Antofagasta PLC wants to expand their port on the northside of Los Vilos and increase the mining activities in the Pelambres mine, which can interfere with the wishes of the fisheries.

Lastly, the project needs to comply with the visions and requirements of the various ministries. This holds that the project needs to be beneficial for the development of the commu-

nity of Los Vilos, needs to enhance tourism in the area, needs to respect the marine ecosystem and needs to pass the SEA (Strategic Environmental Assessment).

5.4.7. Building with Nature example

A possible solution can be to trap sediment in the southern part of the bay, which could lead to sedimentation of the beach and therefore a growth of the beach. This growth of the beach meets the wishes of the residents and leads to a better protected area against the erosion. Safeguarding and enhancing sustainability, the design has to be resistant to future extreme events like tsunamis and earthquakes. Looking at historical events, tsunamis led to a lot of damage of the soft structures located at the coast. Because of these extreme events the design must exist of structures or interventions that can handle the forces of such an extreme event. With this given, the use of a fully natural Building with Nature solution is difficult in this case study.

Breakwaters can in this case function as a solution for this problem. Breakwaters reduce the impact of the waves on the coast and protect the beach from direct impact. The different examples on solving the problems in Los Vilos by constructing a breakwater are given below. These examples are thought of with limited research and available knowledge. So for further studies and a decrease in uncertainty, more research on the Los Vilos case study is advised.

- With tactical placement of the breakwater within the bay, the force of nature (in the case of Los Vilos this will be primarily the wave forcing) within the system can be used to trap sediment and supply sediment for the beach. By placing the breakwater in a tactical way, the forces of nature can be redirected and cause accretion of the beach. Also the availability of sediment in the system needs to be researched in able to see if trapping sediment is possible.
- The amount of material needed for construction of the breakwater is limited because of the shallow bathymetry near the beach of Los Vilos (in the order of 5 meters).
- With the construction it is best to use local natural building materials. An example could be to use the rock formations in the north of the Los Vilos bay and with this increasing swimmer safety on the old location of the rocks. However, there is a deeper investigation needed in the possibilities for this.
- With the construction of a breakwater there is a reduction in wave energy in the sheltered part of the beach. This causes an increase in swimmer safety in parts of the beach. Also the sheltered area can function as a place for animals and vegetation. This can be interesting for touristic activities like snorkeling, but can also offer fisheries an area where they can fish or collect algae and shellfish.
- A breakwater can function as a habitat for different sea creatures. For example shellfish or algae production could increase the food production of the community of Los Vilos.

See figure 5.39 for an example of a multi-functional breakwater.

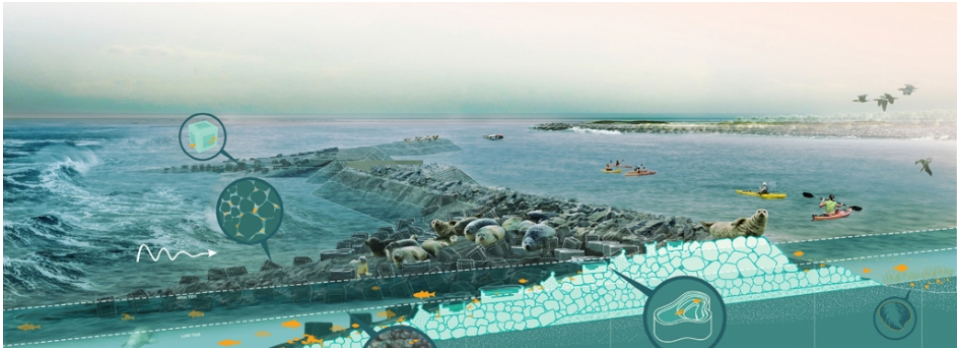

Figure 5.39: Example of a multi-functional breakwater Buckminster Fuller institute, 2007.

Depending on the way in which these breakwaters are designed, it creates different opportunities within the system. When analyzing the alternatives, the diffraction around the Caleta San Pedro must be taken into account. Furthermore, the design needs to ensure that the future activities of the port users will not be impeded.

Building with Nature alternatives

This last section shows different examples of the layout of the breakwater and some possible advantages and disadvantages. This is done to visualise the possible interventions and is based on a very basic analysis of the hydrodynamics. So in this section some rough approximations are made. To see the effectiveness of the solutions further research needs to be performed, specifically on the hydrodynamics of the area.

There are multiple possibilities to arrange the breakwaters. An extension of the pier at the Caleta San Pedro can reduce the impact of the waves in the southernmost part of the bay (the location where the biggest part of the erosion occurs) and it could be used for multiple other uses depending on the design. This also matches the wishes of the local residents. With this extension the impact of waves on the southern part of the beach is reduced due to the diffraction of waves around the breakwater. An approximation of the new wave and sediment transport patterns due to this extension is shown in figure 5.40. This leads to accumulation of sediment in the south part of the bay. This is still a rough approximation, so further modelling studies are recommended before deciding upon a final design.

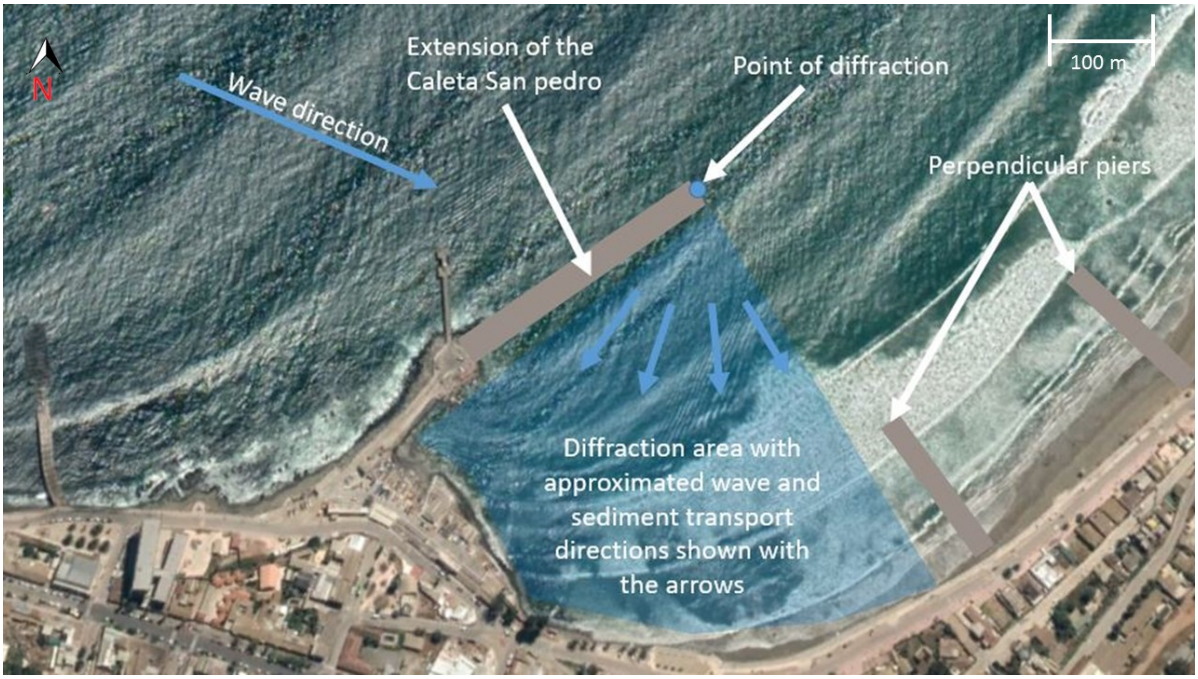

Figure 5.40: The impact of the new interventions is shown on the wave direction and the sediment transport. (Google Earth, 2018a)

Besides the extension of the Caleta San Pedro, perpendicular groynes, located more to the north (visible in figure 5.40) can be constructed. The added value of this kind of pier construction could be the increase in beach area in the more northern part of the beach shown in figure 5.41.

A possible outcome of the interventions, with all the added values included, is shown in figure 5.41. Besides possibly solving the erosion problem, there are possibilities for example for tourism, recreation, fisheries and nature. The design could create possibilities for an

expansion of the current port located at the Caleta San Pedro. Another alternative is to use the new sheltered area for touristic purposes, like a sport fishing spot or even an area for commercial facilities.

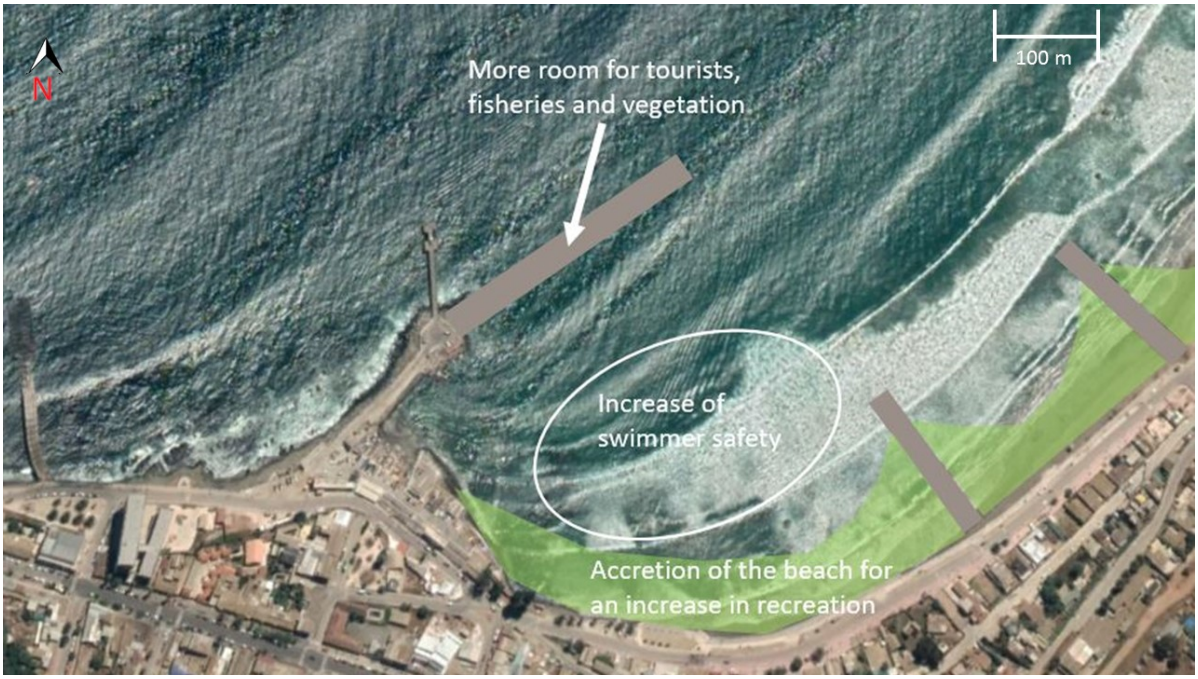

Figure 5.41: The different added values of the new interventions (Google Earth, 2018a).

Another alternative can be to place submerged groynes (in the same configuration as is done with the traditional groynes and piers). This decreases the amount of material needed. Also the breakwater is not visible and is not disturbing the view of the sea.

Some possible variations in configuration of the breakwater are shown in figure 5.42.

Figure 5.42: Different alternatives for configurations of the breakwater (Google Earth, 2018a).

A study more in depth should be preformed to decrease the uncertainties within the different examples, taking into account both the environmental impact and the additional values created for the scenario's.

5.5. Conclusion case studies

The three different case studies, discussed in the previous sections has shown the potential of applying Building with Nature in Chile. For all cases, an example is given on how Building with Nature could be a solution to mitigate the existing problems. It should be noted that

these examples are a result of a primarily analysis, so no precise advice could be given. However, it does provide a first guidance on how the problems could be solved.

There are however different aspects that are important to consider when applying Building with Nature to coastal projects in Chile, which are not present in the Netherlands. Especially earthquakes and tsunamis play an important role in the considered region. This became clear in the Los Vilos case, where fully soft, for example sandy solutions, seemed not to be the best solution for solving the erosion problem. Extreme events like tsunamis, earthquakes and storms, would make these solutions very vulnerable. However, this still provides possibilities for Building with Nature solutions, as mentioned in the design of the multifunctional breakwater in Los Vilos, with for example shellfish or algae production. Furthermore, in the Los Vilos case the local stakeholders are the main problem holders, as they have the most hindrance due to the beach erosion. From this, it can be concluded that it is important to involve the local stakeholders in the design as early as possible to include their wishes and perspectives in the design.

The Pichilemu case underlined the difficulties in finding a Building with Nature solution, because of the dynamic behaviour of the physical system characteristics. Interventions in the sea might be able to solve the erosion, however if the wave climate is affected, new problems possibly occur because of disruptions in the unique surfing conditions. All the different processes that influence the coastal environment in Chile seem not to be fully known yet. The complexity of the Chilean coastal system, in comparison with the coastal conditions in the Netherlands, is also shown in section 3.2 about the physical characteristics of the Chilean coast. This can, in some cases, limit the range of applicability of Building with Nature solutions in Chilean coastal areas. The large scale of the Chilean coast could also be a reason for the minor exact knowledge on specific areas of the coast, for example on the locations of the different cases.

Lastly, San Antonio shows that Building with Nature is also possible on different kind of problems. Where the cases of Pichilemu and Los Vilos primarily focus on erosion problems, San Antonio shows that building new constructions, like a port, is possible with the use of Building with Nature. This underlines the wide scope of application of Building with Nature in coastal areas.

In general, it is important for finding innovative and creative Building with Nature solutions in Chile, to know about the different nature components that can potentially be used in a solution. An increase in knowledge, on the natural system of the local case study level, gives more opportunities for finding Building with Nature solutions. The knowledge on different aspects of nature in Chile is limited, this also limited the range of applicability of Building with Nature in the different cases. When talking to Pilar Muñoz (2019), a marine biologist, it became clear that there are possibilities for Building with Nature solutions with the use of marine life. For example the damping of waves near the coastline using artificial reefs and algae. See appendix C.2 for more details about the meeting with Pilar Muñoz.

6

Awareness in Chile

In order to give recommended actions to create awareness on the introduction of the Building with Nature philosophy in the Chilean water sector related to coastal engineering, the current knowledge about the subject needs to be measured. A questionnaire was made to measure the current level of knowledge on Building with Nature and its aspects on different audiences. In that way, the challenges on where to raise awareness become clear. The results of this questionnaire are shown and discussed in the first part of this chapter.

In the beginning of the project, the project team designed methods to create awareness on Building with Nature in Chile. These methods were based on assumptions on the level of awareness in Chile. This was because the results of the questionnaires were not yet processed as they were giving out simultaneously during the execution of the methods. The short time of the project was the reason for this approach. The results of these tested methods are elaborated in the second part of the chapter. Based on these findings and the results of the questionnaire recommended follow up actions are formulated. These are presented in the conclusion.

6.1. Questionnaire

A questionnaire is made in both English and Spanish (see appendix D.1 and D.2 for the full questionnaire). The Spanish questionnaire is used as the questionnaire for the stakeholders and measures the current level of awareness on Building with Nature in Chile. To measure the awareness on a broad spectrum, several Chilean parties in the water sector and local stakeholders from the cases, with different backgrounds, filled in the questionnaire. The survey was executed in a six-week period, during the meetings with the different parties. A list with meetings and their dates can be found in C.3. All participants of the meetings filled in the questionnaire for the research.

For the questionnaire, a 5-point scale was used. Although the possibility of a neutral answer makes the results of a 5-point scale less clear, the scale is chosen because it is the first questionnaire on awareness of Building with Nature in Chile. Due to the fact that this project is the first project about Building with Nature in Chile, it is assumed that certain subjects in the questionnaire are unknown for the participants. If someone does not have enough knowledge about a certain subject and he/she has to give his/her opinion and has to answer only negative or positive, it would result in a non nuanced conclusion. Therefore, there is no incentive for a forced decision scale, like a 4-point scale.

6.1.1. Variables of the questionnaire

Most of the participants of the questionnaire had never heard of the Building with Nature philosophy, as it is not currently applied in Chile. To measure the awareness on this subject,

the questionnaire tests the awareness on different aspects related to the Building with Nature philosophy. Examples of these aspects are stakeholder participation and environmental knowledge and the value of it. All the questions which are included in the questionnaire are listed in figure 6.1.

	All the questions included within the questionnaire
1	**Was the environment an important subject during your education program?**
2	**Did you ever hear of BwN?**
3	**Do you have experience with BwN?**
4	**Do you think parties in the Chilean water sector related to the coastal engineering are applying an environmental centred design approach in current projects?**
5	**Do you think parties in the Chilean water sector related to the coastal engineering are involving the society within their design process in current projects?**
6	**Do you want coastal projects to be more environmentally centred?**
7	**Do you think there is the ambition in the Chilean water sector to apply an environmental design approach?**
8	**Do you think there is an urgency to apply an environmental design approach?**
9	**Do you want more involvement of the society in coastal projects?**
10	**Do you think there is the ambition in the Chilean water sector to involve the society in the design of coastal projects?**
11	**Do you think there is an urgency to involve the society more into the design of coastal projects?**
12	**Do you think a design approach like BwN can be profitable for your organisation?**
13	**Do you think a design approach like BwN can be beneficial for coastal engineering projects?**
14	**Do you think the government will support an organisation if they apply a BwN approach?**
15	**Who do you think is gaining the most out of coastal projects?**
	Government
	Private sector
	Society
16	**Do you think there is any pressure to apply an environmental centred design approach to projects? From:**
	Government
	Private sector
	Society
17	**Do you think there is any pressure to involve the society in the design of coastal projects? From:**
	Government
	Private sector
	Society

Figure 6.1: List of all the questions used in the questionnaire

With the questions different variables are measured. The variables are listed below, including the questions used to measure these variables:

- The level of environmental education and knowledge (question 1)
- Level of environmental value among important Chilean stakeholders (questions 4, 6, 7, 8 and 16)
- Current knowledge on Building with Nature (questions 2 and 3)
- Level of interest in Building with Nature (questions 12 and 13)
- Governmental support of Building with Nature (question 14)
- Perception on coastal related projects in Chile (question 15)
- Perception on stakeholder involvement within the Chilean water sector (questions 5, 9, 10, 11 and 17)

The questionnaire was handed out at the end of meetings that the project team organised within the project period. During these meetings the project team presented the Building with Nature philosophy and came up with critical questions for the different stakeholders. In this way, before handing out the questionnaire, the participants had a first introduction on the project scope and the Building with Nature philosophy.

A total of 16 people with different backgrounds and functions participated in the questionnaire. Some examples of stakeholder groups that participated are: a local fishery, a municipality, consultancy companies and local residents of coastal towns. During the project period the project team tried to get the opinion and views of as many different stakeholder groups as possible, to get a more complete view of the current level of awareness in the Chilean water sector.

6.1.2. Results

The average results of all the different participants are visible in appendix D.3.4 and the full results can be seen in appendices D.3.1, D.3.2 and D.3.3. The full results in the appendix are categorized in 3 different categories: Pichilemu, San Antonio and others.

The overall results are discussed for each variable that is measured within the questionnaire and elaborated upon below:

- **The level of environmental education and knowledge (question 1)**:
  The level of knowledge and education of the participants was found to be moderate. The participants from the private consultancy companies like GHD and Arcadis had good knowledge and education on the environment. The local stakeholders like the municipality and fisheries had less background on environmental studies.

- **Level of environmental value among important Chilean stakeholders (questions 4, 6, 7, 8 and 16)**:
  The participants attach high value on the environment. The stakeholders believe that coastal projects need to have a more environmental approach and that applying this approach is of high urgency. Stakeholders think that current coastal projects are not as much environmentally centered. The stakeholders stated that most pressure to apply an environmental approach is from the society and the least from the private parties and the government.

- **Current knowledge on Building with Nature (questions 2 and 3)**:
  Most of the participants never heard of the Building with Nature concept before and have no experience with applying this philosophy.

- **Level of interest in Building with Nature (questions 12 and 13)**:
  The interest in Building with Nature shown by the different parties is high. Besides that, they think it can be beneficial for coastal projects.

- **Governmental support of Building with Nature (question 14)**:
  It is doubted if the government would support an organisation if they apply the Building with Nature approach.

- **Perception on coastal related projects in Chile (question 15)**:
  The private sector gains the most out of coastal projects according to the stakeholders. This is followed by the government and in the last place, society.

- **Perception on stakeholder involvement within the Chilean water sector (questions 5, 9, 10, 11 and 17)**:
  A clear trend can be seen in the fact that people think it is necessary to involve society more in the design process of coastal projects. Right now there is not enough involvement of society according to the participants.

6.2. Methods applied to create awareness in Chile

The methods applied to create awareness on Building with Nature in Chile are based on expectations of the results about the current knowledge, due to the fact that the results of the questionnaire were not received yet. The results of these tests are elaborated in this paragraph. A list of the different methods is shown below:

- Presentation and workshop on the university
- Site visit including stakeholder meetings
- Site visit including workshop
- Meetings with parties in the Chilean water sector

This section also looks into the effectiveness of these methods in raising awareness on Building with Nature. The activities are described in detail with accompanying pictures and materials used. For future Building with Nature projects in Chile the descriptions of these practical experiences gained by the project team can be helpful.

6.2.1. Presentation and workshop on the university

A presentation and workshop was performed on the Universidad de Valparaíso on the 22nd of March 2019. The presentation was promoted among all students and professors of the university (see appendix E.1 for the flyer that was used for promotion). About 15 people were present during the presentation. The goal of the presentation was to give the university members an introduction on Building with Nature and the way in which it is already applied in the Netherlands. An impression of the presentation can be seen in left picture in figure 6.2.

After the presentation, the project team performed a workshop. The workshop is a method to raise awareness by walking through the Building with Nature approach with the participants. The workshop focused on the San Antonio harbor expansion case study (see section 5.2 for more information on this case). The aim was to show, in an interactive way, how the first two design guidelines of Building with Nature are applied in a project. These are: understanding the system and coming up with design alternatives. First, the important socio-economic and physical aspects which are of importance in the San Antonio case were discussed. The participants were asked for aspects of the system that they thought were of importance. After this the participants were divided in two groups and were given the assignment to think of Building with Nature solutions for the harbour expansion in San Antonio. The picture on right of figure 6.2 was taken during the workshop. At the moment of the picture the two different groups were thinking of Building with Nature solutions.

Figure 6.2: Pictures taken during the presentation and workshop on the Universidad de Valparaíso on 22-03-2019

The combination of a presentation and performing a workshop was deliberately done, as the goal of the workshop was to let the participants apply the information they obtained during the presentation to a local Chilean case. In this way, with a workshop, the participants could gain a better understanding about the Building with Nature philosophy in addition to the presentation.

The response of the participants during this event was overall positive. This became clear during the workshop where the participants had good suggestions and ideas about possible Building with Nature solutions. This showed that they gained some awareness on Building with Nature during the presentation and could apply it during the workshop.

The presentation and workshop were performed in English. As not all the participants had good skills in English, part of the audience was not able to fully understand the topics discussed during the presentation. With the help of the supervisor, that translated some parts of the questions, especially during the workshop, this language barrier was reduced. In this way, the effectiveness of the workshop was not affected much.

On the website of the Universidad de Valparaíso an article with a picture was published after the presentation and workshop. This also functions as a way to raise the awareness on Building with Nature. The article can be seen in figure 6.4. The full article is presented in appendix E.1.

Figure 6.3: News article published on the website of the Universidad de Valparaíso

6.2.2. Site visit including workshop

A site visit, including a workshop with different stakeholders, was planned for Pichilemu. After discussion with Mauricio Reyes, the workshop was eventually not performed. It is expected that a workshop in Pichilemu would need a lot of time to set up so within the eight-week project period it was found not to be the most effective way to raise awareness on Building with Nature. Each stakeholder had its specific agenda for the period of the site visit which made it difficult to get them together for a workshop. Furthermore, it was expected that there would be some difficult issues between the parties, which reduces the effectiveness

of the workshop. Moreover, the arrangement of a location for the workshop would have taken too much time. This is why the project team decided to carry out a site visit with separate stakeholder meetings in Pichilemu. More details on this site visit is shown in the next section.

Still, the project team thinks that performing a workshop can be a good way to raise awareness on Building with Nature. As Building with Nature is about involvement of all relevant stakeholders in the project, the gathering of local stakeholders for a workshop could show the potential of this working method. In this way also the communication and cooperation of the different local stakeholders can be improved.

6.2.3. Site visit including stakeholder meetings

Two different site visits including stakeholder meetings were performed. The two locations of the site visits were San Antonio and Pichilemu. Besides raising awareness concerning the Building with Nature philosophy among the local stakeholders, the site visits functioned as informational input for the case studies. Meeting with different stakeholders helped to gain knowledge on the local socio-economic system of the specific cases. Furthermore, visiting the location of the case study, helped to get a better view on the problems. The presentation shown in appendix E.2 was used during the meetings to explain Building with Nature.

The site visit in Pichilemu was performed on the 4th and 5th of April 2019. During those two days of the site visit five different stakeholders were met. An overview of these people with their function and background is listed below.

- Flor Ilic: Director Culture center Pichilemu (A picture taken during this meeting is shown in the upper part of figure 6.4.)
- Andres Margozzini and Sophia Claro: Fundación Punta de Lobos
- Genaro Gverrero: President of Fishery federation Pichilemu
- Daniela Paz González Cordero and Macarena Cornejo: Municipality of Pichilemu
- Nicolás Recordón: surf community (a picture taken during this meeting is shown on the bottom of figure 6.4.)

For specific information on the stakeholders whom the project team met during the Pichilemu site visit, see appendix C.4.1.

The site visit in San Antonio was performed on the 10th of April 2019. Loreto Trigo, student of the Universidad de Valparaíso and resident of San Antonio, gave a tour in the city during this day. Also two meetings were performed with local parties. An overview of these two parties with their function/background is listed below:

- Loreto Denisse Trigo: Thesis student Universidad de Valparaíso and resident of San Antonio
- Oscar Tapia Rojas: Head of Economics municipality
- Horacio Moggia, Pedro Celis and Samatha Hartwig: Puerto Central (PCE)

For specific information on the stakeholders whom the project team met with during the San Antonio site visit, see appendix C.4.2.

At the end of each of the meetings the questionnaire was filled in by the local parties. The results of the questionnaires are elaborated upon in the previous section. Besides these results the project team got some interesting perspectives from the meetings. When looking at ways to incorporate Building with Nature in Chile, the following perceptions from the stakeholder meetings are worth noticing:

Figure 6.4: Picture of meetings with Flor Ilic (top) and Nicolás Recordón (bottom) who are both stakeholders in Pichilemu

- Most of the local stakeholders at the various cases explained that they have the feeling that governmental organisations (for example DOP and EPSA), who are responsible for the large coastal projects, are not involving them enough in the design process. The municipality of Pichilemu (2019) mentioned that the government is organizing citizen participation events but the attendance of these events is low most of the times. The reason for this low attendance is not further researched in this study. A possible reason could be that the citizens are not interested in these kind of events, as was also indicated by local surfer Nicolás Recordón (2019). A second reason could be that the state organisation is not doing their best to inform the citizens about those events. And lastly, citizens could have the feeling their opinion is not taken into account. The views of the different local stakeholders showed that in there is not a good communication between the communities and the governmental organisations.

- In Building with Nature, early involvement of the relevant stakeholders is very important in the project. The local stakeholders think their involvement within the project needs to be in an earlier stage. The local stakeholders point out that they are mainly invited to participation events if the design is already completed. On top of that they have the feeling that the project owners do not take their opinions and wishes into account.

- The opinion of the local stakeholders on the general Chilean environmental knowledge and education was clear. The local stakeholders think that the overall education knowledge of the Chileans on the environment is low. Some of them argued that it is getting better. The younger students are getting more education on the environment, however this is still in the first stage.

- The role of the municipalities within coastal projects is not that significant. This came forward during the meeting with the municipality of Pichilemu (2019). The coastal projects are not within the budget of the municipality. The role of the municipality within coastal projects is to represent the citizens during stakeholders participation meetings and offer a platform them. The minor role of the municipality within coastal project might be a reason for the disturbance in the connection between the citizens and governmental parties.

6.2.4. Meetings with parties in the Chilean water sector

The project team had various meetings with different parties within the Chilean water sector. During the meetings, the main goal was to raise the awareness among the different parties. Besides this, the project team asked questions to gain information on the socio-economic aspects of the Chilean water sector, the role of the parties within the Chilean water sector and background information on the case studies. The two parties who were met with are Arcadis Chile and GHD.

Arcadis Chile

In the meeting with Arcadis Chile the project team met with two employees of the consultancy firm (see figure 6.5):

- Fernando Calle: Head of innovation
- Teresa Cabral: Hydraulic Engineer

Figure 6.5: Picture taken during the meeting with Fernando Calle and Teresa Cabral at Arcadis Chile

Arcadis Chile is a consultancy company in Chile with experience and knowledge within sectors as water, transport and renewable energy. During the meeting with Arcadis Chile, a lot of interest was shown in the Building with Nature philosophy. According to the persons we met, the ability to implement Building with Nature in Chile within the business sector depends on different things. Firstly, they think it needs to be proven that the Building with Nature approach is a good alternative in Chile for the traditional engineering approach within the business sector. This can be done by comparison of the two approaches and with this highlighting the added values of the new Building with Nature approach. Lastly, the introduction of extra incentive for environmental approaches by the client (clients of Arcadis Chile can be both governmental and private instances) could be beneficial for Building with Nature like solutions.

Arcadis Chile indicated, after the meeting, that they are willing to spread the word about Building with Nature within the different departments of the company. A follow-up appointment for a presentation was due to time restrictions unfortunately not possible. However, the meeting with Arcadis Chile appeared to be very effective in raising awareness on the subject.

GHD

In the meeting with GHD the project team met with three employees of the consultancy company:

- Cristopher Zambra: Project engineer and ex-student of Universidad de Valparaíso
- Patricio Opazo: Project engineer and ex-student of Universidad de Valparaíso
- Mario Veneciano: Project engineer (expert on the Los Vilos case ad ex-student as well)

GHD is originally an Australian consultancy firm who operates in Chile. In Chile, they provide services in markets like transport, maritime engineering and coastal engineering. The meeting was arranged with the engineering department of the company. The employees of GHD had some knowledge on the Building with Nature philosophy which made it easier for the project team to explain it in more detail.

The clients of GHD can be both governmental and private companies. GHD itself is very interested in applying more environmental based solutions and starting to work with, for example, the Building with Nature philosophy. However, because of business purposes, they are forced to adapt to the requirements which are proposed by the client within the tenders of projects. They stated that projects of the DOP, which are tendered to private companies, have a very bureaucratic character. These bureaucratic systems do not match well with the business objectives of GHD. The late payments are an important reason why GHD thinks that the DOP is not the ideal client. When asking about their possible involvement in the San Antonio port expansion project, it became clear that the tenders included very traditional ways of engineering that did not fit the more innovative and sustainable project objectives of GHD. This also limits the space for the private companies to apply creative and different solutions.

For specific information on the parties whom the project team met with within the Chilean water sector, see appendix C.3. Conclusions regarding the results of the questionnaire and various methods to raise awareness can be found in the next chapter.

7

Conclusion

The Building with Nature philosophy has two fundamental principles. When applying the philosophy, it makes use of the natural forces and elements as a part of the solution in coastal infrastructure and creates possibilities and opportunities for future development of nature areas. In order to safeguard these principles, the parties involved in the Dutch organisation EcoShape can be divided into three different categories: knowledge, governance and business. To answer the main research question *"What are the recommended actions to create awareness on the Building with Nature philosophy in the Chilean construction sector?"*, this chapter discusses the conclusions and the recommended actions per category.

7.1. Recommended actions

Knowledge

One of the most important findings that followed from the results of the questionnaire, was the potential for an increase in the environmental awareness and knowledge among the Chilean population (see section 6.1.2 for these results). Among the participants of the questionnaire the environmental knowledge was moderate. However, during the meetings the main tendency among the parties was that, in general, the environmental knowledge and value in Chile is low.

Furthermore, when designing Building with Nature solutions, the physical conditions in Chile are different than in the Netherlands, as discussed in chapter 3.2. The characteristics of the coast are different: instead of the wide sandy beaches, the Chilean coast is characterized by rocky and steep shorelines. This makes implementing soft solutions, like those implemented in the Netherlands, more difficult and harder solutions like breakwaters (possibly combined with soft solutions) could be considered, as in the Los Vilos case study.

Additionally, the effect of extreme events like tsunamis, storms and earthquakes are important to consider in Chile. These events causes the Chilean coastline to be unpredictable and dynamic. In addition, there is a lack of in depth knowledge on coastal processes at some places along the coast, which makes it difficult to find suitable solutions. This was, for instance, visible during the case study in Pichilemu, where solutions for the erosion problem are hard to implement because the local conditions are not fully understood and researched. Modelling coastal processes is an example of more in depth knowledge. This lack of in depth knowledge can also be devoted to the large scale of the Chilean coastline with a lot of different coastal environments and processes.

To increase the knowledge on both the environment as the physical system, knowledge institutes like universities can play an important role. By increasing the amount of studies on the coastal processes, universities could raise awareness on this topic for the next genera-

tion of engineers and also increase the amount of trust in alternative solutions. Therefore, it is of importance to engage these knowledge institutes in a Building with Nature consortium to enhance and exploit more expertise on the ecosystems and pass this on to the students. When various knowledge institutes work together, expertise can be exchanged and cooperations can be established to enhance the understanding of the coastline systems in Chile, with respect to the physical, social and ecological characteristics. In this collaboration a multidisciplinary approach is essential. This multidisciplinary approach is also one of the important aspects of Building with Nature. An example of an institute that can be involved is the Universidad de Valparaíso, including their department of Oceanic sciences and Maritime Biology. Additional knowledge institutes can be approached to increase the support and awareness on Building with Nature among those parties .

Governance

The various case studies and meetings showed that local stakeholders of a coastal project are usually involved at the end of a project, after a design is made. When stakeholders are involved from the beginning of the project, 'in a Building with Nature way', the value of their input can be much higher and useful for the design of the solution. With this early involvement, the projects are likely to be more successful as it was found that previous large Chilean projects had difficulties with opposition of the public (see chapter 3.1.5 for more details on those projects). Additionally, GHD stated in a meeting that tenders of governmental clients usually have limited space for innovative solutions. Therefore, it is recommended to review the tender procedure and to find ways to encourage innovative solutions. By generating this incentive in tenders, innovative and sustainable solutions, like Building with Nature are more accessible and profitable for a design.

The important parties for the coastal sector in Chile to consider to implement a Building with Nature consortium, from a governmental viewpoint are the Dirección de Obras Portuarias (DOP), which is a coastal directory of the Ministerio de Obras Públicas (MOP). The DOP is the client for public coastal projects and is therefore an important actor to engage in the implementation of Building with Nature in Chile. They could create an incentive for innovation in the design, like the Building with Nature philosophy, when they give out a tender for projects. Other parties who are valuable to engage in such a type of consortium are the Ministerio Medio Ambiente (Ministry of the Environment), the Ministerio Desarrollo Social (Ministry of Social Development) and the Gobernacion Maritima Directemar (Maritime government).

Business

There is a significant difference in the involvement of private parties in coastal projects between the Netherlands and Chile. Where in the Netherlands all coastal projects are initiated by governmental organisations, in Chile it is also possible for private companies to be the client of a coastal project (for example with private land owners in the coastal zone). This makes the economical profitability of a solution a more important aspect of a tender. Therefore, it is of importance to show the possible economic benefits when applying Building with Nature solutions. An example of cost reduction in a Building with Nature solution is the involvement of the stakeholders from the beginning of the project and with this, design changes in a later design phase, due to public opposition are less likely to occur. Additionally, the interviewed private parties stressed out that there is a conservative way of thinking among the clients, in both the private parties as well as the governmental institutes. In this conservative way of thinking, hard structures are seen as the most safe solution for coastal projects because of the dynamics of the coast and the scarcity of data on natural processes. Besides of the conclusions drawn from the meetings and questionnaire, Hofstede (2019) indicated a high uncertainty avoidance among the Chilean society which could also be an explanation for the lack of trust in innovative designs of the clients. Therefore, it is valuable to enhance the trust in nature based solutions by studying and proving the possibilities. Additionally, an improvement in the understanding of ecological and coastal processes can complement the feeling of certainty in Building with Nature solutions within private companies and the

cooperation with knowledge institutes.

The private parties that are on the employer side of the project hold, in general, a positive attitude towards the Building with Nature approach. Especially the consultancy parties showed interest in the philosophy and the creation of a platform for it. These parties can be valuable to involve when introducing the Building with Nature philosophy in Chile and establish a consortium.

Overall the culture in the Chilean building sector related to coastal structures shows a very individual and conservative way of designing compared to the Netherlands. As the nature is highly unpredictable, the trust in large concrete structures plays a leading factor in the current coastal designs. Also the short term political structure is clearly visible in the way of designing. Cooperation between different parties can be a time consuming process and makes it difficult to succeed such a project in the elected period of one single major. This is reflected in the, by Hofstede (2019) indicated, high uncertainty avoidance as described before, and short term orientation in the Chilean culture. This holds that the focus in Chile is on quick results and short term gains, something that does not characterize the Building with Nature philosophy and which can cause challenges when implementing it.

7.2. Initial steps for introducing Building with Nature in Chile

To introduce Building with Nature in Chile, more awareness on the topic needs to be created. To do so, different methods (described in chapter 6.2) have been tested during the project. Especially the workshop on the Universidad de Valparaíso had good results. Performing a workshop with stakeholders was found to be difficult if the relationship between the parties is disturbed. Furthermore, it also takes time to organise such a meeting. Still, performing a workshop is advised as a good way to raise awareness on Building with Nature. As Building with Nature is about involvement of all relevant stakeholders in the project, the gathering of local stakeholders for a workshop could show the potential of the philosophy. In this way also the communication and cooperation of the different local stakeholders can be improved. The low score on the culture aspect of Individualism in Chile, as indicated by Hofstede (2019), means that there is a more collective attitude in the Chilean society where the relation with friends and family are tight. This characteristic of the culture can be beneficial and valuable when establishing a Building with Nature consortium.

Furthermore, meetings with various engineering consultancy firms, showed the presence of a strong interest to enlarge the consciousness on the environmental and societal characteristics of Chile and the ambition for a more co-creative and multidisciplinary design approach. Arcadis Chile has shown interest to establish a platform to introduce the Building with Nature approach in Chile. Together with the Universidad de Valparaíso, Arcadis Chile can be the initiator for the implementation of the philosophy and the increase of awareness among other important actors in the coastal engineering sector. The methods which are tested and described in this report can be used by the Universidad de Valparaíso and Arcadis Chile to further increase the awareness in Chile. Besides that, a first step for the Universidad de Valparaíso could be to start involving Building with Nature in the curriculum at the faculties of Ingeniería Civil Ambiental and Ingeniería Civil Oceanico, several professors indicated that they thought this was a good idea. And besides this, they could start with trying to raise awareness on other universities in Chile.

8

Discussion

The project team used different methods, described in chapter 6, to answer the main research question. When reviewing the results of these applied methods, it must be stated that the research is to some extent limited. In this chapter, the limitations of the research are elaborated.

8.1. Limited project period

The short project duration of 8 weeks meant that the research is limited to a certain extent, so that some parts of the research are advised to develop further.

First of all, the case studies are elaborated on a general level. With the different case studies the variability of the Building with Nature approach could be shown. However, the example of a Building with Nature solution is therefore based on a general literature study with sometimes limited data and meetings with stakeholders.

Secondly, the meetings with local stakeholders showed that the communication between the local communities and the governmental organisations is, in some way, disturbed. Due to time limitations of the research the project team was not able to meet with important government parties to get more insight in this situation. With the scope of the current research it is not possible to conclude what the cause of this disturbance is.

Furthermore, a questionnaire is used to measure the current level of knowledge about the Building with Nature approach and its aspects. Due to time limitations, this questionnaire is only filled in by sixteen different individuals related to the subject. Therefore, no statistical value could be attached to the results of this questionnaire.

8.2. Language barrier

Since the project was carried out in a country with a different language than the language spoken by the project team, the interpretation of conversations with Chilean people can be questioned. On the other hand, the Chilean parties with whom the project team spoke, may also have incorrectly interpreted parts of the conversation. This may be of influence on some conclusions. This risk was minimized due to the fact that our Chilean supervisor, who was constantly engaged in the project, functioned as an interpreter during the project. However, the language barrier could still cause some variations to the conclusions drawn.

The Chilean supervisor is the only one who functioned as an interpreter in the project. On one hand it helped minimizing the language barrier as discussed, however, the interpretation of the supervisor can be of influence on the results. The same has to be noticed about the questionnaire translated from English to Spanish. In potential future research it is recom-

mended to involve multiple interpreters for the translation of the questionnaire.

8.3. Potential colored view of the participants of the research

Due to the fact that the participants of the research showed an initial interest in Building with Nature by willing to participate in meetings, it might be the case that their opinions about certain aspects of the philosophy are biased. It could have caused colored results of the questionnaire and conclusions drawn from the various meetings.

9

Recommendations

The limitations on the research are presented in chapter 8, some of these limitations ask for further investigation.

As mentioned in the discussion, the case studies can be elaborated further to prove the potential of the Building with Nature philosophy in a more detailed way. Modelling work can be used to gain a better understanding of the physical system and possible solutions. Furthermore, it is suggested to organise meetings in which different stakeholders get together to generate more mutual understanding. This can also contribute to better Building with Nature solutions.

Furthermore, organising meetings with different governmental organisations is recommended in order to have their perspective on the disturbance of communication with the local stakeholders. Due to the fact that there have been no meetings with the governmental organisations, like the MOP and DOP, their point of view on Building with Nature is missing. Furthermore the possible future role of different governmental organisations can be discussed during these meetings. In this way all different parties (governmental, business and knowledge) are included for the potential consortium develop Building with Nature in Chile.

Lastly, in order to generate a more thorough conclusion based on the questionnaire, it is desirable to extend the list of participants with people of different backgrounds. In this way, a statistical value can be attached to the results of the questionnaire and the current awareness and perception on Building with Nature can be measured better.

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A

Background study

A.1. Earthquakes: overall information and terminology

This chapter gives context to chapter 3.2.6 in the form of overall information and terminology about earthquakes. The information in this chapter is obtained from (Reyes, 2019).

Earthquakes origin from relative movement between the component plates of the earths crust. The movement that origins from the litosphere (the outermost shell of the earth) causes earthquakes. Earthquakes can be divided into two categories: interplate and intraplate earthquakes. Interplate earthquakes result from either lateral movement or convergence of two plates of the earth. Intraplate earthquakes are generated inside of one particular plate. It is very uncertain where interplate earthquakes occur, and they don't cause as much problems or damage worldwide as the interplate earthquakes.

The worldwide prevalence of earthquake is shown in figure A.1 below. It can be clearly seen that the seismic activity is focused around the boundaries between component plates of the earth. This confirms the statement that interplate earthquakes are more dominant.

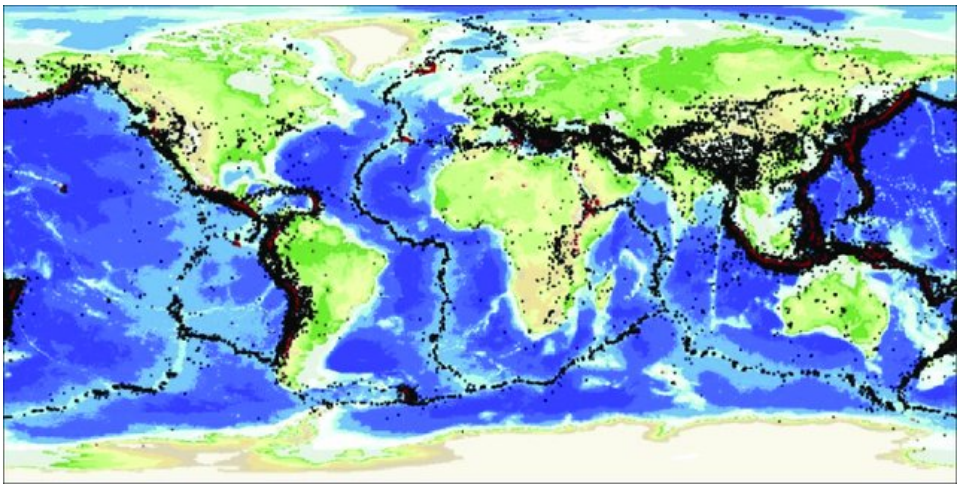


Figure A.1: The worldwide prevalence of earthquakes (S Kelly and Witt, 2015)

An earthquake starts from its hypocenter. This is the point under the earths surface where the first energy is released (see figure A.2), this can also be considered as the start of the rupture. The point directly above the hypocenter on earths surface is called the epicenter. The vertical distance between the hypocenter and the epicenter is called the hypocentral

depth, this depth is different for every earthquake. Earthquakes can be split up by the following:

- Superficial (hypocentral depth of 0 to 70 km)
- Intermediate (hypocentral depth of 70 to 300 km)
- Deep (hypocentral depth more than 300 km)

From the hypocenter, seismic waves (which are waves of energy) are transmitted through the earths crust. There are two types of seismic waves which are of the most importance in seismic movement due to earthquakes: the P-wave (primary wave) and the S-wave (secondary wave). Visualizations of the different waves can be seen in figure A.2 shown below.

- The P-wave is the fastest kind of seismic waves and therefore arrives first in case of an earthquake. It is a pressure wave with relatively low energy. As it is a pressure wave it can move through both solids and fluids.
- The S-wave is the wave which will arrive after the P-wave. It is a slower paced wave but has more energy than the P-wave. This wave is not a pressure wave but a real moving wave. This makes it that it can only travel through solid rock (since water cannot transfer shear stresses).

In more practical terms, the P-wave is the lower energy wave that arrives first to the place of interest. After that the more energetic and destructive S-wave arrives. The time between the arrival of these waves depends on the distance to the hypocenter. When you feel the P-wave, it can function as a warning to get to a safer place before the S-wave arrives. The time between the arrival of the two waves was for example around 20 seconds in Valparaíso, Chile during the big earthquake on 27th of February 2010 (Reyes, 2019).

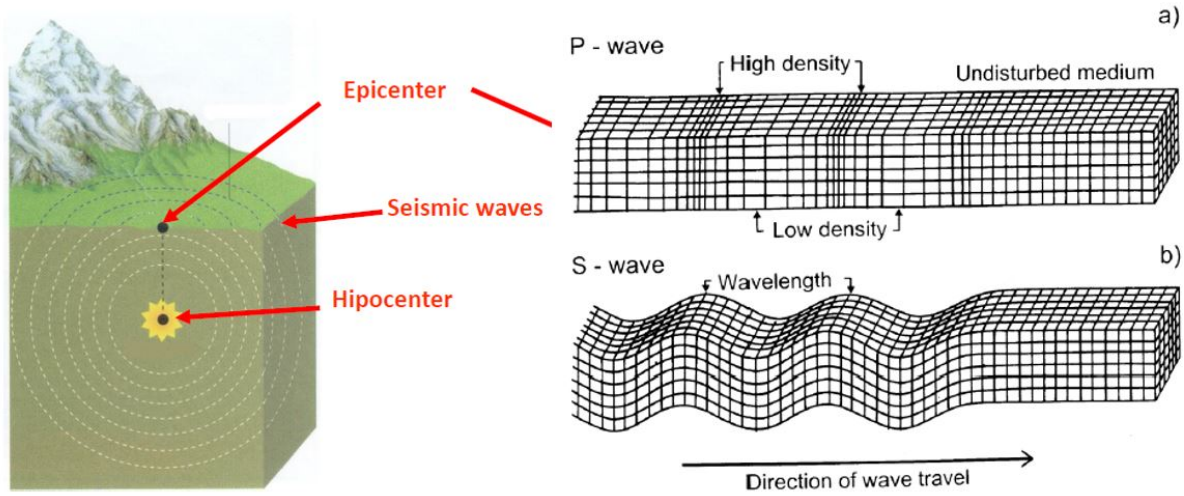


Figure A.2: Earthquake terminology (Reyes, 2019)

Earthquakes can be described by intensity and magnitude. To characterise specific earthquakes on the scale of intensity the Mercalli scale is used. This scale is related to the damage caused by an earthquake. This Mercalli scale can differ among the different locations affected by the specific earthquake. The most common way to describe an earthquake is by its magnitude. The Richter magnitude is the most used factor for this. This number describes the relative size of an earthquake by measuring the maximum motion recorded by a seismograph (a device which can detect and record earthquakes). Seismographic stations along the coastline are able to detect earthquakes when they occur.

A.2. Tsunamis: characteristics

This chapter provides context to chapter 3.2.7 in the form of overall information about tsunamis. The information in this chapter is obtained from (Winckler, 2019a).

Tsunami waves have very unique characteristics. A tsunami wave acts like a shallow water wave, even in the deep ocean. This is because of the long typical wave length in the range of 20 to 500 km. A typical characteristic of a shallow water wave is the fact that the wave impacts and moves the whole water column. This consequently means that tsunamis transport a lot of sediment. Because of the long wave lengths a tsunami wave can travel big distances without losing much energy. In image A.3, the propagation of the 2010 Chile earthquake can be seen over the whole pacific ocean. The tsunami was still measurable in China. This confirms the fact that tsunamis have minor loss of energy during propagation (Reyes, 2019).

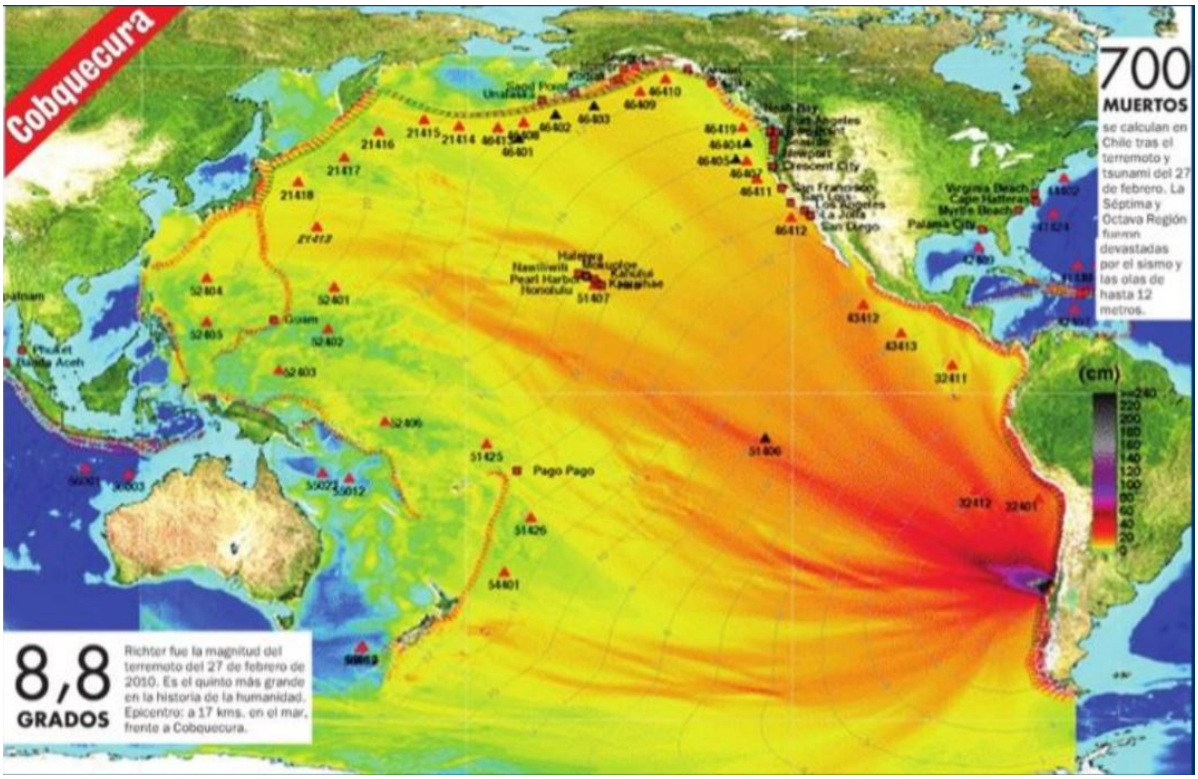


Figure A.3: Propagation of the 2010 earthquake in Chile over the whole world (Reyes, 2019)

The speed of tsunami waves are dependent on the depth of the water. For example a 100km wavelength tsunami in a depth of 6km (wave length is much higher than the water depth which means this wave is a shallow water wave) has a wave speed of: $v = (g * d)^{0.5} = (9.81 * 6000)^{0.5} = 242m/s = 871km/hr$. These are huge propagation speeds and confirm the fact that tsunamis can travel around the world very rapidly.

The transformation of tsunami waves when they approach the coast is very dependent on the bathymetry and shape of the coast. When tsunamis approach the coast (decrease in water depth along path of propagation) the length and speed of the wave decreases. The wave height dramatically increases due to the shoaling process, which means the energy flux stays almost constant and is dependent on the wave speed and wave height, so with a lower wave speed the wave height increases. Tsunamis can arrive at the coast in different forms. They can look similar to rising and falling tides with different periods, they can behave like a normal wave approaching the coast and they can for example arrive as a bore (which most of the times occur at very flat coasts) (Damen et al., 2005).

A.3. Earthquake and tsunami in 2010

To illustrate the massive force of an earthquake and tsunami, one in the year 2010 is used. On the 27th of February of 2010, a heavy earthquake with a magnitude of 8.8 MW struck the coast of Chile, with the epicentre located 35 km offshore from Maule , see figure A.4. As a result of the earthquake, a large tsunami occurred with wave run-up of around 10m. At the place Tirúa a run-up of 30m was recorded (Edge, 2013).

Figure A.4: Map of the 2010 earthquake (BBC News, 2010b)

The United States Geological Survey (USGS) stated that at least 521 people didn't survive the events, 56 people went missing and 12,000 people were injured. Also large damage to houses, schools, hospitals and infrastructure occurred. The estimated damage was around 30 billion U.S. dollars according to the Chilean president Piñera (BBC News, 2010a).

After the earthquake an ASCE-COPRI Investigation team, consisting of coastal, structural and geotechnical engineers, was formed to conduct a field investigation about the effects of the earthquake and the following tsunami on the infrastructure and ports. The damage varied widely, both in cause and severity. However, overall the damage was less than could be expected and the main failure mechanism was soil fracture. They concluded that the usual design code was conservative and Chile should investigate the use of a more performance-based design. Furthermore, the tsunami damage to ports was small, because of a tsunami protocol of the port authorities, to order vessels out immediately after a major earthquake. Lastly they concluded that Chile needs a more extensive network of seismic instrumentation (Edge, 2013).

B

Building with Nature, project level

This chapter provides the necessary background on the natural system of the 3 different case studies: San Antonio, Pichilemu and Los Vilos, Pichilemu.

B.1. San Antonio

This section provides more detailed information on the natural system of San Antonio, fully described in section 5.2.

B.1.1. Tsunamis

A map of the tsunami hazard zone of San Antonio can be found in figure B.1.

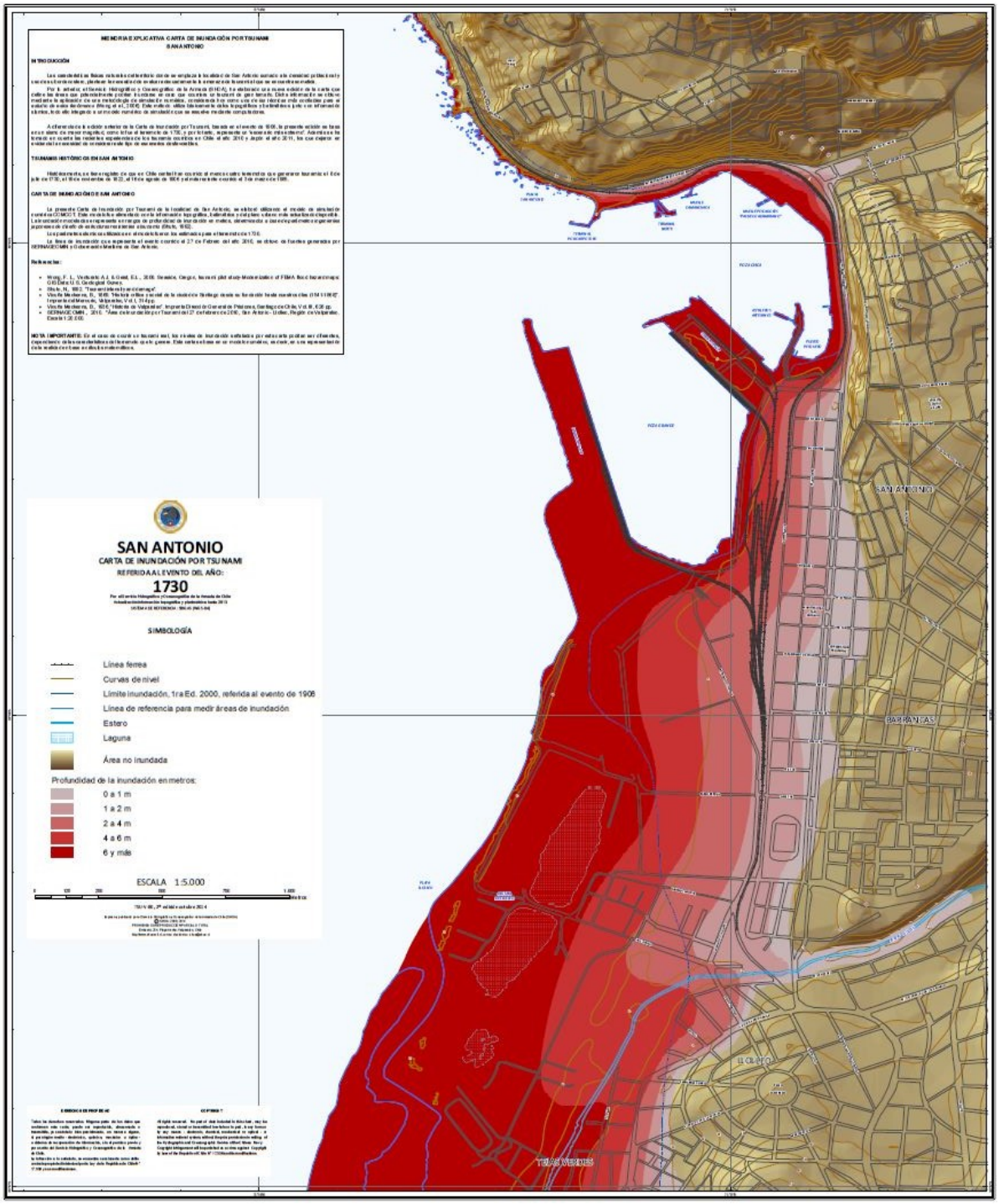


Figure B.1: Tsunami inundation map of San Antonio (SHOA, 2017)

B.2. Pichilemu

This section provides more detailed information on the natural system of Pichilemu, fully described in section 5.3.

B.2.1. Erosion

The figure B.2 below, the decrease in beach area from 2009 to 2018 is shown. In figure B.3 the location of the cross section is shown.

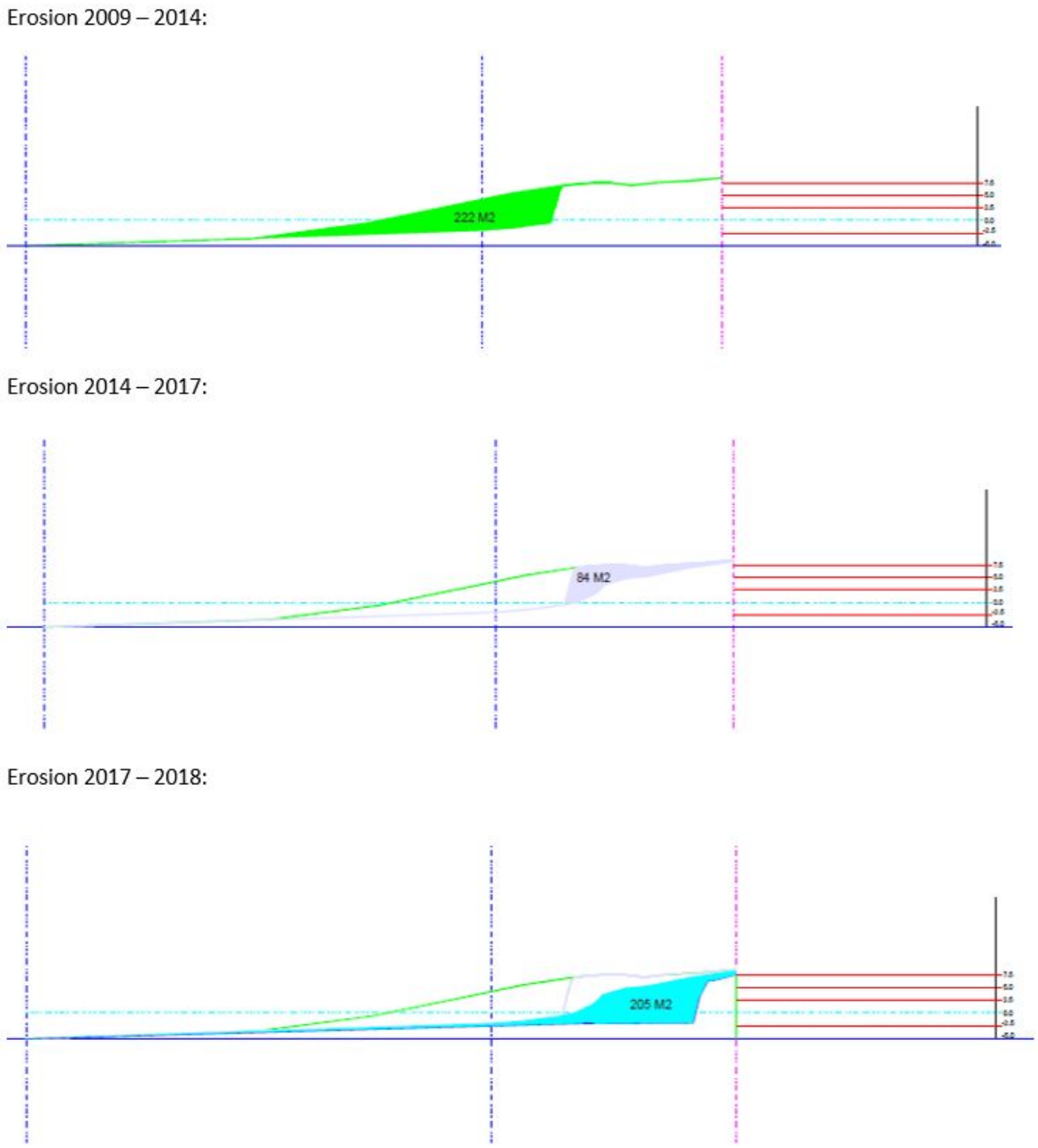


Figure B.2: Eroded areas in different time windows (Recordon,2018)

Figure B.3: The location of the cross section (Recordon,2018)

B.2.2. Tsunamis

In figure B.4 a tsunami inundation map is shown of Pichilemu and its surroundings. There is some significant flooding in the case of a big earthquake in the area behind the Punta de Lobos beach. The people living on the dunes directly behind the beach will definitely be in danger in the case of a tsunami.

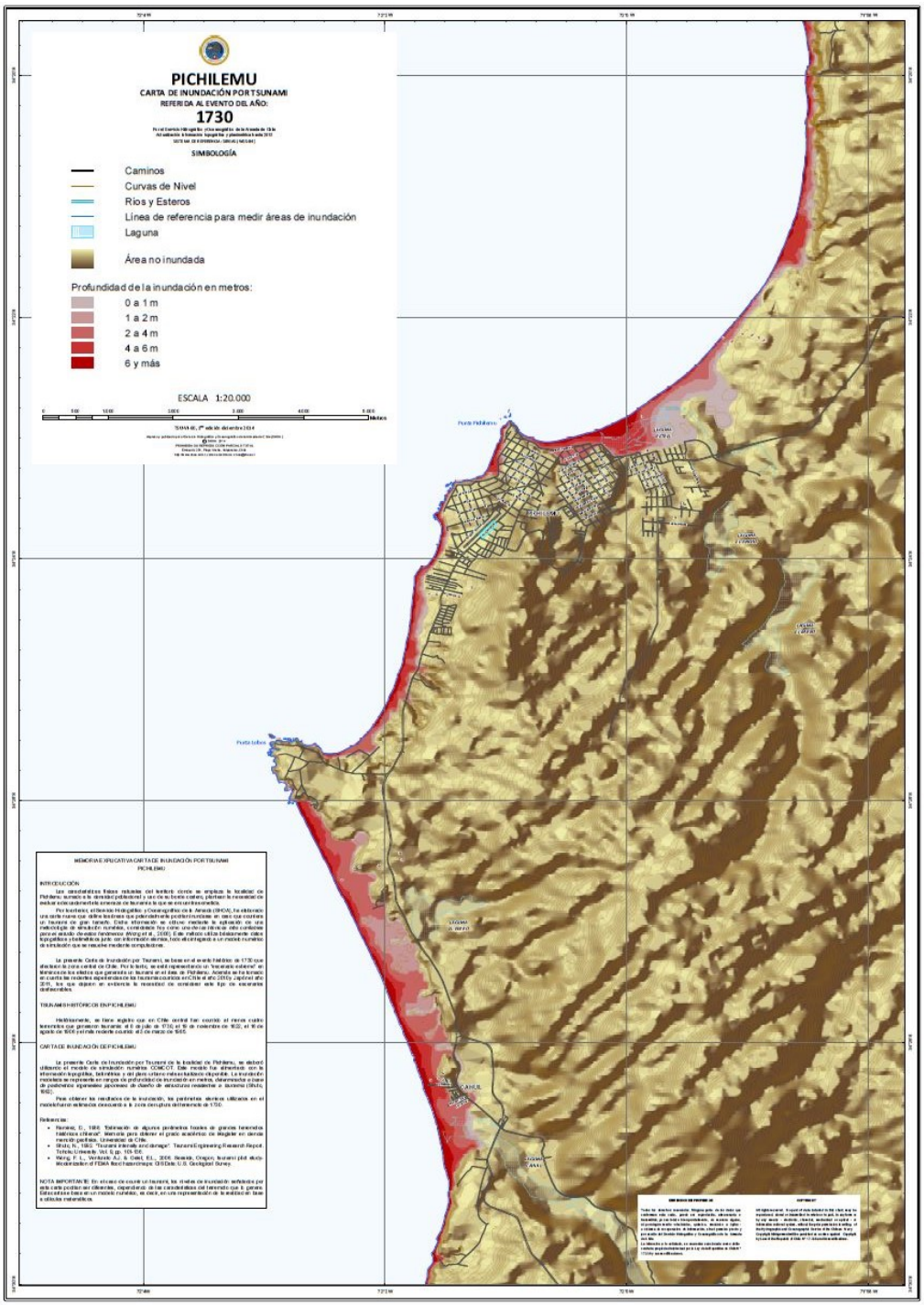


Figure B.4: Tsunami inundation map of Pichilemu (SHOA, 2017)

B.3. Los Vilos

This section provides more detailed information on the natural system of Los Vilos, fully described in section 5.4.

B.3.1. Waves

Waves (offshore)

For the wave study, data from the offshore deep water point at (72E, 30S), situated around 220 km from Los Vilos, is used. The figure below shows the directional spreading of the significant wave height.

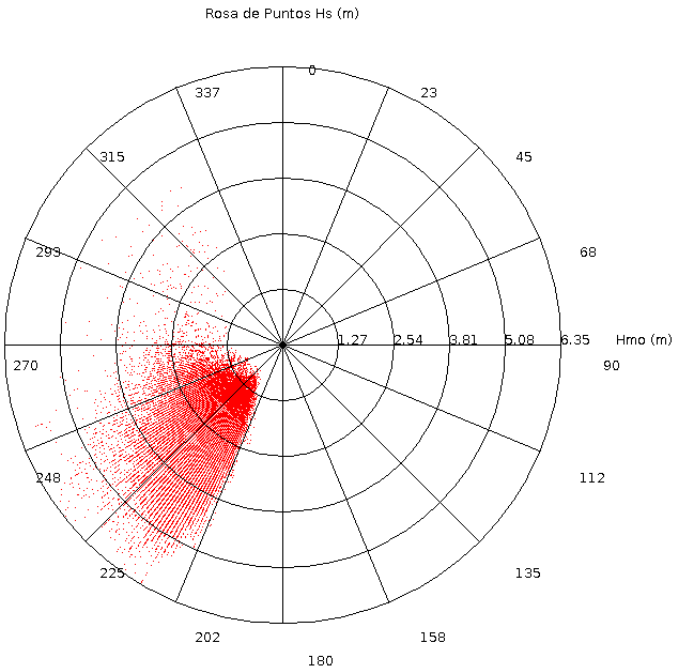


Figure B.5: Directional spreading of the offshore wave height (DOP, 2016)

The directional spreading of the peak periods can be found in figure B.6.

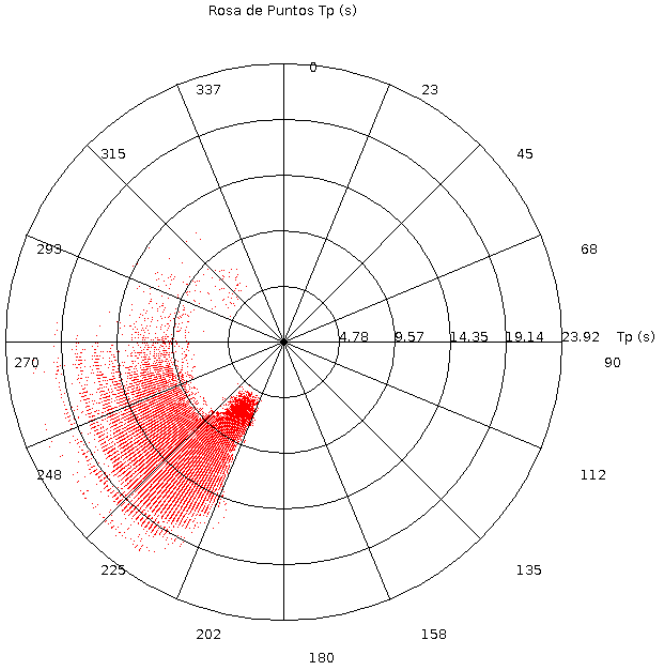


Figure B.6: Directional spreading of the offshore wave period (DOP, 2016)

For the extreme wave analyses, two directions are important: west (247.5 – 292.5) and south-west (202.5 - 247.5). The extreme wave height with a 50-year return period is 5.69m, for the westerly direction and 6.73m for south-westerly directions.

To transfer the offshore wave conditions to the bay of Los Vilos, a SWAN computation has been performed in the wave atlas. In this analyses, the wave characteristics at certain points in the bay are modelled, depicted in figure B.7 below.

Figure B.7: Modelled points in the Los Vilos bay (DOP, 2016)

As can be seen in the different figures, the waves propagate from the southwest at deep water, when propagating more the the Los Vilos bay, the waves refract around Caleta Las Conchas. Therefore the wave direction in the bay is changed to north-west (see figure B.8).

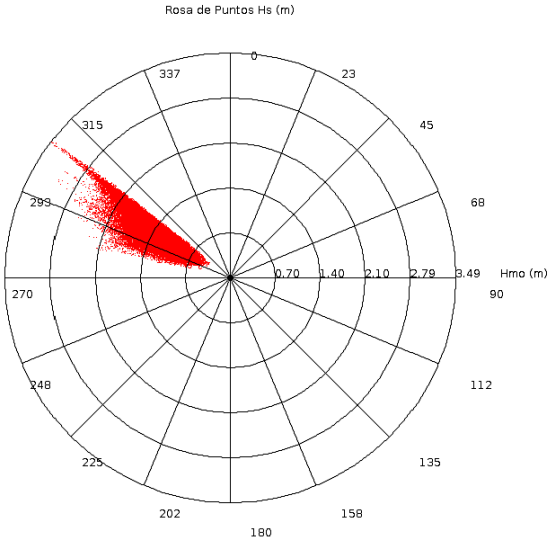


Figure B.8: Waveheight in point 7 (DOP, 2016)

B.3.2. Bathymetry

A map of the bathymetry of the whole bay of Los Vilos can be found in the figure B.9.

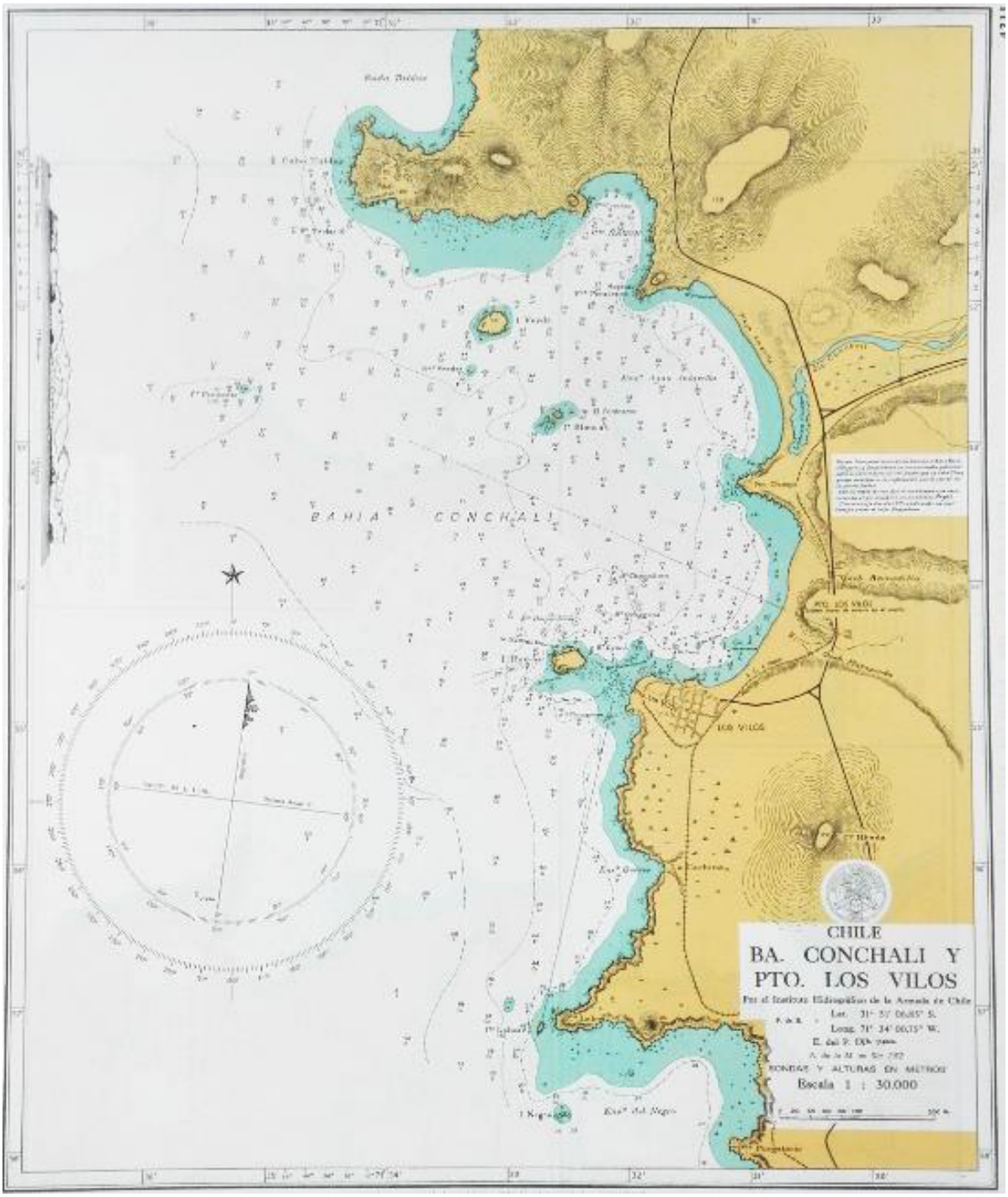


Figure B.9: Bathymetry of the ocean at Los Vilos (GHD, 2017b.)

B.3.3. Tsunamis

The map below shows the areas that could potentially be flooded due to a tsunami, including the flood levels at specific locations. This map is created by the SHOA and this information was obtained using numerical modelling. The model combines topographic and bathymetric data in combination with seismic information in an integrated way. The flood levels shown in this picture can differ for a specific tsunami event. This map can however give a good

indication of the vulnerability of parts of Los Vilos in the case of a tsunami (SHOA, 2017.).

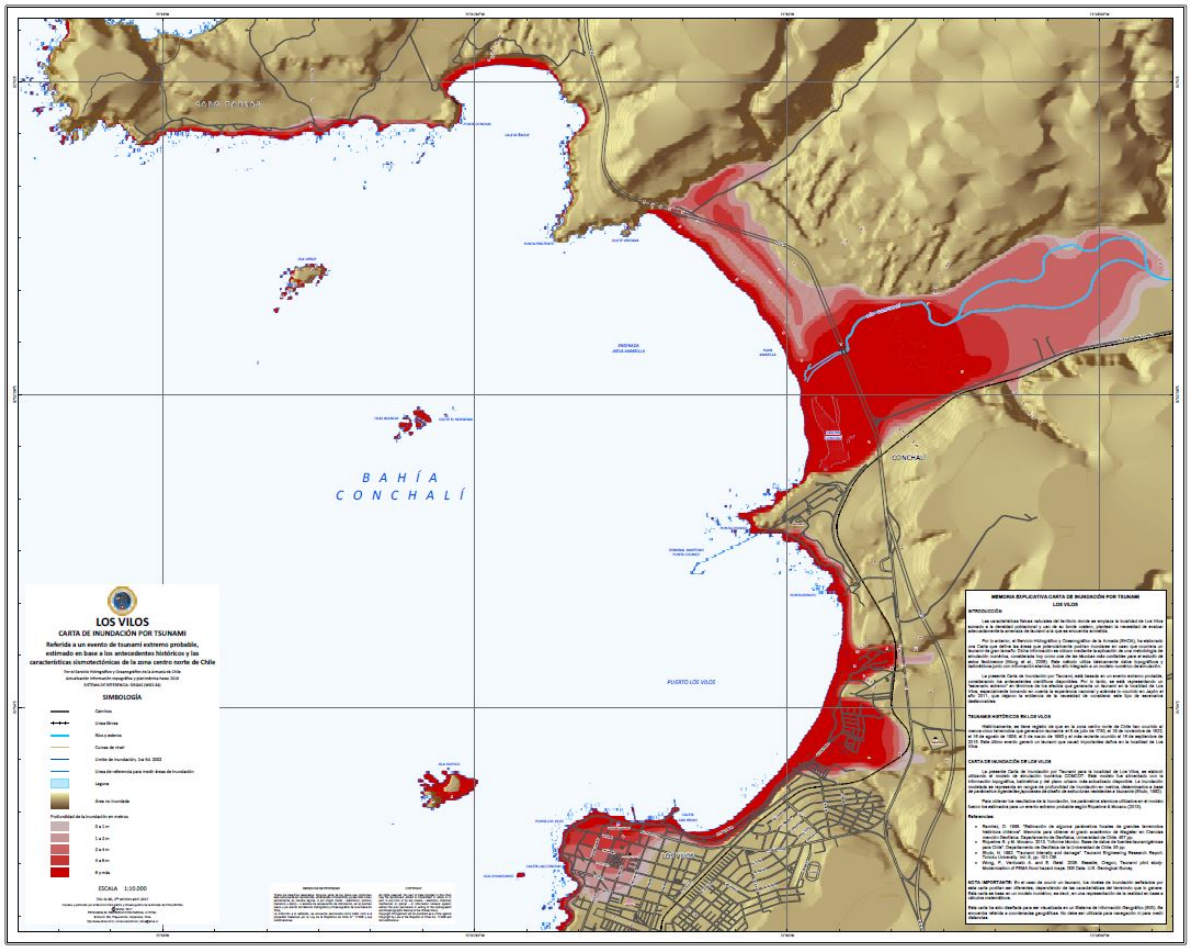


Figure B.10: Tsunami inundation map of Los Vilos and its surroundings (SHOA, 2017.)

The main vulnerable zones in the Los Vilos area are the nature area called Matagorda and the area near to the river mouth of the Rio Conchali to the North of the system that is considered. Near the main beach of Los Vilos there is some inundation but this is limited and only impacts the first row of buildings along the shore (SHOA, 2017).

B.3.4. Sediment characteristics

The sediment distribution of the los Vilos bay tells something about the way the beach will react to changes in the environment. To gain knowledge about the granular sediment distribution, nine different samples are analysed, 3 below the water line (x.1) , 3 in the swash zone (x.2) and 3 samples on the beach (x.3). The experiment has been done twice and the results are shown in figure B.11.

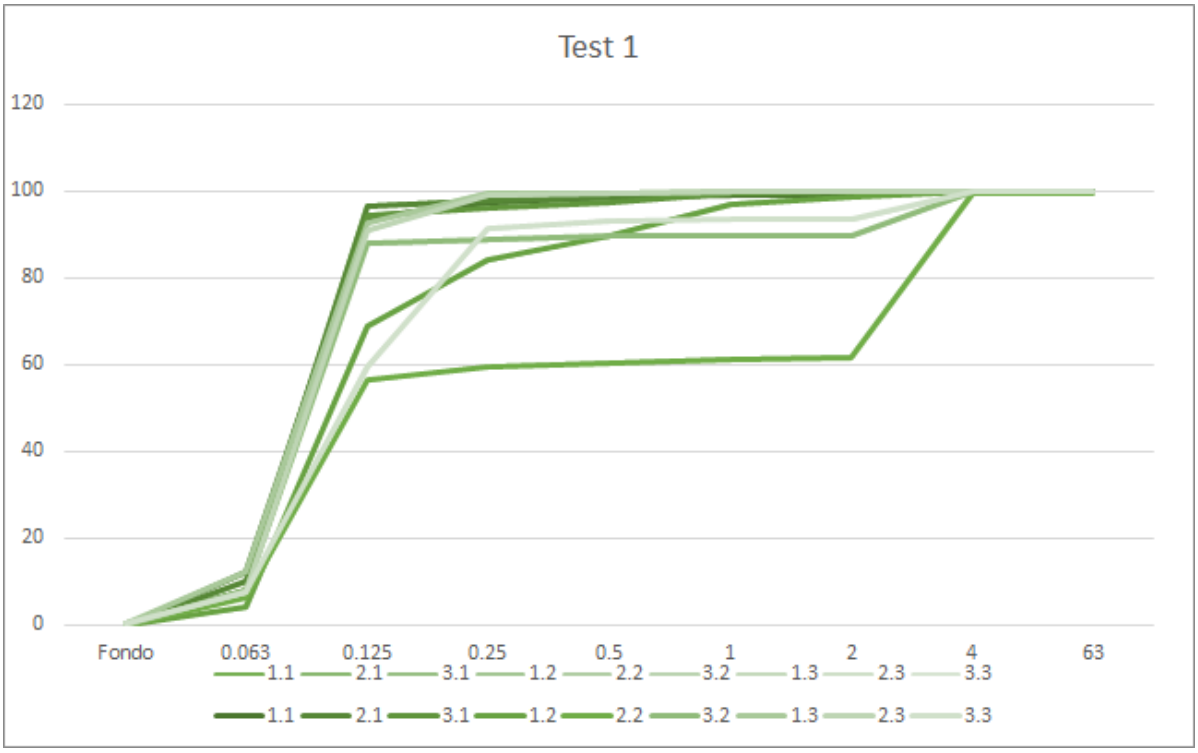


Figure B.11: Grain size distributions test 1 (data based on GHD,2017d)

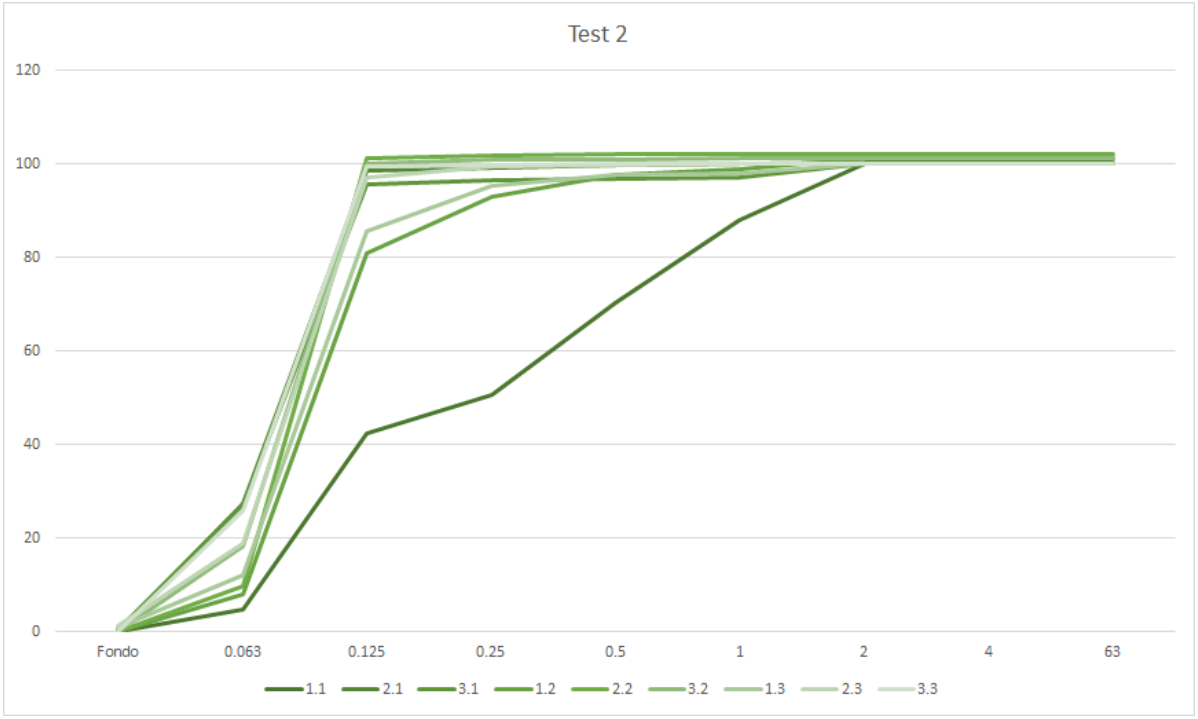


Figure B.12: Grain size distributions test 2 (data based on GHD,2017d)

As can be seen the main grain size is in the range of 0.125mm and 0.250mm for all the 9 locations. This can be classified as fine sand.

To characterize the sediment present in Los Vilos, several samples where taken from the

locations shown in figure B.13.

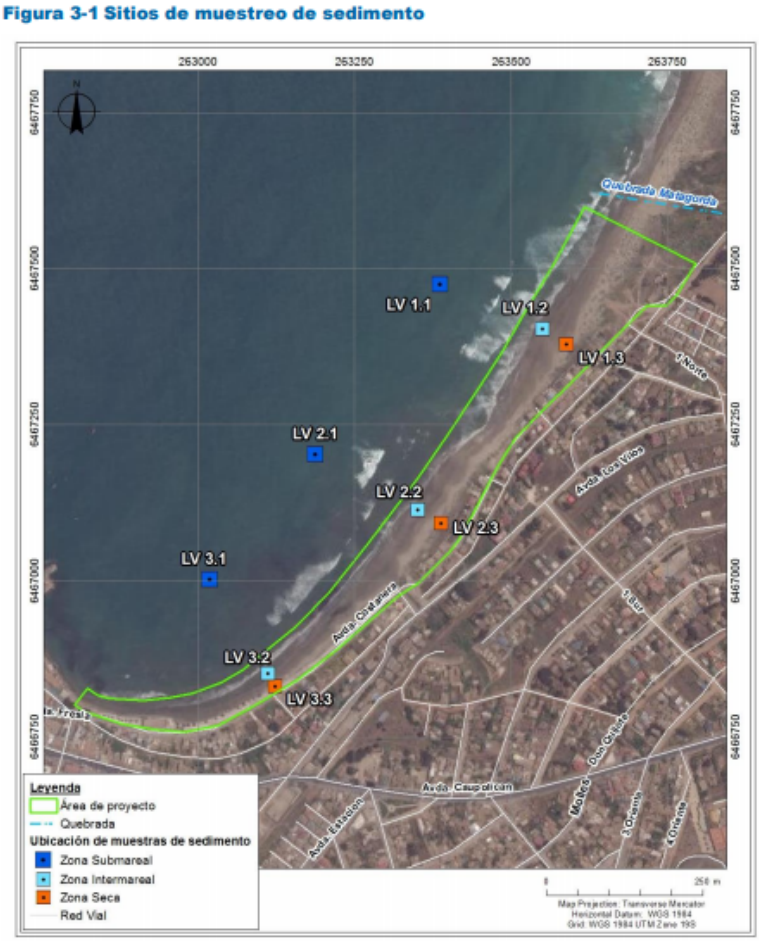


Figure B.13: Location of the soil sampling (GHD, 2017b)

The samples can be categorized in 3 different zones with the following d50:

- Beach zone, $d_{50} = 0.16mm$
- Swash zone, $d_{50} = 0.19mm$
- Underwater zone, $d_{50} = 0.18mm$

As the grain size is in the region 0.125-0.250 mm, it can be classified as fine sediment (GHD,2017d).

The chemical composition of the sand, indicating whether the soil is contaminated is studied too. In Chile there is no a law determining the maximum amount of contamination, therefore guidelines according the Environment and Human Health (CCME, 2011) and the Guide of the Centre of Studies and Experimentation of Public Works of Spain (CEDEX, 20042) are followed to determine the contamination. For both guidelines, the contamination with different metals is lower than the maximum. Only one positive sample with fecal coliform has been found in the first campaign. It can therefore be concluded that the current sand can function as building material for the new design (GHD,2017d).

B.3.5. Vegetation

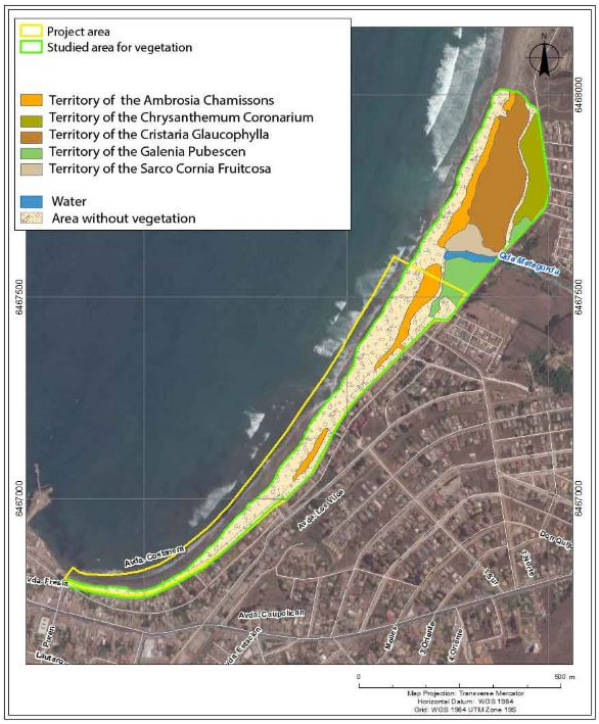


Figure B.14: The different locations of vegetation along the main beach of Los Vilos (GHD, 2016a)

In figure B.14, an overview of the area has been given concerning the vegetation in the Los Vilos bay. It can be seen that in the northern part, just outside the project scope, an area with a high biodiversity can be found (Matagorda). There are some small areas of vegetation near the more central part of the main beach (GHD, 2016a).

B.3.6. Tides

A tidal record around Los Vilos from August 2016 can be found in the figure B.15. As is visible, the maximum tidal range is around 1.50m. Furthermore, the tide can be characterised as a predominantly semidiurnal type, indicating two high and low waters a day.

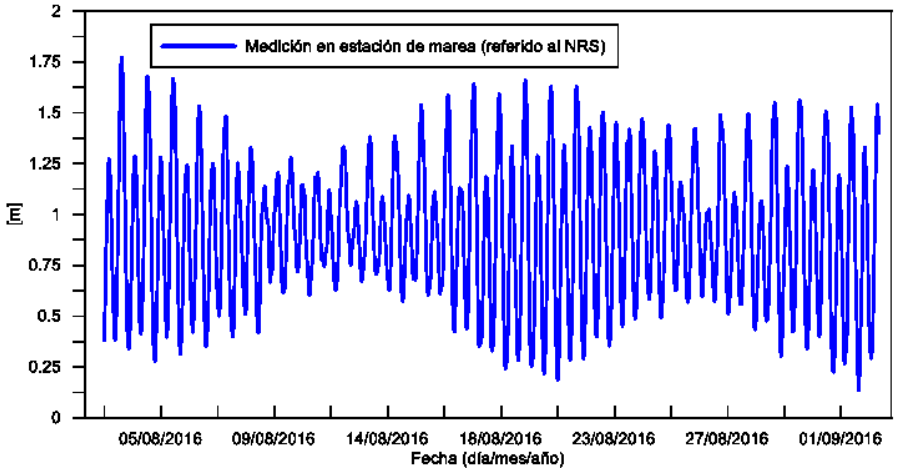


Figure B.15: Tidal movement near Los Vilos (GHD, 2016b)

C

Meetings

C.1. Preparation

To gain knowledge about the building with nature philosophy and gather different perspectives on the subject, multiple conversations have been conducted in advance.

Stefan Aarninkhof ,professor of coastal engineering at TU Delft, previously employed at Boskalis and involved in Ecoshape 13-12-2018
Conversation about the Building with Nature philosophy.

Henk Nieboer, director of EcoShape and consultant at Witteveen+Bos. Mark Bruggeling, environmental engineer at Boskalis 20-12-2018
Conversation about the Building with Nature philosophy and the application in different countries.

Claudia Schutte, program advisor at Netherlands Enterprise Agency (RVO). Iris Bijlsma, senior project manager at Arcadis. 14-01-2019
Details about the Los Vilos case were discussed.

C.2. Background study Chile

To get a clear view of the Chilean physical and social-economic characteristics, multiple conversations and lectures have been attended.

Mauricio Reyes, professor at the Universidad de Valparaíso. 07-03-2019
Lecture about earthquakes to get insight in the behavior of the Chilean coastline.

Patricio Winckler, professor at the Universidad de Valparaíso 07-03-2019
Lecture about Tsunamis to get insight in the behavior of the Chilean coastline.

Paul van de Grift, trade advisor at Embajada del Reino de los Países Bajos en Chile 08-03-2019
Conversation about the role of the embassy and the differences between dutch and Chilean projects.

Patricio Winckler, professor at the Universidad de Valparaíso 27-03-2019
Lecture about previous studies on the port of San Antonio.

Jurgen Bartelink, Embassy of the Kingdom of the Netherlands in Lima, Peru. Linda Walstra, regional business developer and trade advisor at Embajada del Reino de los Países Bajos en Santiago, Chile 02-04-2019

Conversation about the port of San Antonio.

Paul van de Grift, trade advisor at Embajada del Reino de los Países Bajos en Chile 09-04-2019
A conversation about the current state of the Los Vilos Project.

Pilar Muñoz, marine biologist at the Universidad de Chile, faculty of marine sciences and natural resources 16-04-2019
With Pilar Muñoz we talked about her current research on algaes, seaweeds and kelps. In coastal projects kelps could be used to reduce wave impact and to provide food for both the environment and the people. The size of the kelps depend on the size of the waves, as larger kelps need more nutrients, so a faster refreshment of the seawater is needed. The kelps grow in the photic zone, as they need light for photosynthesis. As there are multiple species of kelps, algues and seaweeds it can possibly be implemented along the whole coast of Chile.

Jaap Scheele, manager South America for Boskalis 18-04-2019
To get a Dutch perspective on the Chilean water construction sector we talked with Jaap Scheele from Boskalis. Boskalis was involved in the dredging activities of the current port of San Antonio and is aware of the plans of the current port expansion. The conversation was about the reasons of the port expansion, the Environmental Impact Assessment in Chile and the way Dutch companies deal with construction works in a foreign country.

C.3. Parties in the Chilean water sector

Fernando Calle, head of innovation at Arcadis Chile. Teresa Cabral, hydraulic design engineer at Arcadis Chile 09-04-2019
A conversation about the coastal construction sector in Chile and the possibilities to a future implementation of Building with Nature from the perspective of Arcadis Chile.

Cristopher Zambra, Patricio Opazo and Mario Veneciano, project engineers at GHD. 09-04-2019
A conversation about the coastal construction sector in Chile and the possibilities of a future implementation of Building with Nature from the perspective of GHD.

C.4. Case Studies

In the building with nature philosophy the perspective of multiple stakeholders is of high importance. At the same time, the visits provided the project team with information on the current level of awareness of Building with Nature in Chile.

C.4.1. Pichilemu

Flor Ilic, director of the culture center of Pichilemu 04-04-2019
As a Director of the cultural center and a citizen of Pichilemu for the past 6 years, Flor Ilic is in a neutral position to tell something about the political structure of Pichilemu. She told about the differences between the original community and the people who moved to Pichilemu. The largest differences can be found in the fact that mainly the people who moved to Pichilemu want to protect the nature, while the local people don't see the beauty of it.

Andres Margozzini, Fundación Punta de Lobos, Pichilemu. Sophia Claro, manager Hotel Alaia 04-04-2019
The Fundación Punta de Lobos is a foundation directed towards the protection of the environment and creating space for surfing. They try to involve the local community, the fishery, the local schools and the surfing associations in their projects. Their main strategy is to buy the land and create a space where the environment is protected and different activities can take place.

Genaro Guerrero, president of fishery federation Pichilemu 04-04-2019
To gain insight in the sealife environment, regulations and organisation around the Chilean fishery industry we talked to Genaro Guerrero. In Chile governmental money is available for the fishery federations to be distributed over its members. The problem according to Genaro Gverrero is that in some of those federations more than only the fisheries are located, so the money is partly lost to profiteers. The fishery is mainly focused on the harvesting of algae, so strict harvesting regulations to stimulate the growth exist. But also the fishery of fishes is controlled by season.

Daniela Paz González Cordero, director communal planning at the municipality of Pichilemu. Macarena Cornejo, environmental management at the municipality of Pichilemu 05-04-2019
To get a more local, governmental perspective on the local projects we went to talk to the municipality. The influence of the municipality in projects is limited, as most of the financial affairs are controlled by the DOP. The main role of the municipality concerning civil projects is to make the land use plan and to organise meetings for larger projects.

Nicolás Recordón, surfer geologist and architect living in Pichilemu 05-04-2019
Nicolás Recordón is one of the first wind surfers in Pichilemu. He live in Pichilemu for a long time and knows the evolution of the coast as one of the best in the area. In the past 40 years the land has shown both subsidence and rise. The beach is accreting and eroding, but eventually everything is balanced out according to Nicolás. Only the dunes are constantly eroding due to human interventions.

C.4.2. San Antonio

Loreto Denisse Trigo, graduate student at the Universidad de Valparaíso on the development of port cities
A guided tour through San Antonio with information concerning the current port and the cooperation between the port and the city of San Antonio was done under guidance of Loreto. In the city a few mural statements are made against the expansion of the port. But according a survey spread under more than 100 citizens, 67% is for an expansion of the port as it creates more work and large opportunities for the city.

Oscar Tapia Rojas, head of economics at the municipality of San Antonio 10-04-2019
To gain knowledge about the cooperation between the municipality and the port authority, especially concerning the port expansion, we talked to Oscar Tapia Rojas. There are regular meetings about the port expansion with the municipality, mainly about the land use plan. For all the land the port uses for its expansion a land inward compensation has to be made.

Horacio Moggia, operational manager at Puerto Central. Pedro Celis, deputy commercial manager at Puerto Central. Samantha Hartwig, project engineer at Puerto Central 10-04-2019
The conservation was about the cooperation between the current port operators and the port authority, especially concerning the port expansion. The port operators are not included in the plans for the port expansion and don't see the need at this point to be a stakeholder in the project. The port of San Antonio is not used at its full capacity and the future growth is very unpredictable.

D

Questionnaires

D.1. Questionnaire: English version

The English version of the questionnaire is shown below.

Which organisation do you represent?

.....

***Building with Nature (BwN)**: A new innovative design approach that make use of natural processes and thereby creating opportunities for the economy, nature and society. A Building with Nature design can cope with changing conditions like climate change, can fulfil more than one purpose, like additional environmental value, and does not work against the natural ecosystem but is in harmony with it by using natural forces. During the development of a Building with Nature project the aim is to realize a product out of co-creation between problem owners, stakeholders and experts with different backgrounds. Building with Nature is a philosophy based on the analyses of a system as whole. By including all the aspects of a system, it becomes clear where shortage or disruptions occur and what the consequences are. The philosophy encourages a design approach that moves from building in nature to building with nature.*

Was the environment an important subject during your education program?

Disagree ◯ ◯ ◯ ◯ ◯ **Agree**

Did you ever hear of BwN?

Disagree ◯ ◯ ◯ ◯ ◯ **Agree**

Do you have experience with BwN?

Disagree ◯ ◯ ◯ ◯ ◯ **Agree**

Do think parties in the Chilean water sector related to the coastal engineering are applying an environmental centred design approach in current projects?

Disagree ◯ ◯ ◯ ◯ ◯ **Agree**

Do think parties in the Chilean water sector related to the coastal engineering are involving the society within their design process in current projects?

Disagree ◯ ◯ ◯ ◯ ◯ **Agree**

Do you want coastal projects to be more environmentally centred?

Disagree ◯ ◯ ◯ ◯ ◯ **Agree**

Questionnaire Building with Nature in Chile

Do you think there is the ambition in the Chilean water sector to apply an environmental design approach?

Disagree ◯ ◯ ◯ ◯ ◯ Agree

Do you think there is an urgency to apply an environmental design approach?

Disagree ◯ ◯ ◯ ◯ ◯ Agree

Do you want more involvement of the society in coastal projects?

Disagree ◯ ◯ ◯ ◯ ◯ Agree

Do you think there is the ambition in the Chilean water sector to involve the society in the design of coastal projects?

Disagree ◯ ◯ ◯ ◯ ◯ Agree

Do you think there is an urgency to involve the society more into the design of coastal projects?

Disagree ◯ ◯ ◯ ◯ ◯ Agree

Do you think a design approach like BwN can be profitable for your organisation?

Disagree ◯ ◯ ◯ ◯ ◯ Agree

Do you think a design approach like BwN can be beneficial for coastal engineering projects?

Disagree ◯ ◯ ◯ ◯ ◯ Agree

Do you think the government will support an organisation if they apply a BwN approach?

Disagree ◯ ◯ ◯ ◯ ◯ Agree

Questionnaire Building with Nature in Chile

Who do you think is gaining the most out of coastal projects?

Government:	Least	○ ○ ○ ○ ○	Most
Private sector:	Least	○ ○ ○ ○ ○	Most
Society:	Least	○ ○ ○ ○ ○	Most

Do you think there is any pressure to apply an environmental centred design approach to projects? From:

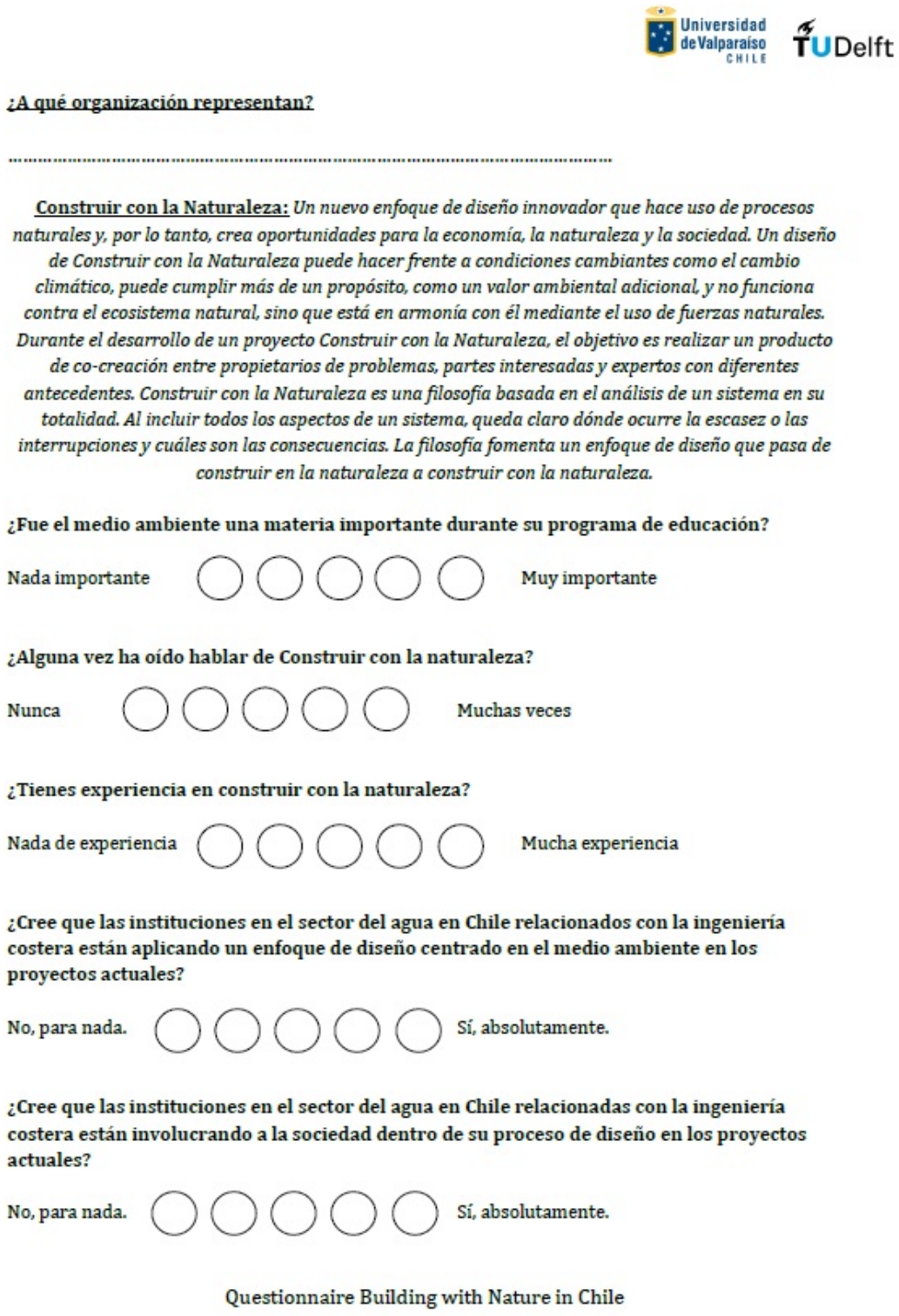
Government:	Disagree	○ ○ ○ ○ ○	Agree
Private sector:	Disagree	○ ○ ○ ○ ○	Agree
Society:	Disagree	○ ○ ○ ○ ○	Agree

Do you think there is any pressure to involve the society in the design of coastal projects? From:

Government:	Disagree	○ ○ ○ ○ ○	Agree
Private sector:	Disagree	○ ○ ○ ○ ○	Agree
Society:	Disagree	○ ○ ○ ○ ○	Agree

D.2. Questionnaire: Spanish version

The Spanish version of the questionnaire is shown below.



Universidad de Valparaíso CHILE TU Delft

¿A qué organización representan?

.....

Construir con la Naturaleza: *Un nuevo enfoque de diseño innovador que hace uso de procesos naturales y, por lo tanto, crea oportunidades para la economía, la naturaleza y la sociedad. Un diseño de Construir con la Naturaleza puede hacer frente a condiciones cambiantes como el cambio climático, puede cumplir más de un propósito, como un valor ambiental adicional, y no funciona contra el ecosistema natural, sino que está en armonía con él mediante el uso de fuerzas naturales. Durante el desarrollo de un proyecto Construir con la Naturaleza, el objetivo es realizar un producto de co-creación entre propietarios de problemas, partes interesadas y expertos con diferentes antecedentes. Construir con la Naturaleza es una filosofía basada en el análisis de un sistema en su totalidad. Al incluir todos los aspectos de un sistema, queda claro dónde ocurre la escasez o las interrupciones y cuáles son las consecuencias. La filosofía fomenta un enfoque de diseño que pasa de construir en la naturaleza a construir con la naturaleza.*

¿Fue el medio ambiente una materia importante durante su programa de educación?

Nada importante ○ ○ ○ ○ ○ Muy importante

¿Alguna vez ha oído hablar de Construir con la naturaleza?

Nunca ○ ○ ○ ○ ○ Muchas veces

¿Tienes experiencia en construir con la naturaleza?

Nada de experiencia ○ ○ ○ ○ ○ Mucha experiencia

¿Cree que las instituciones en el sector del agua en Chile relacionados con la ingeniería costera están aplicando un enfoque de diseño centrado en el medio ambiente en los proyectos actuales?

No, para nada. ○ ○ ○ ○ ○ Sí, absolutamente.

¿Cree que las instituciones en el sector del agua en Chile relacionadas con la ingeniería costera están involucrando a la sociedad dentro de su proceso de diseño en los proyectos actuales?

No, para nada. ○ ○ ○ ○ ○ Sí, absolutamente.

Questionnaire Building with Nature in Chile

¿Desearía que los proyectos costeros estén más centrados en el medio ambiente?

No, para nada. ◯ ◯ ◯ ◯ ◯ Sí, absolutamente.

¿Cree que existe intención en el sector del agua en Chile de aplicar un enfoque de diseño ambiental?

No, para nada. ◯ ◯ ◯ ◯ ◯ Sí, absolutamente.

¿Cree que es urgente aplicar un enfoque de diseño ambiental en los proyectos costeros?

No, para nada. ◯ ◯ ◯ ◯ ◯ Sí, absolutamente.

¿Considera que debe implicarse más la ciudadanía en proyectos costeros?

No, para nada. ◯ ◯ ◯ ◯ ◯ Sí, absolutamente.

¿Cree que existe la intención en el sector del agua de Chile de involucrar a la ciudadanía en el diseño de proyectos costeros?

No, para nada. ◯ ◯ ◯ ◯ ◯ Sí, absolutamente.

¿Cree que hay urgencia de involucrar más a la ciudadanía en el diseño de proyectos costeros?

No, para nada. ◯ ◯ ◯ ◯ ◯ Sí, absolutamente.

¿Cree que un enfoque de diseño como Construir con la Naturaleza puede ser rentable para su organización?

No, para nada. ◯ ◯ ◯ ◯ ◯ Sí, absolutamente.

¿Cree que un enfoque de diseño como Construir con la naturaleza puede ser beneficioso para los proyectos de ingeniería costera?

No, para nada. ◯ ◯ ◯ ◯ ◯ Sí, absolutamente.

Questionnaire Building with Nature in Chile

¿Cree que el gobierno apoyará a una organización si aplica un enfoque de Construir con la naturaleza?

No, para nada. ◯ ◯ ◯ ◯ ◯ Sí, absolutamente.

¿Quién creen que está aprovechando al máximo los proyectos costeros?

Gobierno:	Menos	◯ ◯ ◯ ◯ ◯	Más
Sector privado:	Menos	◯ ◯ ◯ ◯ ◯	Más
Ciudadanía:	Menos	◯ ◯ ◯ ◯ ◯	Más

¿Cree que existe alguna presión para aplicar un enfoque de diseño centrado en el medio ambiente para proyectos desde:

Gobierno:	No	◯ ◯ ◯ ◯ ◯	Sí
Sector privado:	No	◯ ◯ ◯ ◯ ◯	Sí
Ciudadanía:	No	◯ ◯ ◯ ◯ ◯	Sí

¿Cree que hay alguna presión para involucrar a la sociedad en el diseño de proyectos costeros desde:

Gobierno:	No	◯ ◯ ◯ ◯ ◯	Sí
Sector privado:	No	◯ ◯ ◯ ◯ ◯	Sí
Ciudadanía:	No	◯ ◯ ◯ ◯ ◯	Sí

D.3. Results

The full results of the questionnaire are shown in this chapter. The full results are categorized in 3 different categories: Pichilemu, San Antonio and others.

D.3.1. Pichilemu stakeholders

With: 1 = No for sure 2 = No 3 = Neutral 4 = Yes 5 = Yes absolutely		President of the fishery federation: Genaro Gverrero	Local surfer: Nicolás Recordón	Director of cultural center: Flor Ilic	Fundación Punta de Lobos: Andres Margozzini	Fundación Punta de Lobos: Hotel owner: Sophia Claro	Municipality: Director of communal planning: Daniela Paz González Cordero	Municipality: Marine Biologist: Macarena Cornejo	Average:
1	Was the environment an important subject during your education program?	1	4	2	2	3	4	5	3
2	Did you ever hear of BwN?	1	2	1	1	2	1	4	2
3	Do you have experience with BwN?	5	1	1	1	1	1	3	2
4	Do you think parties in the Chilean water sector related to the coastal engineering are applying an environmental centred design approach in current projects?	1	2	1	1	1	3	1	1
5	Do you think parties in the Chilean water sector related to the coastal engineering are involving the society within their design process in current projects?	1	2	1	1	1	2	3	2
6	Do you want coastal projects to be more environmentally centred?	5	5	5	5	5	5	5	5
7	Do you think there is the ambition in the Chilean water sector to apply an environmental design approach?	1	3	1	2	2	3	3	2
8	Do you think there is an urgency to apply an environmental design approach?	5	5	5	5	5	5	5	5
9	Do you want more involvement of the society in coastal projects?	5	4	5	5	5	5	5	5
10	Do you think there is the ambition in the Chilean water sector to involve the society in the design of coastal projects?	1	2	1	1	2	4	3	2

Figure D.1: Results of the questionnaire of the Pichilemu related stakeholders: part 1

11	**Do you think there is an urgency to involve the society more into the design of coastal projects?**	5	3	5	5	5	5	5	5
12	**Do you think a design approach like BwN can be profitable for your organisation?**	5	4	5	3	3	5	5	4
13	**Do you think a design approach like BwN can be beneficial for coastal engineering projects?**	5	5	5	5	5	5	5	5
14	**Do you think the government will support an organisation if they apply a BwN approach?**	1	3	3	3	3	4	4	3
15	**Who do you think is gaining the most out of coastal projects?**								
	Government	3	2	3	4	5	2	3	3
	Private sector	5	2	5	4	5	4	3	4
	Society	1	2	1	2	1	2	3	2
16	**Do you think there is any pressure to apply an environmental centred design approach to projects? From:**								
	Government	1	3	2	2	3	2	2	2
	Private sector	1	2	1	2	4	2	2	2
	Society	5	5	5	5	5	4	4	5
17	**Do you think there is any pressure to involve the society in the design of coastal projects? From:**								
	Government	1	2	2	2	1	2	2	2
	Private sector	1	2	1	2	3	2	2	2
	Society	5	5	5	5	5	5	4	5

Figure D.2: Results of the questionnaire of the Pichilemu related stakeholders: part 2

D.3.2. San Antonio stakeholders

With: 1 = No for sure 2 = No 3 = Neutral 4 = Yes 5 = Yes absolutely		Municipality: **Head of economics: Oscar Tapia Rojas**	Puerto Central: **Operational manager: Horacio Moggia**	Puerto Central: **Commercial manager: Pedro Celis**	Puerto Central: **Project Engineer: Samatha Hartwig**	Thesis student San Antonio: **Loreto Denisse Trigo**	**Average**
1	**Was the environment an important subject during your education program?**	4	3	1	3	2	3
2	**Did you ever hear of BwN?**	5	4	1	3	3	3
3	**Do you have experience with BwN?**	3	1	1	1	2	2
4	**Do you think parties in the Chilean water sector related to the coastal engineering are applying an environmental centred design approach in current projects?**	2	3	2	3	3	3
5	**Do you think parties in the Chilean water sector related to the coastal engineering are involving the society within their design process in current projects?**	3	3	3	2	4	3
6	**Do you want coastal projects to be more environmentally centred?**	5	4	5	5	5	5
7	**Do you think there is the ambition in the Chilean water sector to apply an environmental design approach?**	5	4	3	4	4	4
8	**Do you think there is an urgency to apply an environmental design approach?**	5	5	5	5	5	5
9	**Do you want more involvement of the society in coastal projects?**	5	5	5	5	5	5
10	**Do you think there is the ambition in the Chilean water sector to involve the society in the design of coastal projects?**	3	4	4	4	4	4

Figure D.3: Results of the questionnaire of the San Antonio related stakeholders: part 1

11	**Do you think there is an urgency to involve the society more into the design of coastal projects?**	5	3	5	4	5	4
12	**Do you think a design approach like BwN can be profitable for your organisation?**	5	3	4	3	4	4
13	**Do you think a design approach like BwN can be beneficial for coastal engineering projects?**	5	4	4	5	5	5
14	**Do you think the government will support an organisation if they apply a BwN approach?**	3	3	4	5	4	4
15	**Who do you think is gaining the most out of coastal projects?**						
	Government	1	2	3	3	4	3
	Private sector	5	4	4	5	5	5
	Society	1	2	2	2	2	2
16	**Do you think there is any pressure to apply an environmental centred design approach to projects? From:**						
	Government	3	3	3	4	3	3
	Private sector	1	4	3	3	3	3
	Society	5	2	5	5	5	4
17	**Do you think there is any pressure to involve the society in the design of coastal projects? From:**						
	Government	2	2	4	5	4	3
	Private sector	1	3	2	3	3	2
	Society	5	2	5	5	5	4

Figure D.4: Results of the questionnaire of the San Antonio related stakeholders: part 2

D.3.3. Other stakeholders

With: 1 = No for sure 2 = No 3 = Neutral 4 = Yes 5 = Yes absolutely		Arcadis Chile: **Head of innovation: Fernando Calle**	Arcadis Chile: **Hydraulic design engineer: Teresa Cabral**	GHD: **Project Engineer: Cristopher Zambra**	GHD: **Project Engineer: Mario Veneciano**	GHD: **Project Engineer: Patricio Opazo**	Average:
1	**Was the environment an important subject during your education program?**	4	3	5	5	4	4
2	**Did you ever hear of BwN?**	2	1	3	3	4	3
3	**Do you have experience with BwN?**	1	1	2	3	5	2
4	**Do you think parties in the Chilean water sector related to the coastal engineering are applying an environmental centred design approach in current projects?**	4	3	3	2	3	3
5	**Do you think parties in the Chilean water sector related to the coastal engineering are involving the society within their design process in current projects?**	4	3	4	5	5	4
6	**Do you want coastal projects to be more environmentally centred?**	5	5	5	5	5	5
7	**Do you think there is the ambition in the Chilean water sector to apply an environmental design approach?**	5	4	4	4	3	4
8	**Do you think there is an urgency to apply an environmental design approach?**	4	4	5	5	4	4
9	**Do you want more involvement of the society in coastal projects?**	4	5	5	5	5	5
10	**Do you think there is the ambition in the Chilean water sector to involve the society in the design of coastal projects?**	3	3	4	5	5	4

Figure D.5: Results of the questionnaire of the other stakeholders: part 1

11	**Do you think there is an urgency to involve the society more into the design of coastal projects?**	5	5	3	5	5	5
12	**Do you think a design approach like BwN can be profitable for your organisation?**	4	4	4	4	5	4
13	**Do you think a design approach like BwN can be beneficial for coastal engineering projects?**	5	5	5	5	5	5
14	**Do you think the government will support an organisation if they apply a BwN approach?**	3	4	3	5	3	4
15	**Who do you think is gaining the most out of coastal projects?**						
	Government	4	4	3	4	3	4
	Private sector	4	4	4	2	5	4
	Society	4	3	3	5	5	4
16	**Do you think there is any pressure to apply an environmental centred design approach to projects? From:**						
	Government	5	4	3	1	3	3
	Private sector	2	3	3	1	4	3
	Society	5	3	4	5	3	4
17	**Do you think there is any pressure to involve the society in the design of coastal projects? From:**						
	Government	5	4	3	5	5	4
	Private sector	2	3	2	3	5	3
	Society	5	3	4	5	5	4

Figure D.6: Results of the questionnaire of the other stakeholders: part 2

D.3.4. Overview

With:
1 = No for sure
2 = No
3 = Neutral
4 = Yes
5 = Yes absolutely

	Questions	Overall Average
1	**Was the environment an important subject during your education program?**	3
2	**Did you ever hear of BwN?**	3
3	**Do you have experience with BwN?**	2
4	**Do you think parties in the Chilean water sector related to the coastal engineering are applying an environmental centred design approach in current projects?**	2
5	**Do you think parties in the Chilean water sector related to the coastal engineering are involving the society within their design process in current projects?**	3
6	**Do you want coastal projects to be more environmentally centred?**	5
7	**Do you think there is the ambition in the Chilean water sector to apply an environmental design approach?**	3
8	**Do you think there is an urgency to apply an environmental design approach?**	5
9	**Do you want more involvement of the society in coastal projects?**	5
10	**Do you think there is the ambition in the Chilean water sector to involve the society in the design of coastal projects?**	3
11	**Do you think there is an urgency to involve the society more into the design of coastal projects?**	5
12	**Do you think a design approach like BwN can be profitable for your organisation?**	4
13	**Do you think a design approach like BwN can be beneficial for coastal engineering projects?**	5
14	**Do you think the government will support an organisation if they apply a BwN approach?**	4
15	**Who do you think is gaining the most out of coastal projects?**	
	Government	3
	Private sector	4
	Society	3
16	**Do you think there is any pressure to apply an environmental centred design approach to projects? From:**	
	Government	3
	Private sector	3
	Society	5
17	**Do you think there is any pressure to involve the society in the design of coastal projects? From:**	
	Government	3
	Private sector	3
	Society	5

Figure D.7: Overview of the results with the average result of all the different people that filled in the questionnaire

E

Awareness in Chile

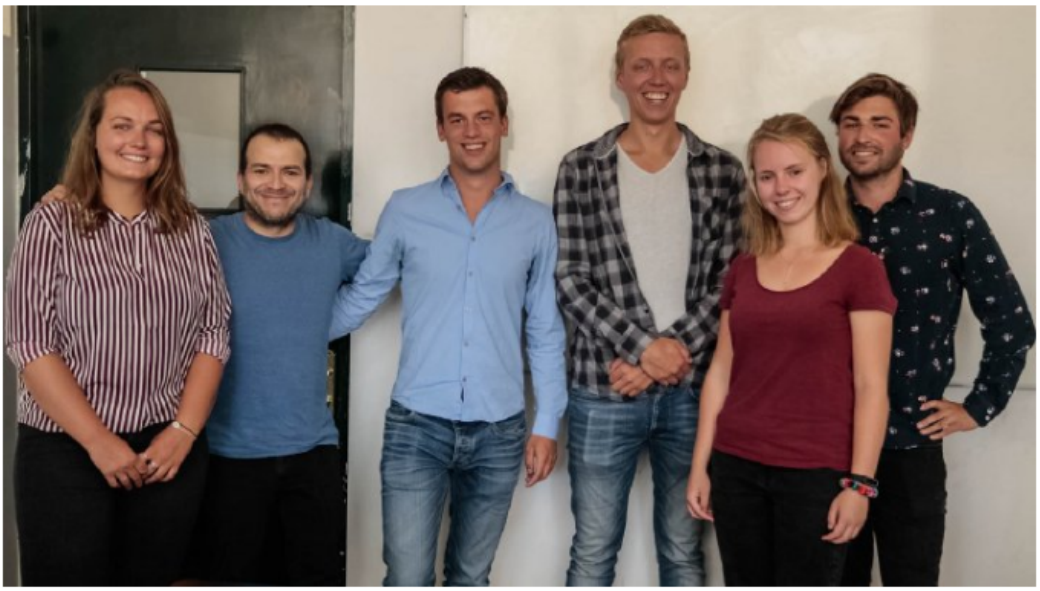
E.1. Presentation and workshop on the university

A presentation and workshop was performed on the Universidad de Valparaíso on the 22nd of March 2019. The invitation of this event is visible in figure E.1 and the news artictle that was published after this event is visible in figure E.2

Figure E.1: The flyer to promote the presentation and workshop made by our supervisor Mauricio Reyes

Ingeniería Civil Oceánica busca estrechar vínculos con Universidad de Delft

Cinco estudiantes del máster en Ingeniería Civil de esa casa de estudios expusieron su proyecto de investigación.



"Building with nature o ¿qué hacen cinco holandeses en nuestra escuela" fue el nombre del seminario que marca el inicio de las actividades conjuntas entre Ingeniería Civil Oceánica de la UV y la Universidad Técnica de Delft, uno de los centros de enseñanza superior más importantes de los Países Bajos y una de las universidades técnicas con mayor prestigio de Europa y del mundo.

Como parte de este convenio, los estudiantes del máster en Ingeniería Civil de la universidad holandesa Kimberley van Batenburg, Boudewijn van Heijningen, Hugo Hoogendoorn, Lara Klarenbeek y Geert Ridderinkhof expusieron parte de su proyecto de investigación que busca explorar la implementación de la filosofía de gestión de proyectos "Building with nature" en Chile.

Los estudiantes holandeses explicaron que el concepto que están investigando en vez de destruir la naturaleza para la construcción de infraestructura llamada gris o convencional, busca promover el enfoque verde que integra procesos naturales en el diseño de proyectos de construcción, en especial aprovechando su amplio conocimiento en la gestión del agua.

Mauricio Reyes, académico de Ingeniería Civil Oceánica UV y uno de los principales gestores de la visita, señaló que "nuestra escuela firmó un convenio de intercambio con la Universidad de Deflt, la cual tiene un programa de máster en Ingeniería Civil en distintos campos, como hidráulica o construcción, por medio de una forma de hacer negocios llamada Eco Shape que involucra instituciones gubernamentales, académicas y privadas".

"Nos interesa profundizar el vínculo con esta universidad holandesa porque tiene un área de especialización fuerte de ingeniería marítima. Los estudiantes que nos visitan están en su última fase de estudios del máster y están investigando sobre implementación de la filosofía de construir con la naturaleza", explicó.

El académico añadió que "es una ventaja para nuestros profesores y estudiantes estudiar de forma conjunta cómo se puede implementar ese tipo de proyectos, porque en Chile hay ciertas dificultades políticas, técnicas y físicas. Los holandeses están haciendo un primer diagnóstico y sus casos de estudio son Valparaíso, San Antonio, Pichilemu y Los Vilos. Esperamos poder reunirnos en esos lugares con agentes relacionados con las construcciones costeras".

Publicado martes 26 de marzo de 2019

Figure E.2: Full news article published on the website of the Universidad de Valparaíso

E.2. Presentation about Building with Nature

This presentation was used during the meetings with the different stakeholders to explain the Building with Nature philosophy.

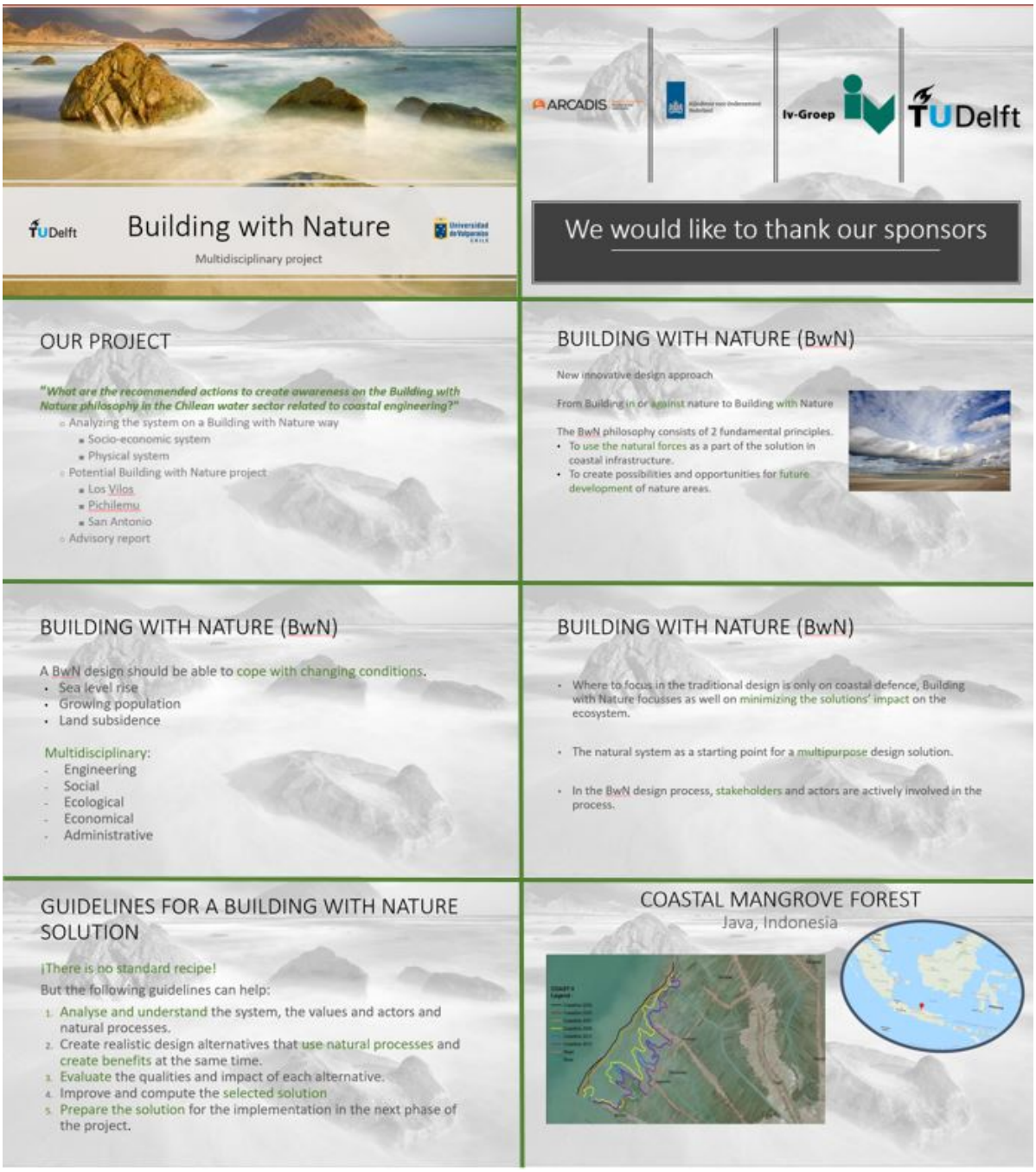


Figure E.3: Presentation part 1

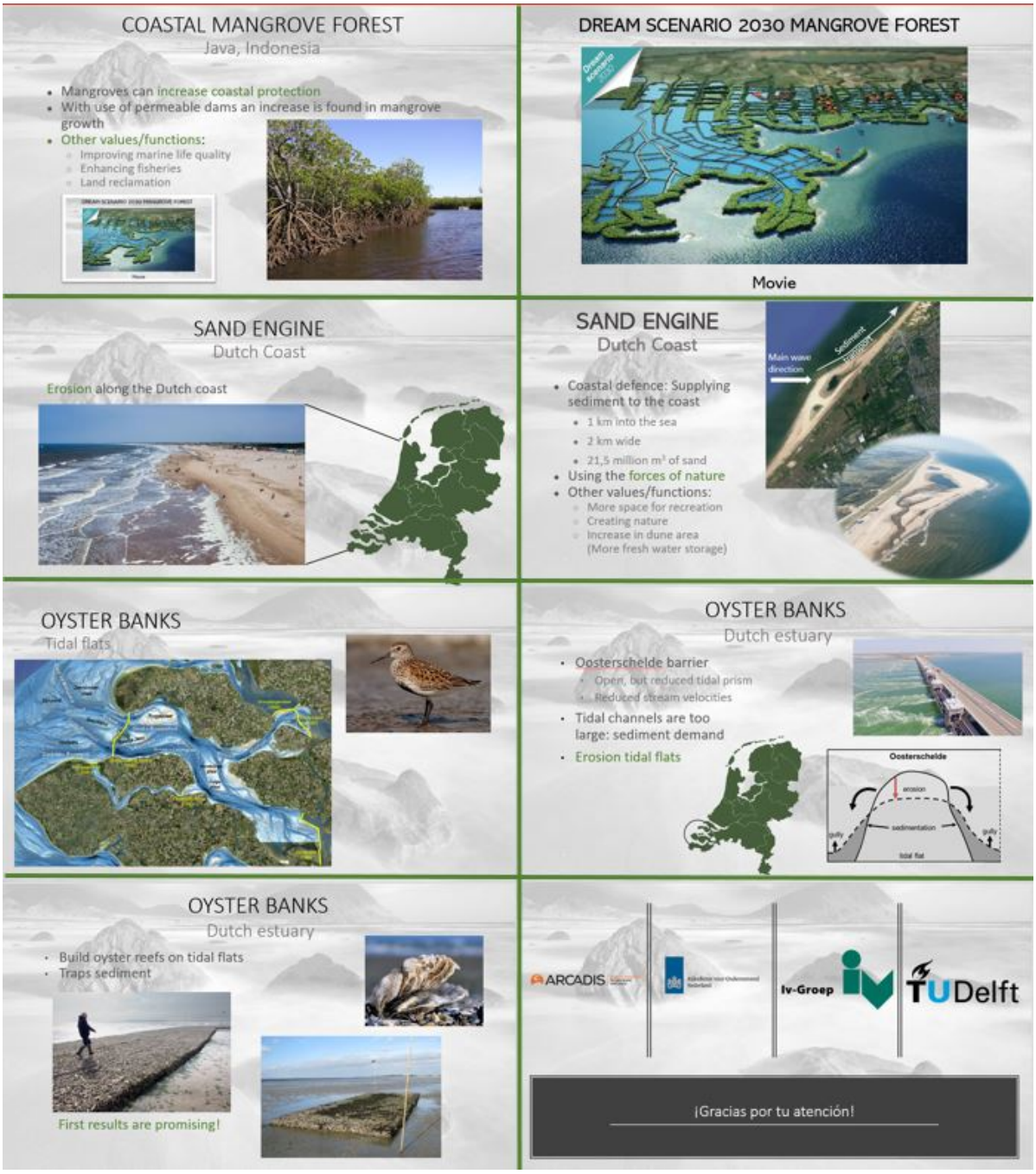


Figure E.4: Presentation part 2