Reclaiming the Isla

How to remediate and redeveloped the Isla refinery, to benefit Curacao's local citizens, ecosystems and economies

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Graduation Report
Transitional Territories

Colophon

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Keywords: Sustainable development, brownfield reclamation, nature based solutions, phytotechnology, Curacao.

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Abstract

This thesis focusses on a method for sustainable brownfield redevelopment of polluted industrial areas, using a phased approach. In a case study, the method is applied to the polluted area of the Isla Refinery site on Curaçao.

Brownfield redevelopment projects typically consist of three main activities: site assessment, site remediation and site redevelopment. In conventional remediation projects, methods like soil incineration and disposal are used, which take a relatively short amount of time to clean-up the soil and water in these areas. However, a growing demand for nature-based solutions in the urban planning field is challenging this paradigm. Phyto technologies are remediation methods that use plants to extract or stabilize pollution particles in soil and water. These less invasive remediation methods need a longer amount of time to clean-up the pollution compared to conventional methods. This changes the typical timeline of brownfield redevelopment projects drastically, meaning the remediation phase will be significantly longer.

This thesis will research how this longer remediation phase can be best approached to increase sustainability during brownfield redevelopment projects. This is done by focusing on increasing the value of people, planet and prosperity (triple bottom line concept) in the case study area. The aim of this study is to inspire decision makers to use a more sustainable approach to brownfield remediation projects.

Contents

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01 | Introduction

Motivation
Theory and concepts

Motivation

During my studies I have developed a deep interest in sustainable development in urban environments. This interest was sparked during my minor in sustainable development at Leiden University, which later led to my decision to pursue the master Urbanism at the TU Delft. I am especially motivated to increase sustainability during urban development projects around the world, ensuring that both people and nature benefit from the changes developments provide in their living environment.

This motivation has inspired me to improve the redevelopment process of brownfield sites that are polluted from past industrial activities. I believe this topic will have great impact on sustainable development, Due to its widespread occurrence across the globe. My interest in brownfields stems from a site visit to the TATA Steel factory in IJmuiden during my minor. This visit uncovered the deep wounds these polluting brownfield sites inflict on the local communities and environment surrounding them.

Moreover, after discussing this topic with my own community, I discovered that there is an obsolete and polluted oil refinery site on Curacao, an island in the Caribbean Sea. This former Shell and PDVSA refinery covers a large area of Willemstad, the main capital of Curacao. Redevelopment is necessary, as the refinery activities became obsolete due to the global energy transition and the decline of crude oil export from nearby Venezuela. The large area of this refinery also provides chances for new activities. I hope, that the outcome of my thesis supports decision makers on the island of Curacao in creating a sustainable future vision for their brownfield sites, benefitting people and nature.

Figure 1: Site visit to the Isla Refinery, Source: Author.

1.2 Theory and concepts

This thesis will primarily focus on a method for sustainable brownfield redevelopment of polluted industrial areas. This method will be applied to the redevelopment of the former oil refinery in Curacao, also called the Isla site.

Due to the ambiguity of the term sustainability, a further explanation on how this thesis defines this term is needed. The triple bottom line theory from Elkington (1994) will be used as a basis for this definition. This theory stems from the idea that sustainable development consists of three components; people, planet and profit. Meaning, projects and businesses should aim to provide besides monetary profit a positively impact on society and the environment. In more recent years the word prosperity was adopted to replace profit, this emphasizes a broader scope of economic well-being and considers factors beyond just financial gains. In this theory people is described as societal impact, adding benefits for local communities and their cultures. Planet stands for the environment, meaning ecosystems and biodiversity are not harmed but instead rejuvenated (Elkington, 2004).

The three components ‘people’, ‘planet’ and ‘prosperity’ are often used as theories in sustainable development projects. To link this theory to urban planning, each component will be discussed using different concepts from the urban planning field. For ‘people’ the concept of spatial justice triangle by Rocco (2023) is used, for ‘planet’ the concept of ecosystem services is applied and for ‘prosperity’ the concept of autotroph cities by Rizzetto & Hooimeijer (2022) is used. The table below shows the relationship between the three components and the different concepts with their corresponding urban planning strategies.

Main value	Theory	Concepts	Pillars	Strategies
Sustainable Brownfield redevelopment	People	Spatial justice triangle Rocco (2023)	Distributive, recognition and procedural justice	Stakeholder participation
	Planet	Ecosystem services	Provisioning, regulating, cultural and supporting services	Nature based solutions
	Prosperity	Autotroph cities Rizzetto & Hooimeijer (2022)	Reduce, reuse and recycle of resources	Linking open-loop system circularity

Table 1: Concepts and theories overview, source: Author.

The following text will further explain the relationship between these concepts and the theories of people, planet and prosperity.

People

The impact on society is addressed in this thesis through the spatial justice triangle by Rocco (2023). This concept explains spatial justice through three main types of justice; distributive, recognition and procedural.

Distributive justice is described as ‘’the geography of the distribution of benefits and burdens of society’’ (Rocco, 2023). This justice is fair when public goods, amenities, resources and services are accessible and distributed among all people in a community, and not restricted by any form to a (pre-)selected part of a community.

Procedural justice focusses on the procedures of planning and governance of cities. Meaning ‘’how space utilization in cities and communities are negotiated, planned, designed and managed by actors from the public sector, the private sector and civil society.’’(Rocco, 2023). Rocco (2023) pleads that procedural justice is fair when developments include participation, sharing of expert knowledge and transparency of

decisions, because this increases the chance that all voices are heard during a decision-making process. He also emphasises the importance of a combination between expert knowledge and citizen participation, as this supports a more inclusive decision-making process.

Recognition justice relates to the cultures, experiences and identities of people in society. Focussing on identity, culture, history, representation and respect. Recognition justice is fair when society emphasises the importance of the recognition, validation and respect for marginalised groups' cultures, experiences and identities.

Spatial justice is a key concept in achieving fair and sustainable brownfield redevelopment. By incorporating transparency, stakeholder participation and a deep understanding of communities, this thesis will try to adhere to the requirements set for a spatially just project.
Planet

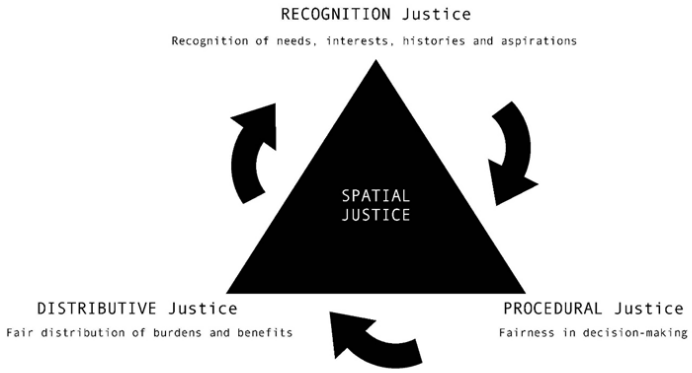


Figure 2: The three dimensions of spatial justice are interdependent and mutually reinforce one another. Source: Rocco (2023).

Planet
Ecosystem services are a concept used to describe the benefits communities get from natural resources, clean drinking water and places to recreate. This helps protect ecosystems from degradation, by being vocal about the negative impact this can have. These benefits consist of four categories, that describe their role to communities; regulating services, provisioning services, supporting services and cultural services (Acheampong, 2020). For a sustainable redevelopment, each of these four benefits needs to be fair for the community.
The figure below shows the different ecosystem services.

Figure 3: The four main categories of ecosystem services. (MA 2005)

Regulating services are benefits that the community obtains from the impact on the ecosystems, that can have direct or indirect impacts to well-being. Direct impacts to humans are caused by benefits on a local scale, for example the air quality, quality of (public) green areas/parks, and quality of open water bodies. Indirect impacts are caused by natural processes on a global scale, for example climate (greenhouse emissions), natural disasters (flood protection from rising sea levels) and pollination (spread of biodiversity). Regulating services of a development are fair when it has positive impact on the ecosystem for the (in-) direct impacts to human well-being.

Provisioning services are benefits that the community obtains related to the production of resources. In general, important resources for communities are clean drinking water, food, building materials and usable energy (fuel). Provisioning services of a development are fair when it has no negative impact on the production of resources.

Supporting services are benefits that are vital to the ecosystem's own survival. These benefits support the endurance of natural systems and are necessary for all species that live in the ecosystem. Typically this includes the quality of soil/water but also the nutrient cycle and the ability to use photosynthesis to convert sun energy into biomass. Supporting services of a development are fair when it gives no harm to the endurance of natural systems.

Cultural services are benefits that the community obtains as non-physical resources from being in their (local) natural environment. These benefits can be valuable on a personal level, like spiritual enrichment and religious practices, but can also be on a community level, like appreciation of aesthetic values or on a global level, like sharing the benefits in tourism. Cultural services of a development are fair when the non-physical resources are not negatively affected.

Prosperity

This thesis uses the concept of 'autotroph city' as developed by Rizzetto & Hooimeijer (2022)to determine the sustainability of the development for the prosperity that communities get from the impact of a development. Prosperity encompasses good fortune, health, strong relationships, and overall fulfilment in life, making it a broader concept than just good economics. Rizzetto & Hooimeijer (2022) linked prosperity to the ability of communities to become self-sufficient providing a community with their needs without relying on outside resources. This concept was derived from the idea that currently communities (and cities) act mainly as "heterotrophic organisms", which cannot sustain themselves. Cities depend on the continuous inflows of air, water, matter and energy as well as the outflow of produced waste and emissions that move beyond the borders of the city.

Rizzetto & Hooimeijer (2022) suggest that the city can become 'autotrophic', meaning they become a primary producer of their own resources and will become self-sufficient, avoiding or reducing the continuous inflow and outflow. Self-sufficiency, for cities, is becoming more important when The inflow of products are disrupted during (pollical) crisis or instability or even collapsed during a global crisis, which was the case during the global COVID19 pandemic when many products that were created all around the globe were not available anymore in many countries. These communities had become fully dependent on the globalized economy where continuous inflow and outflow is encouraged.

In the concept of 'autotroph city' a zero in- and outflows is promoted, using a circular economy within the city. Circularity is based on the following sequence (also by priority) of activities to reduce in- and outflow: reduce, reuse and recycle resources.

- Reduce: decreases the demand for resources, like energy, water and food.
- Reuse: uses resources available as many times as possible.
- Recycle: creates something new out of waste products.

This strategy can be applied to urban systems, however Rizzetto & Hooimeijer stress that every development will be different with respect to the contribution it can achieve to the city becoming autotrophic. A development is fair for prosperity when it contributes to balancing the economic and environmental benefits by reducing, reusing and/or recycling resources.

The figure below shows the conceptual framework used in this thesis. It shows the relationship between the theory of people, planet and prosperity and the different concepts with their corresponding strategies. In the middle of the framework is the main value of this research; sustainable brownfield redevelopment.

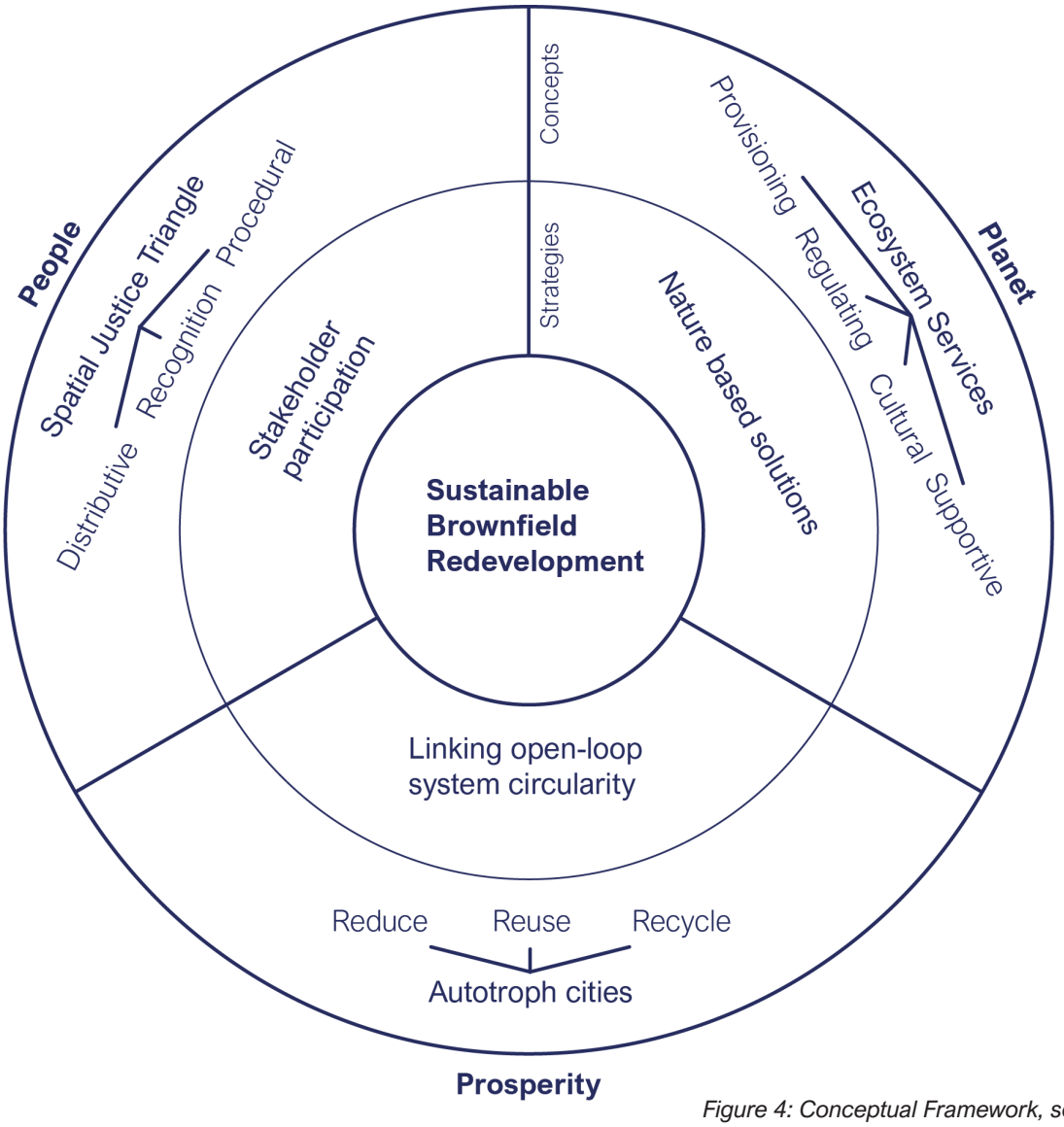


Figure 4: Conceptual Framework, source: Author.

To conclude, for a development to become fair, the following values need to be checked:

People:
- public goods, amenities, resources and services are accessible and distributed among all people in a community and not restricted by any form to a (pre-)selected part of a community (Distributive justice).
- includes participation, sharing of expert knowledge and transparency of decisions (Procedural justice)
- emphasises the importance of the recognition, validation and respect for marginalised groups' cultures, experiences and identities (Recognition justice)

Planet:
- positive impact on the ecosystem for the (in-)direct impacts to human well-being (Regulating services).
- no negative impact on the production of resources. (Provisioning services)
- gives no harm to the endurance of natural systems (Supporting services)
- non-physical resources on personal, community or global level are not effected (Cultural services)

Prosperity:
- contributes to balancing the economic and environmental benefits by reducing, reusing and/or recycling resources

The previously mentioned values shows similarity to the Sustainable Development Goals as adopted by all 193 countries of the United Nations in 2015.
Out of the 17 Sustainable Development Goals the following 10 will be included in this thesis:

- Good Health & Well-being: Ensure healthy lives and promote well-being for all ages.
- Clean Water & Sanitation: Ensure availability and sustainable management of water and sanitation for all.
- Decent Work & Economic Growth: Promote sustained, inclusive, and sustainable economic growth, f ull and productive employment, and decent work for all.
- Industry, Innovation & Infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
- Reduced Inequalities: Reduce inequality within and among countries.
- Sustainable Cities & Communities: Make cities and human settlements inclusive, safe, resilient, and sustainable.
- Responsible Consumption & Production: Ensure sustainable consumption and production patterns.
- Climate Action: Take urgent action to combat climate change and its impacts.
- Life on Land: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt biodiversity loss.
- Peace, Justice & Strong Institutions: Promote peaceful and inclusive societies for sustainable deve lopment, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.

02 | Research approach

Problem statement
Research aim and questions
Methodology

2.1 Problem statement

Brownfields are defined by the US government as “real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.”. The threats brownfields pose on the environment and public health can be significant. Brownfield reclamation can mitigate these threats and work against urban sprawl by being an alternative to greenfield development (Bartke & Brownfield Regeneration, 2014; BenDor et al., 2011; Cizler, 2013). This is why UN SDG target 15 (Life on Land: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt biodiversity loss) is important. More specifically SDG 15.3 states ‘’ By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.’’.

Developments are often called a ‘brownfield redevelopment’ to imply that the development is inherently sustainable, due to the scarcity of land as a commodity. However, this is not true, according to Eisen “Any argument that all brownfield redevelopment is inherently sustainable is unjustified” (1999). To make a brownfield redevelopment project sustainable, a holistic approach to sustainability should be adopted. Meaning people, planet and prosperity should have equal influence on the project (Elkington, 2004). Past and present brownfield redevelopment projects often fail to incorporate all three aspects to sustainability and are usually driven primarily by the goal of economic growth (Schilling, 2022).

Moreover, conventional remediation methods used in brownfield redevelopment projects typically lack a sustainable approach as well. These methods often include activities like; incineration, sealing/capping and/or disposal of contaminated soil. However, these methods fail to neutralize hazardous particles in the environment and instead these actions either displace the hazardous materials, create new hazardous substances or only isolate the hazardous materials from the ecosystem by stabilizing them (Singer & Groeneveld, 1999). Meaning, the contamination itself is transferred to another place (by location) or generation (by time). However, these remediation methods are not in line with the definition of sustainability, which the United Nations Brundtland Commission formulated as ‘’meeting the needs of the present without compromising the ability of future generations to meet their own needs.” (1987).

To date, sustainable remediation methods are available, for example, phyto-extraction, bio-remediation and rhizo-degradation. These sustainable methods are based on the principle to neutralize hazardous materials, but take significantly more time compared to the above-mentioned conventional methods, ranging from 5 to 40 years (Kennen & Kirkwood, 2015). During that time, typically the redevelopment is halted as development is considered possible when the remediation phase is finished. The long waiting times create uncertainty for the developers of the polluted sites, making the selection for sustainable methods seldomly attractive.

A ‘Brownfield phased redevelopment” method will be designed that ensures the sustainability of a development in a polluted area that requires a long remediation phase to neutralize the hazardous materials. The method focuses not only on the applied sustainable remediations methods, but also on the fairness of the redevelopment with increased value for people, planet and prosperity.

The phased redevelopment method will be tested on the brownfield redevelopment of the polluted Isla Refinery site on Curaçao.

Since 2019 the former Shell Isla Refinery on Curaçao has been closed and is falling into decay, after the lease contract with the Venezuelan oil company (PDVSA) came to a halt (Jong, 2015).
Curaçao’s local government prefers to re-open the refinery and is looking for new parties to lease the property to. The refinery is however mainly suitable to refine heavy oil from nearby Venezuelan oil fields. Due to ongoing geopolitical constraints imposed by US government on the export of Venezuelan oil, this party has not (yet) been found. The Curacao government is very eager to reopen the refinery as it (historically) provides many job opportunities, tax revenues and it postpones the costs for clean-up/ dismantling (Beumer & Verster, 2012).

To date, the state-owned company Refineria di Kòrsou (RdK) manages the site. The company underwent a rebranding last year, renaming it to 2Bays and publicly pleading for a sustainable future for the site. The

redevelopment plans show a focus on the following five commercial segments; oil and gas, sustainable energy and resources, harbour and logistics, light industry and food production and local needs (Reijmer, 2024).

However, this redevelopment plan remains mainly reliant on the continued exploitation by the oil industry as a refinery and lacks sustainability goals, including the activities for the clean-up of the pollution. This plan is therefore not in line with the Sustainable Development Goals set by the government of Curacao (Mordt et al., 2018). Implementing this plan will result in a site that remains heavily polluted due to the minimal clean-up efforts. This is causing health and environmental risks and will negatively affect local citizens and ecosystems (Al-Rubaye et al., 2023; Pulster et al., 2018).

2.2 Research aim and questions

The aim of this thesis is to create a sustainable future vision for the Isla Refinery, using phytoremediation as its base for cleaning the pollution in the water and soil.

The main research question of this thesis is; *How can the former Isla Refinery site be remediated and redeveloped to benefit local citizens, ecosystems and economies?*

This main research question will be answered by examining the following sub questions for the case study;

1. What is the current context and what future trends are expected of the case study and how will this context interact with the redevelopment?
2. How can the pollution on the case study site be sustainably remediated?
3. What are possible new activities in the case study area, during and after remediation, and how fair are these developments to ensure their contribution to the value of People, Planet and Prosperity?
4. What is the final result after the completion of the sustainable remediation for the case study?

The second sub-question focusses on the strategy for cleaning up the pollution in the area. The objective of answering this question is to gather Information on the contamination types and levels on the specific site in the case study.

The third sub-question focusses on potential new activities that can be developed on the site. The possibility for activities depends on the level of pollution and the interaction with the remediation method. This can be different in the site, both for locations as well as in time, as pollution levels will vary. To ensure the sustainability of these new activities, fairness of the developments will be evaluated for their contribution to the value of people, planet and prosperity.

The last sub-question combines the answers of the previous sub- questions and uses them to provide a sustainable future outlook for the site after the brownfield redevelopment is completed.
The following table shows the different sub-questions and the expected outcomes.

Subject	**SRQ**	**Method**	**Outcomes**
Caste study contextualization	*What is the existing context of the case study and how will this research interact with that context?*	Triangulation: GIS-mapping, stakeholder analysis, reference projects and semi-structured interviews	Contextualisation
Remediation methods	*How can the pollution on the case study site be sustainably remediated?*	Literature review	Remediation strategy
Sustainable future program	*What are possible new sustainable activities for the case study and how are they contributing to the value of People, Planet and Prosperity?*	Theory and semi-structured interviews	Program recommendation and scenario's
Final outcomes case-study	*What will a sustainable future look like for the case study?*	Research and design	Future design case study through scales and time

Table 2: Sub research questions scheme, source: Author.

2.3 Methodology

To following text explains the different methods used in this thesis to answer the above mentioned questions. These methods vary from exploratory to systematic, each have their own input data and their outcomes influence each other's course. This is an iterative process, meaning methods can change throughout the research process. This will be made explicit once the research has been completed.

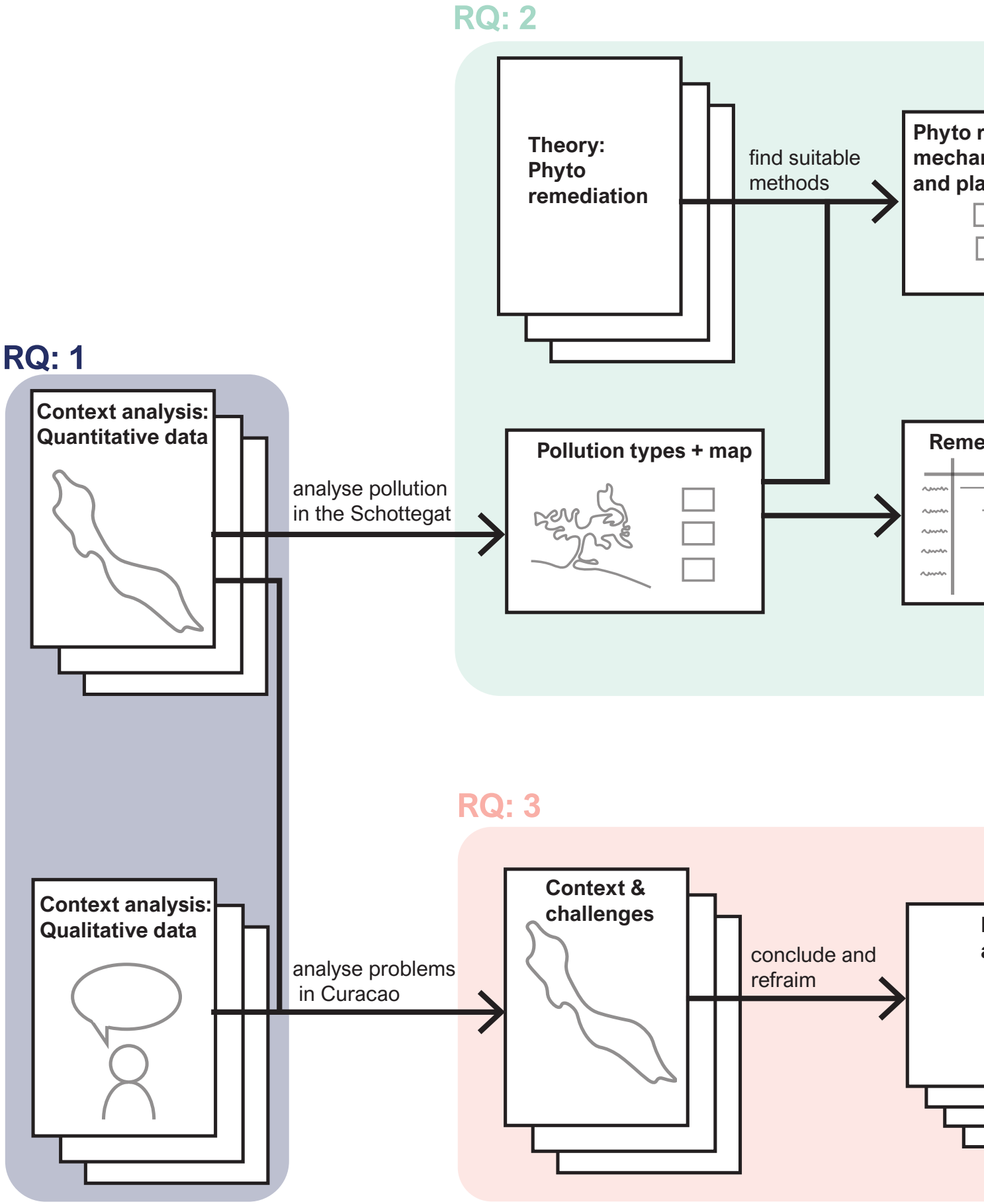
The first research question is answered by a combination of different existing systematic and participatory research methods. The existing context of the case study is analysed, through GIS-mapping, semi-structured interviews, stakeholder analysis, historical analysis, analogue mapping and by comparing the case study area to reference projects. The information needed from this analysis is determined through the input needed for research questions two and three. Research question two requires input data about the pollution in the case study area to be able to determine which remediation methods are possible on this specific site. Research question three requires stakeholders' input to determine what future program needs to be analysed using the semi-structured interviews.

The second research question is answered using a systematic approach. Information on the contamination types and levels on site of the case study are gathered through desktop research, similar reference projects and interviews with the site's current operator Input from existing literature about the different phyto-technology mechanisms and planting typologies and species, that are suitable for cleaning up contaminations (phytoremediation) will be used. Data from the case study provided by the first research question will be used to determine which remediation method is appropriate for the different locations on the site in the case study. The main sources to provide information about phytoremediation are the book Phyto by Kennen & Kirkwood (2015), the publication Phyto-technology Technical and Regulatory Guidance and Decision Trees, Revised by ITRC (Interstate Technology & Regulatory Council) (2009) and the publication Brownfields Redevelopment, A Guidebook for Local Governments and Communities by ICMA (the International City/County Management Association) (1999).

The third research question takes an exploratory and participatory approach. First, theory and reference projects are used to create an overview of possible future activities that can be developed on the site. These activities need to take into account the local levels of contaminations, as these vary along the site depending on the status of the phytoremediation progress. Next, sustainable fairness of the activities will be evaluated for their contribution to the value of people, planet and prosperity. This fairness will be determined through the input from different stakeholders using semi-structured interviews and by using information about the current (social) state of the island. These are then further evaluated and different scenarios are sketched, showing what the fairness effect of the developments on the site can look like.

The final research question is answered using a design-driven approach. Using the outcomes from the previous sub-questions a spatial design for the year 2075 is created. The year 2075 is used as the future moment when the brownfield redevelopment is expected to be completed. The final design will be the result from an iterative research and design process, as the possible activities on the site depend on the level of contamination. The final outcome of the design process will therefore develop both in time and space. Scenario development exercises, maximalization exercises, and sketching through multiple scales in space and time will be used as tools to develop possible outcomes. Finally, the outcome will be reflected on and a conclusion will be drawn on the suitability of the 'Brownfield phased redevelopment" method for other brownfield redevelopment projects.

2.3 Methodology



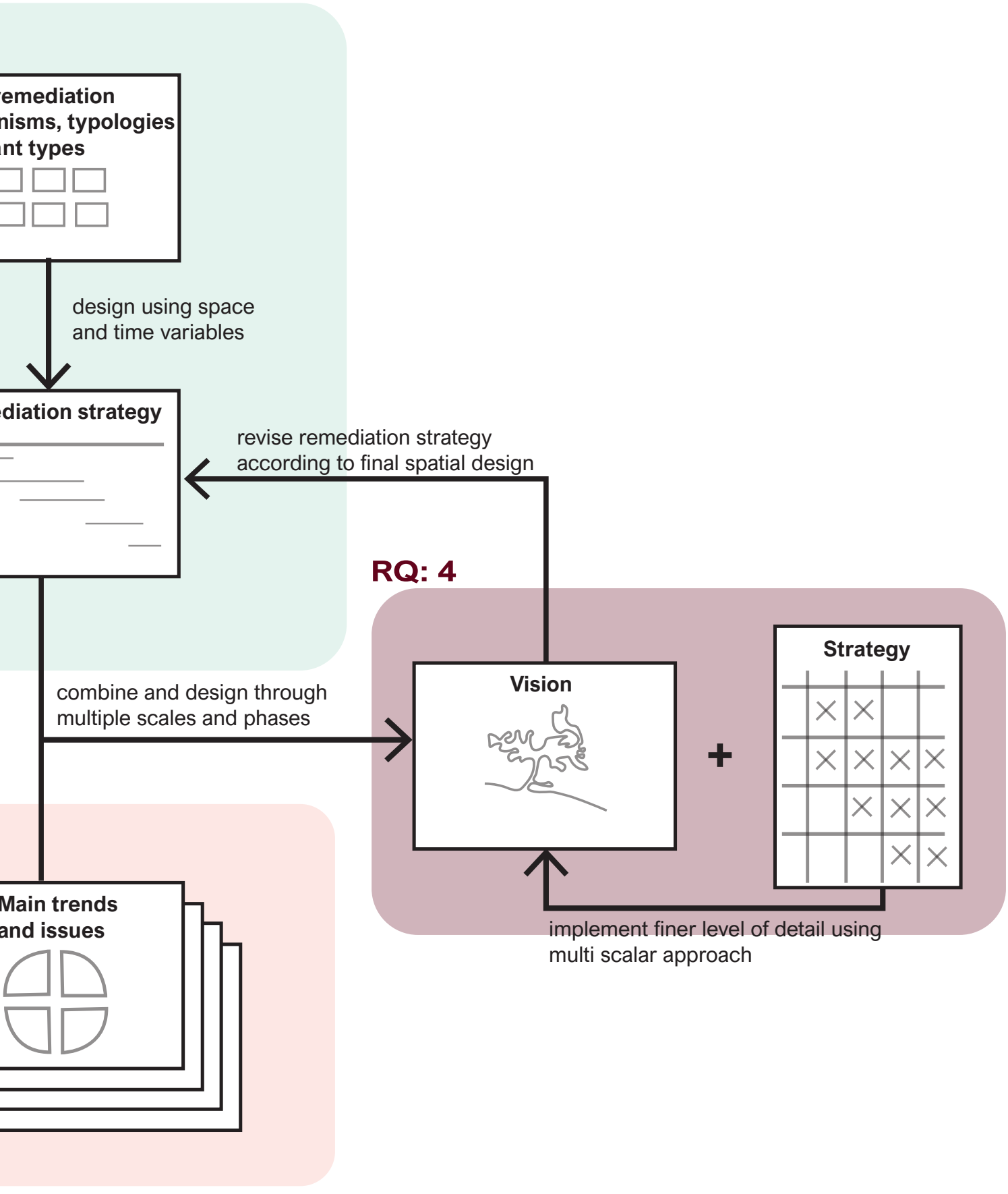


Figure 5: Methodological Framework, Source: Author.

03 | Analysis

Context
- Historical analysis
- Stakeholder analysis
- Land-use analysis
- Infrastructure
- Pollution analysis

Future trends
- Climate change
- Brain drain
- Import dependency
- Over tourism

In the analysis phase of the redevelopment, the following sub-questions will be answered and used for the redevelopment of the polluted Isla Refinery location:

- What is the current context for the redevelopment area and what future trends are expected that can be relevant for the location?
- How will this context interact with possible sustainable redevelopment activities?

Historical analysis, stakeholder analysis, landscape analysis, Infrastructural analysis, and pollution analysis, will be conducted to determine the interactions of the Isla Refinery location with its surrounding areas on the island of Curaçao. The results of these analyses provide the context for the brownfield phased redevelopment of the former refinery area.

3.1 Context
Historical analysis

Scattered throughout the island are multiple important archaeological sites. Figure 6 shows where these are located. Both pre-colonial and more recent artefacts can be found at multiple sites. Many interesting finds have already been discovered, however many more are still unfound. For example, the old city walls of Punda are still not yet located. New research is increasing knowledge about the history of Curaçao. This provides opportunities to better communicate the past and increase public engagement with Curaçaos history (A.H. Speckens, 2024).

Since 1997, the historic city centre and harbour of Willemstad have been put on the UNESCO World Heritage List. It was added based on the ‘’Statement of Outstanding Universal Value’’ (OUV).

In Curaçao about 860 buildings are monuments, 743 of which are in the city centre. In addition, Willemstad’s historic city centre has a protected cityscape with the aim of preserving and restoring the existing monuments and historic structure. Meanwhile, new developments focussed on high quality development of the built environment and public spaces, are encouraged to utilize the full potential of the existing urban structure (A.H. Speckens, 2024).

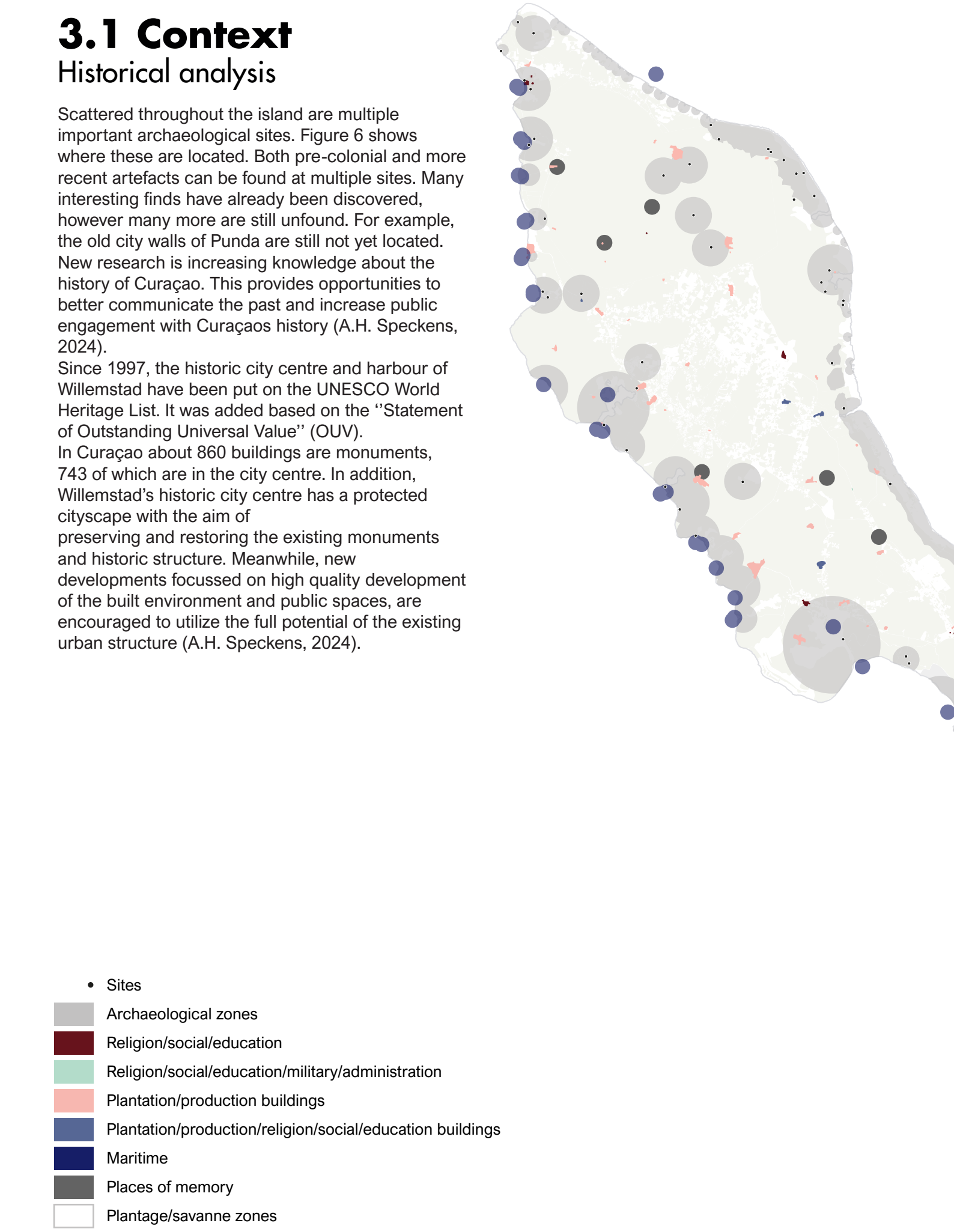
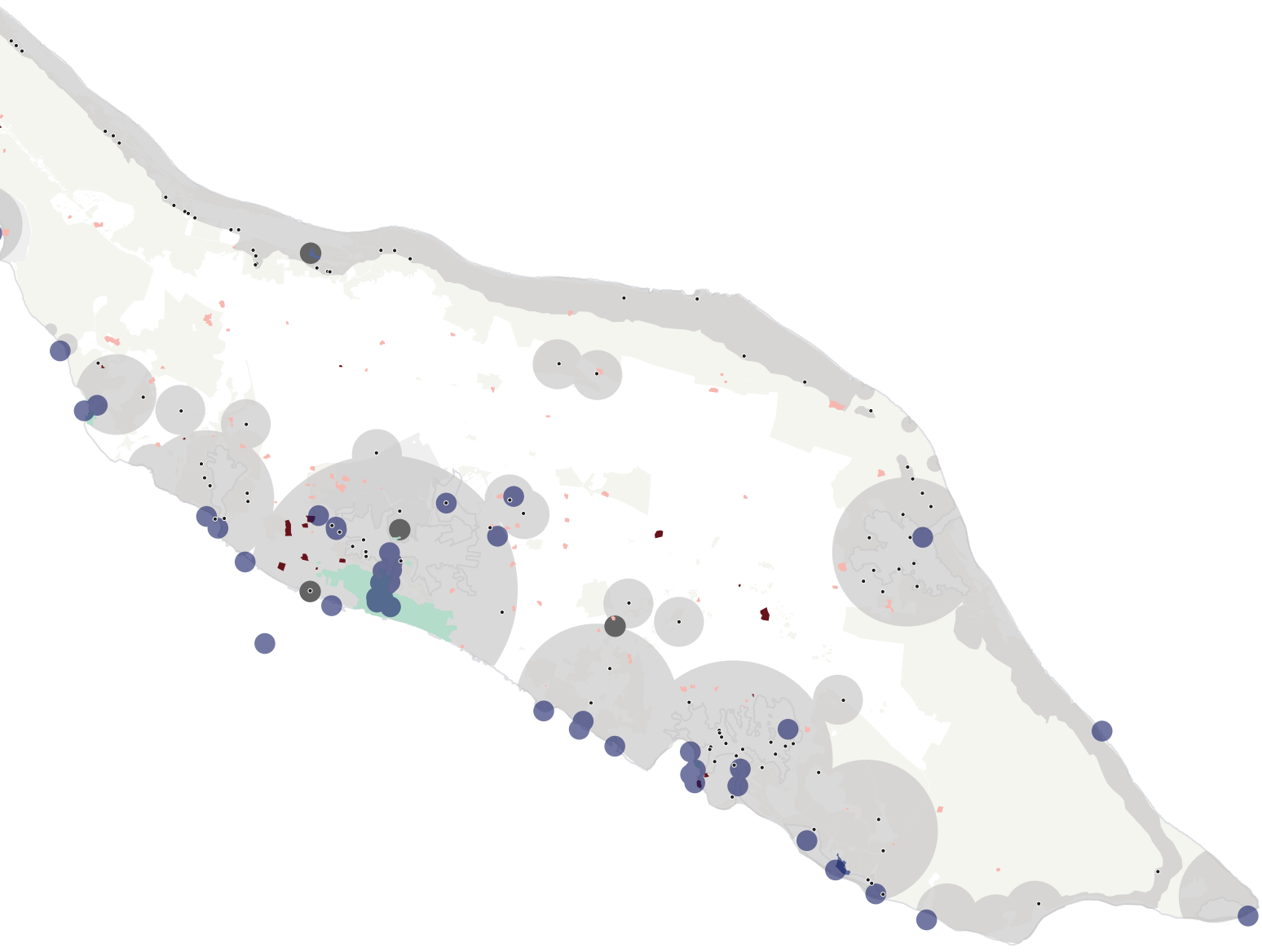


Figure 6: Hertitage map, source: Author, based on Curacaomonuments (z.d.)



3.1 Context
Historical analysis

In the historical analysis, the history of the island will be investigated to provide an understanding of the development of the suburbs surrounding the former refinery area. The history of Curaçao can be divided into different main historical periods, namely; the pre-historic period, colonial period, emancipation period, industrial period, and finally the present period with the rise of tourism. During these periods the island was characterized by different economic rises and falls, influencing the demographic and development of the city Willemstad on the island. The full historical analysis is included in appendix 7.1. This chapter will give an overview of the relevant information extracted from this analysis.

During the start of the Dutch colonial period (in 1634) a settlement grew north of Fort Amsterdam, which evolved into a walled city called Willemstad. When the walled city was becoming over-populated in the 18th century, people began living outside the city walls resulting in the emergence of more neighbourhoods. (Dr. R. M. Allen et al., 2020f; Toelichting EOP, 1995).

Pietermaai was the first neighbourhood that emerged on the strip of land between the Waaigat and the sea. Houses were built on both sides of the road that ran to the eastern part of the island. The city wall was demolished between 1861 and 1866, resulting in the expansion of both Punda and Pietermaai towards the north and in the empty areas between them (Dr. R. M. Allen et al., 2020f; Toelichting EOP, 1995).

In the second half of the 19th century the second neighbourhood called Scharloo emerged. Large, scattered houses were built along the north side of the Waaigat, on the former Scharloo plantation. This neighbourhood grew exponentially and within a few decades, Scharloo developed into a prominent residential area (Dr. R. M. Allen et al., 2020f; Toelichting EOP, 1995).

In the same period the suburb of Otrobanda (meaning on the other-side) expanded rapidly on the opposite side of St. Anna Bay. This neighbourhood initially developed similarly to Pietermaai along the two sides of a road, the one that ran to the west of the island. Because Otrobanda was never walled, people didn't have to build within a limited space. Most buildings in this area were initially spacious on large walled plots. Later, small, adjoining houses called 'kura's' were built at the edges of these walls. Otrobanda grew rapidly, and by the mid-eighteenth century, it was already larger than the city center Punda (Dr. R. M. Allen et al., 2020f; Toelichting EOP, 1995).

Industrialization on Curaçao began in the 20th century. This period started with the establishment of an oil refinery by Shell. Shell's concession in the Mene Grande oil field in Venezuela required an oil refinery. It was decided to build this refinery on Curaçao, due to Curaçao's deep waters and more stable government compared to Venezuela (Dr. R. M. Allen et al., 2020j; Toelichting EOP, 1995). From 1915 onwards, the refinery on Curaçao was developed by Shell. The company acquired large plots of land north of the Schottegat, including the Asiento, Valentijn, and De Hoop plantations. Other plantations (including Groot St. Joris, Zatapeer, Groot Piscadera, and Brakkeput Meimei) were purchased for groundwater pumping and rainwater harvesting (Jong, 2015; Nationaal Archief Curaçao, n.d.).

Shell had not only a significant influence on the composition of Curaçao's population, but also on its urban development. Over the course of the next 25 years, the company built entire neighbourhoods for employees at various locations near the refinery, such as Julianadorp, Rio Canario, Groot Kwartier, Suriname Dorp, and Suffisant. This was followed by many low-density developments, resulting in the large urban area consisting of many different districts, now known as the city of Willemstad (Toelichting EOP, 1995).

This urban expansion was further developed as cars provided mobility to live further away from workplaces. By 1938, there were already more than 1,500 cars and 400 buses on the island. Developments continued with housing projects for lower incomes in Steenrijk and Marie Pompoen between 1947 and 1951. More projects followed in 1954 in Brievengat, in 1957 in Buena Vista, and later (in the 1960s and 1970s) Koraal Specht, Brievengat (phase 2), Ceru Domi and Ceru Fortuna. During the Shell's reign the population grew from 32,000 in 1920 to 125,000 inhabitants by 1959 at its peak. Approximately 90% of this population lived in Willemstad or in the neighbouring suburbs. Shell's success led to the expansion of the Bullenbaai oil port on the southwest coast of Curaçao, which opened in 1974. Crude oil is stored there and then transferred to

smaller tankers (Jong, 2015).

Shell wanted to sell the refinery, due to a decline in export and rising prices of crude oil in the 1980s. This eventually led to the agreement of a transfer, that was signed in 1985, which later became known as ‘’the year that Shell left’’. The Netherlands Antilles and island territory Curaçao became the owner of four operating companies for only four symbolic Antillean guilders: the refinery at Schottegat, the oil terminal (COT) at Bullenbaai with the pipelines to the refinery, the dock, and the sales company.

To date, the refinery is redundant and processing facilities are degrading fast. Since 2019, the Refineria di Kòrsou (RdK) has been searching for a new operator (Dr. R. M. Allen et al., 2020m). This state-owned company underwent a rebranding this past year, renaming it to 2Bays and pleading for a sustainable future for the site.

The process of urban sprawl has continued with the construction of new low-density residential neighbourhoods, on the outskirts of Willemstad. Urbanization is still increasing, while, the city centre of Willemstad is depopulating, as many buildings are being transformed to serve tourism functions. (Toelichting EOP, 1995).

3.1 Context

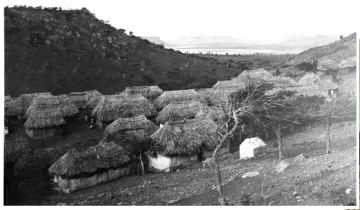
Historical analysis

The timeline shown on the right summarizes the main events that happened during Curaçao's history.

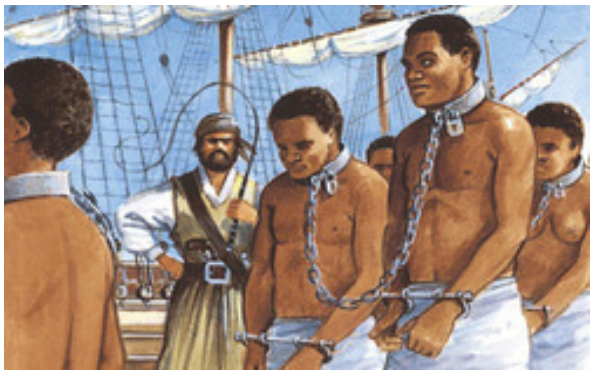
Pre Historic Period | Spanish Colonial Period

Urbanization

Demography

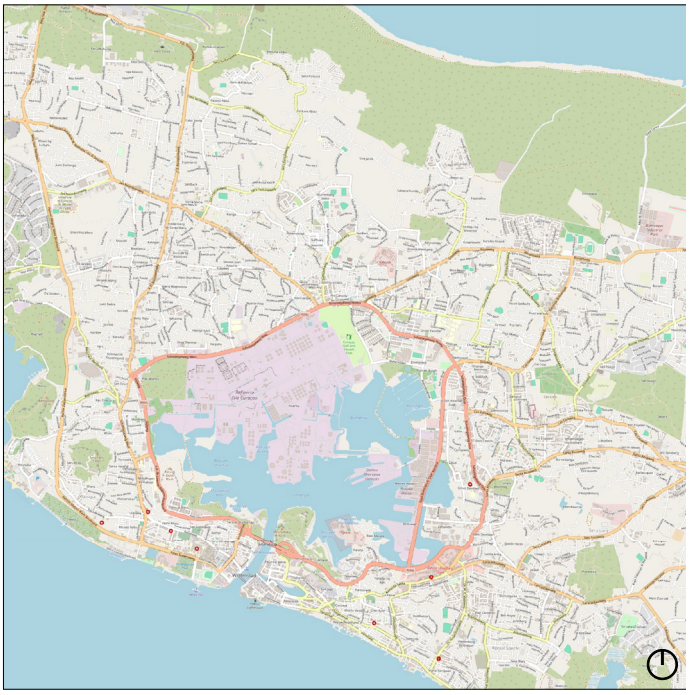


Economic drivers



Historic events

1500 1600



1700 1800 1900 2000

Figure 7: Historical timeline Curaçao, source: Author.

3.1 Context
Stakeholder analysis

The table on the right shows the potential stakeholders that are relevant for the redevelopment of the Isla Refinery. Each stakeholder is analysed with respect to the following aspect: Problem perception, Goals, Interest, Resources, Power and Attitude towards possible new development. These stakeholder aspects provide a comprehensive understanding of the stakeholder dynamics and are used to make engagement strategies effective. These aspects support identification of potential conflicts and opportunities in the development process.

- Problem Perception: Each stakeholder may view the sustainable redevelopment differently, influenced by their own experiences and context. Understanding their perspective about concerns or benefits is important to avoid future conflict and resistance.
- Goals: Each stakeholders hopes to achieve goals through the redevelopment or its new activities. Goals can be specific, such as increasing profit, or more general, such as improving community well-being or preserving the environment. Alignment of goals between stakeholders provides opportunities for collaboration; while competing goals need to be careful consideration between stakeholders.
- Interest: Each stakeholder has its own level of concern or involvement in the redevelopment to become a success or a failure. Interest goes beyond formal goals as it also includes underlying motivations and potential impacts, both positive and negative, that the redevelopment might have.
- Resources: Each stakeholder can bring certain resources to the redevelopment. Resources can include funding, knowledge, expertise, physical assets, access to networks, or an official mandate. These resources can be used to support the development or, if a stakeholder is in opposition, used to hinder it.
- Power: Each stakeholder has an ability to influence the outcome of the redevelopment, or other stakeholders. This influence can be formal (e.g., regulatory authority, decision-making position) or informal (e.g., social standing, public opinion mobilization). Balancing power differences between stakeholders is important when potentially the power is asymmetrical between stakeholders.
- Attitude towards possible new development: Each stakeholder' has its own general disposition towards the proposed change due to the redevelopment. Attitudes can range from very positive (strong support) to neutral to very negative (strong opposition). Understanding the attitude determines the necessary engagement level and efforts required for potential persuasion.

Table 3 shows for the relevant stakeholders the outcome of the analysis.
The most important stakeholders, with respect to Interest and Power are discussed below.

Stakeholders	Problem perception	Goals	Resources	Interest	Power	attitude
PdVSA	No Refinery		bargaining position	●○○○	●○○○	Opponent
Stichting GreenTown	No future vision for the area	Redevelopment of the area	Public attention, local knowledge	●●●●	○○○○	Proponent
CPA	Decrease of harbour activity		Negotiation opportunities	●●●○	●○○○	Opponent
KTK	Decrease of harbour activity		Negotiation opportunities	●●●○	●○○○	Opponent
CRU	No refinery		Negotiation opportunities	●●●●	●●●●	Opponent
2BAYS (former RdK)	No refinery	Re-opening of the refinery	Land ownership	●●●●	●●●●	Opponent
Ministeries:						
Justitie		Public safety	Power	○○○○	●●●○	Opponent
Financiën	Costs land reclamation	Financing policy plans	Funds and power	●●●○	●●●●	Neutral
Algemene zaken			Power	○○○○	●●●○	Neutral
GMN	Environmental and health risks	Environment and health	Power	●●●●	●●●○	Proponent
Economische Ontwikkeling	Inflation	Economic growth	Power	●●●●	●●●○	Conflicted
OWCS		Education and culture	Power	●○○○	●●●○	Proponent
VVRP		transportation	Power	●●●○	●●●○	Proponent
BPD		transparency	Power	●○○○	●●●○	Neutral
SAW	Job insecurity	Prosperity and wealth	Power	●●●○	●●●○	Proponent
Minister van Koninkrijke relaties			Power	●○○○	●●●●	Neutral
USA	China	Cheap oil	Influence	○○○○	●●○○	Opponent
EU	Environment	GreenDeal	Legislation	●●○○	●●●●	Proponent
1e Kamer, NL		Evaluating new laws	Legislation	●○○○	●●●○	Neutral
Venezuela;Maduro		Keeping dictatorship	Oil production	○○○○	○○○○	Neutral
SMOC	Curacao's environment	Clean curacao's Environment	Public influence	●●●●	○○○○	Proponent
Clean Air Everywhere	Air pollution worldwide	Keeping refinery closed	Legal power	●●●○	●○○○	Proponent
MOTE		Research	Knowledge	●●○○	○○○○	Proponent
Former workers Refinery	Lost jobs	Keeping their jobs	Strike power	●●●●	○○○○	Conflicted
Local Residents	Health issues	Getting compensation	Legal power	●●●○	○○○○	Proponent
Schools	Closing due to pollution	Clean air	Political pressure	●●○○	○○○○	Proponent
Healthcare facilities	Increased health issues community	Clean air	Political pressure	●●●○	○○○○	Proponent
Future users		Work and live	Influence	●●●○	○○○○	Proponent

Table 3: Stakeholder analysis part 1, source: Author.

Private stakeholders (2BAYS, Shell and PdVSA)
Since 2019, the Refineria di Kòrsou (RdK) has been searching for a new operator (Dr. R. M. Allen et al., 2020m). This state-owned company underwent a rebranding this past year, renaming it to 2Bays and pleading for a sustainable future for the site. Their plans focus on five commercial segments: oil and gas, sustainable energy and resources, harbour and logistics, light industry and food production and local needs (Reijmer, 2024).
It is noted that Shell and PdVSA are not on the list of Stakeholders. The responsibility of Shell for its damage to the health of local citizens and the environment, remains not liable in court due to the agreement made in 1985. PdVSA has leased the site in a as-is-where-is condition, and due to the lack of status monitoring, cannot be held liable for the damage to the health of local citizens and the environment that occurred during the 34 years of leasing and operating the refinery facilities.

Public stakeholders (Local government, Dutch government and European Union)
The local government is represented by different ministries and its primary role is being the landlord and controlling the refinery operator to adhere to local and international legislations. However, records show that the refinery operator(s) have not published reliable and independent reports that allow effective monitoring of these legislations for the past thirty years. This has resulted in multiple lawsuits against the refinery. Noticeable, most of these lawsuits were led by local NGO's (such as SMOC and GreenTown), set up specifically to improve the living conditions for people living in the environmental impact zone of the refinery (Jong, 2015).

It is further noted that the Dutch parliament has spoken up about the environmental issues on the area of the refinery, by financing research and addressing the issue in parliament, however a hands-off mentality is maintained as the island has its own autonomy on these issues.

Curaçao's relationship with the EU is determined by its status as an Overseas Countries and Territories (OCTs), which limits its relationship with the EU. There is a prospect of intensifying this relationship if Curaçao also qualifies as an Outermost Region (ORs) within the EU's structures, however despite attempts to realise this it has not been implemented, again because of Curaçao's autonomy (Jong, 2015).

Civic stakeholders (Local citizens and labour force)
The power that workers and local citizens have over decisions regarding the refinery lies primarily in their right to protest. In Curaçao, no other event is more strongly associated with the impact of protest than the Trinta di Mei uprising of May 30, 1969. On the morning of May 30, 1969, approximately five thousand

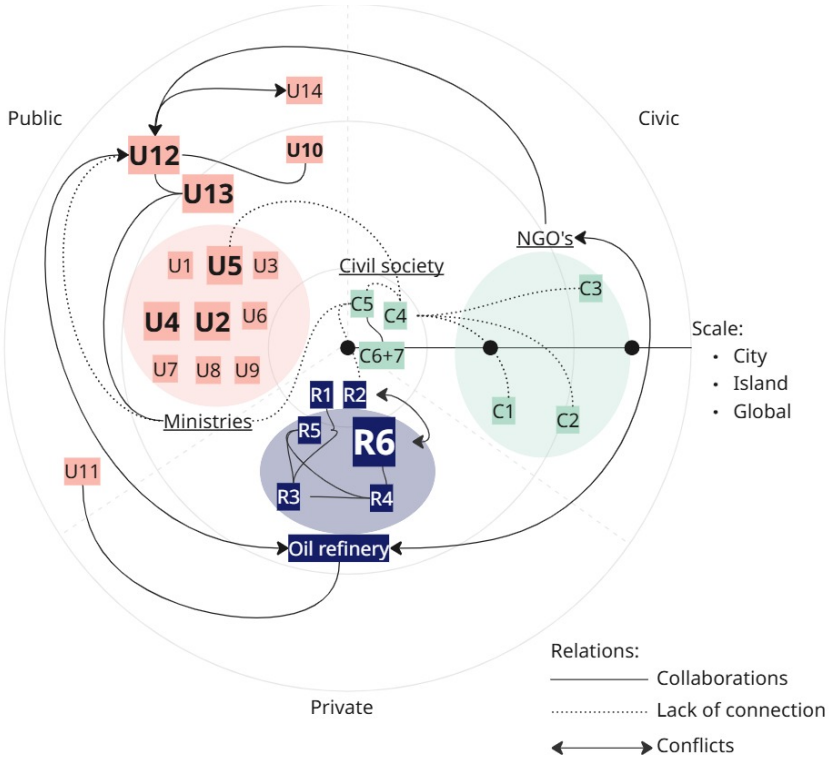


Figure 8: Stakeholder analysis part 2, source: Author.

strikers gathered at the main entrance of the Shell site for a protest march to the government building in Fort Amsterdam to defend the principle of “equal work, equal pay.” This protest was sparked by the Shell oil refinery outsourcing part of its work to various subcontractors, forcing employees who had previously worked for Shell to perform the same work for the subcontractors at lower wages. The protest march gradually spiralled out of control, as buildings were set on fire and shops were looted. May 30 is now seen as a turning point in Curaçaoan history for workers’ rights and in 1994, Trinta di Mei was declared a National Day of Remembrance (Dr. R. M. Allen et al., 2020l).

A few conclusions can be drawn about the different stakeholders:
Firstly, a conflict of interests can be seen between a few stakeholders. For example the former workers of the refinery, which are mainly Curaçaoan people living in neighbourhoods surrounding the refinery, prefer to reopen the refinery due to the ongoing economic decline. However, as local residents they also experiencing negative effects of the air pollution caused by the refinery when it reopens, causing health and environmental risks.
Secondly, most of the private stakeholders are opponents of sustainable redevelopment, since re-opening the refinery would generate economic profits for these stakeholders. Contrastingly, civic stakeholders have a more positive attitude towards the project, making them proponents. For example NGO’s who are fighting for a safe and healthy environment.

Figure 8 shows a clear division between proponents and opponents in the different sectors

Figures 8 and 9 show the results of the next part of the stakeholder analysis. Image X shows at which scale each stakeholder plays a role, what their connections with each other are and divides them into three sectors; Public, Private and Civic. It visualizes how the public and private sectors have strong collaborations within their own sector. However, this is not the case in the civic sector.

Figure 9 shows the power and interest ratio for each stakeholder. There is a clear power imbalance between the three sectors. The civic sector has a relatively high interest rate but contrastingly a very low amount of power. This is the opposite for the public sector. Stakeholders that fall under this sector have a relatively low interest rate, but a high amount of power.

Moreover, the arrows in this diagram show how each stakeholder should either be empowered, engaged or dismantled, for this project to succeed. Meaning stakeholders with a high amount of power and a negative attitude should be dismantled, stakeholders with a low amount of power and a positive attitude should be empowered and stakeholders with a low interest rate but a positive attitude should be engaged.

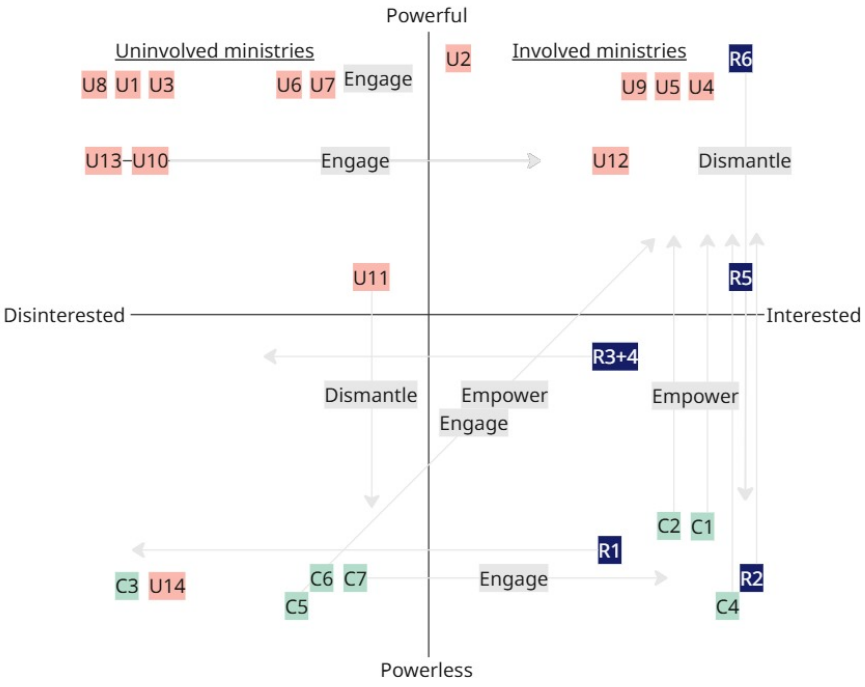


Figure 9: Stakeholder analysis part 3, source: Author.

3.1 Contexts

Land-use analysis

The land usage of the areas surrounding the refinery can be divided into the following landscapes: Urban areas, Rural areas and industrial areas. Below these will be described.

Urban areas

The urban development in Willemstad is characterized by an unstructured and unplanned approach. Low density residential areas are mainly added on the outskirts of the city, resulting in urban sprawl and the degradation of surrounding natural land. Additionally, this has created a divided structure of disconnected neighbourhoods with vacant plots between them. This lack of a spatial structure has an effect on different amenities, for example this has resulted in the current extensive road network and the dependency on the car as a mode of transport. Moreover, this unplanned structure has affected the spread of commercial amenities throughout the urban area. These amenities have settled themselves widely dispersed, often along main roads, following the widespread use of the car as a main mode of transport.

Apart from this lack of a structure in the urban areas, there is a perceived lack of recreational areas. Next to the larger parks (Muizenberg, Kabouterbos, Sapaté and Piscadera) and car-free zones in the city centre, there is a need for more natural (green) and public area's within neighbourhoods. On this neighbourhood-level there is also a need for central places for people to meet each other. Potential solutions include for example adding vegetation, park benches and playgrounds for children, public green to main roads, public transport nodes and shopping areas, have the potential to transform the view of the city in a more attractive one.

Within the urban areas there is approximately 1.000 hectares of vacant land (340 ha government owned and 660 ha privately owned). These areas have the potential to be further developed in either public parks or residential areas (Toelichting EOP, 1995).

Rural areas

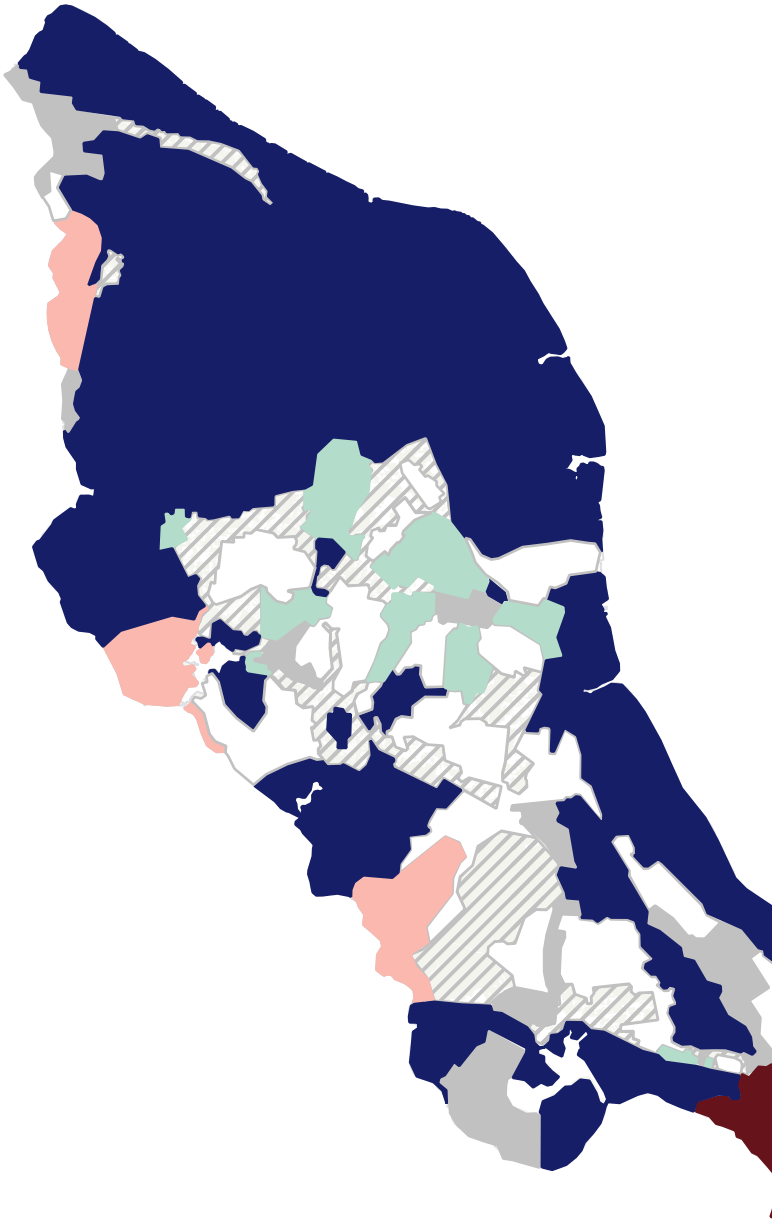
Contrastingly, the rural areas outside of Willemstad are valued by their natural and tranquil character. These qualities in Banda'bou and Banda'riba (the middle and West of the island) are considered as highly valuable and typical for Curaçao. Within this mainly natural structure, there are some settlements with a mixed use of low-density residential areas and agricultural areas (Willibrordus, Soto, Barber, Lagun en Westpunt). Settlements near the south coast (Knip, San Nicolaas, Cas Abao) are adjacent to nature reserves. The rural area in the centre of the island consists of a mix of urban development, industrial development and the preservation of the rural characteristics. The industrial development is situated near the Bullenbaai (COT) and Meiberg. Urbanized areas are adjacent to the outskirts of Willemstad (Tera Cora and Grote Berg). The rural areas are situated more central and consist of the nature reserve Malpais (Toelichting EOP, 1995).

Industrial areas

The industrial areas of Curaçao are situated around the Schottegat and near the Bullenbaai area.
Around the Schottegat there is a mix of different industrial activities. Starting with the Isla Refinery at Asiento with multiple jetties. On the east of the refinery is the so-called Asphalt lake (ca 80 ha). The Brion yards accommodate the dock company of Damen Shipyards and container harbour. On the south-east of the Schottegat is Parera, a mixed-use area with the navy base and its warehouses, workshops, offices and residential buildings. The area adjacent to the St. Anna Bay is used for the mooring of large cruise ships, the other parts of this area remain largely underused. The west side of the Schottegat is mainly undeveloped and polluted with oilspill coming from ships moored at the refinery.

The Bullenbaai area is used as an oil terminal and its location near deep seawater and the adjacent area shows possibilities on land for a large-scale industrial park. The area is ideally suited as a bulk transhipment port, as a supply port for raw materials and an export port for products produced on the island (Toelichting EOP, 1995).

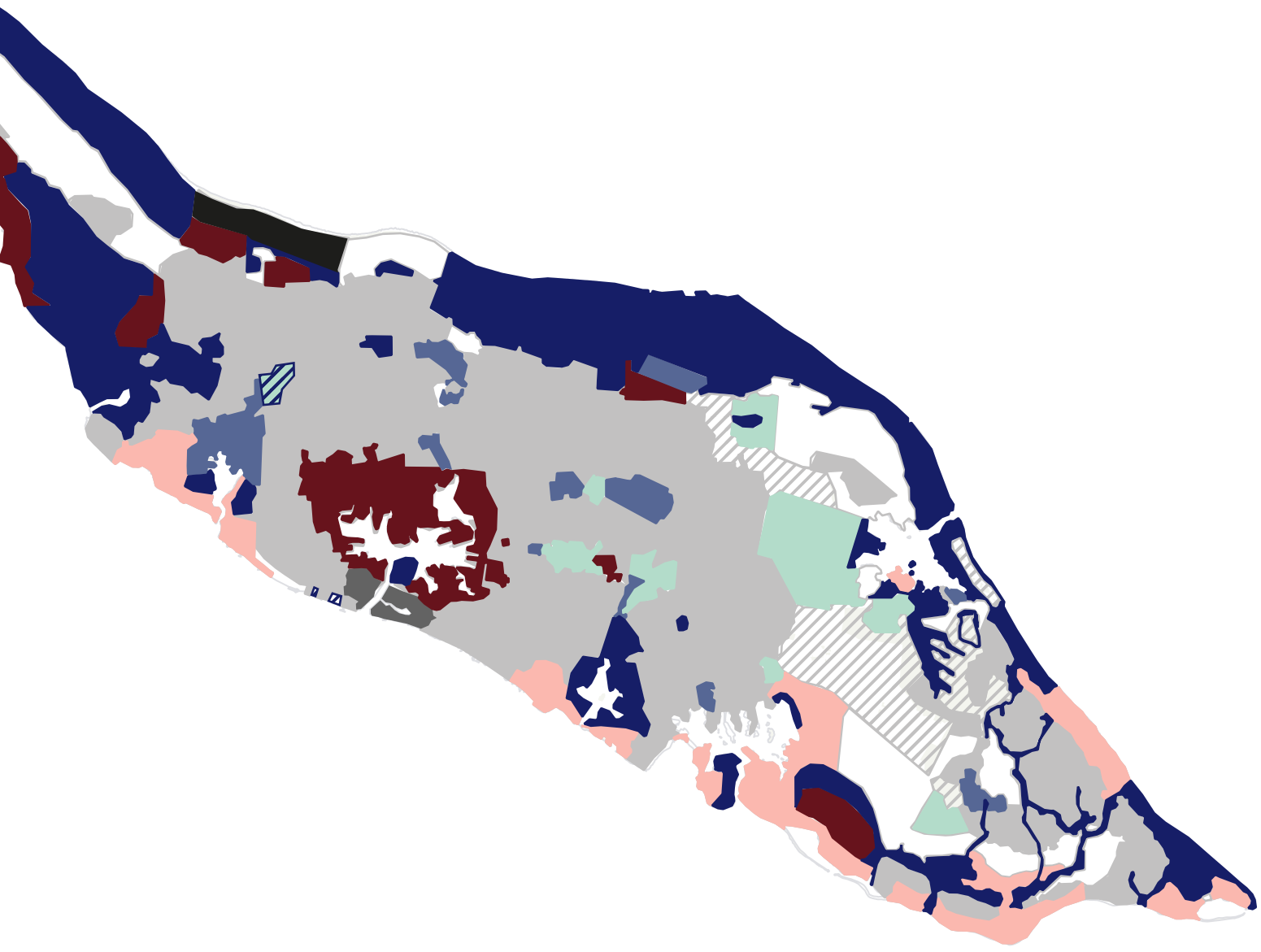
3.1 Contexts
Land-use analysis



Urban Core
Urban
Rural
Open space
Industrial
Agricultural area
Tourism
Park
Conservation
Conservation water
Airport

0 2,5 5 7,5 10 km

Figure 10: Land use map, source: Author, based on EOP (1995).



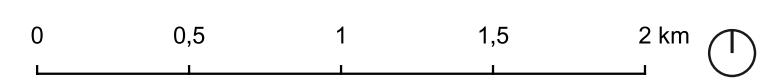
3.1 Contexts

Land-use analysis

Legend:

1. Ecopark
2. Ecopark Expansion
3. Solar Park
4. Blenheim
5. Blenheim Expansion
6. Jewish Cemetary
7. Porkchop Landfill
8. LPG Flare
9. Van Leer
10. Curoil
11. Slop Tanks
12. Sulphur + Amine Teater
13. LPG Plant
14. Vehicle Inspection
15. Workshops
16. Warehouses
17. FCCU
18. Light ends
19. Gastanks
20. Hydro Treatment
21. FEED prep
22. Black oil man
23. TC1+2
24. CD2
25. CD3
26. Asiento Flare
27. Utilities
28. Aqualectra Plant
29. Knowledge Centre
30. New Natural Area
31. New Recreational Area
32. Curoil Filling Station

- Nature
- Social Amenities
- Neighbourhoods
- Light Industries / Commercial Area's
- Refinery Installations
- Refinery Area



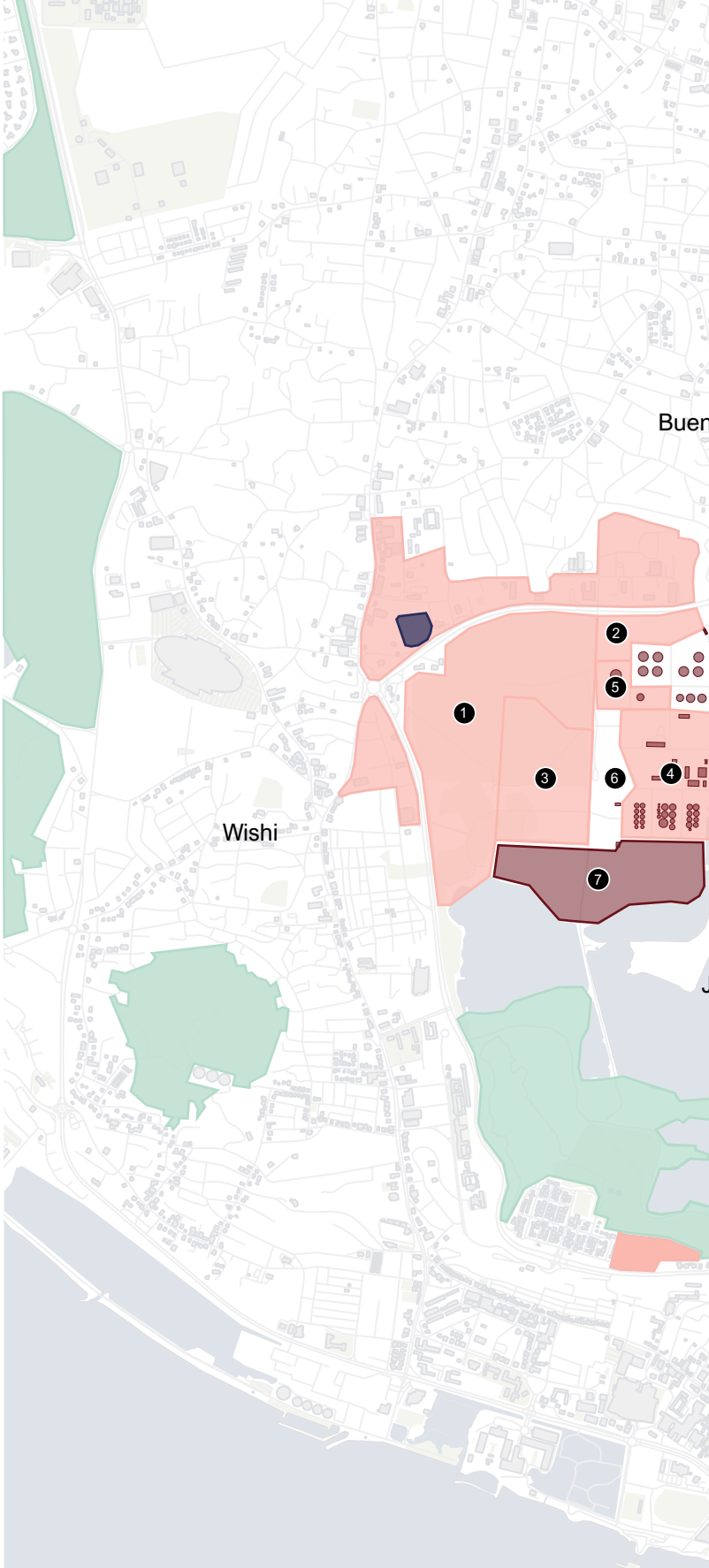
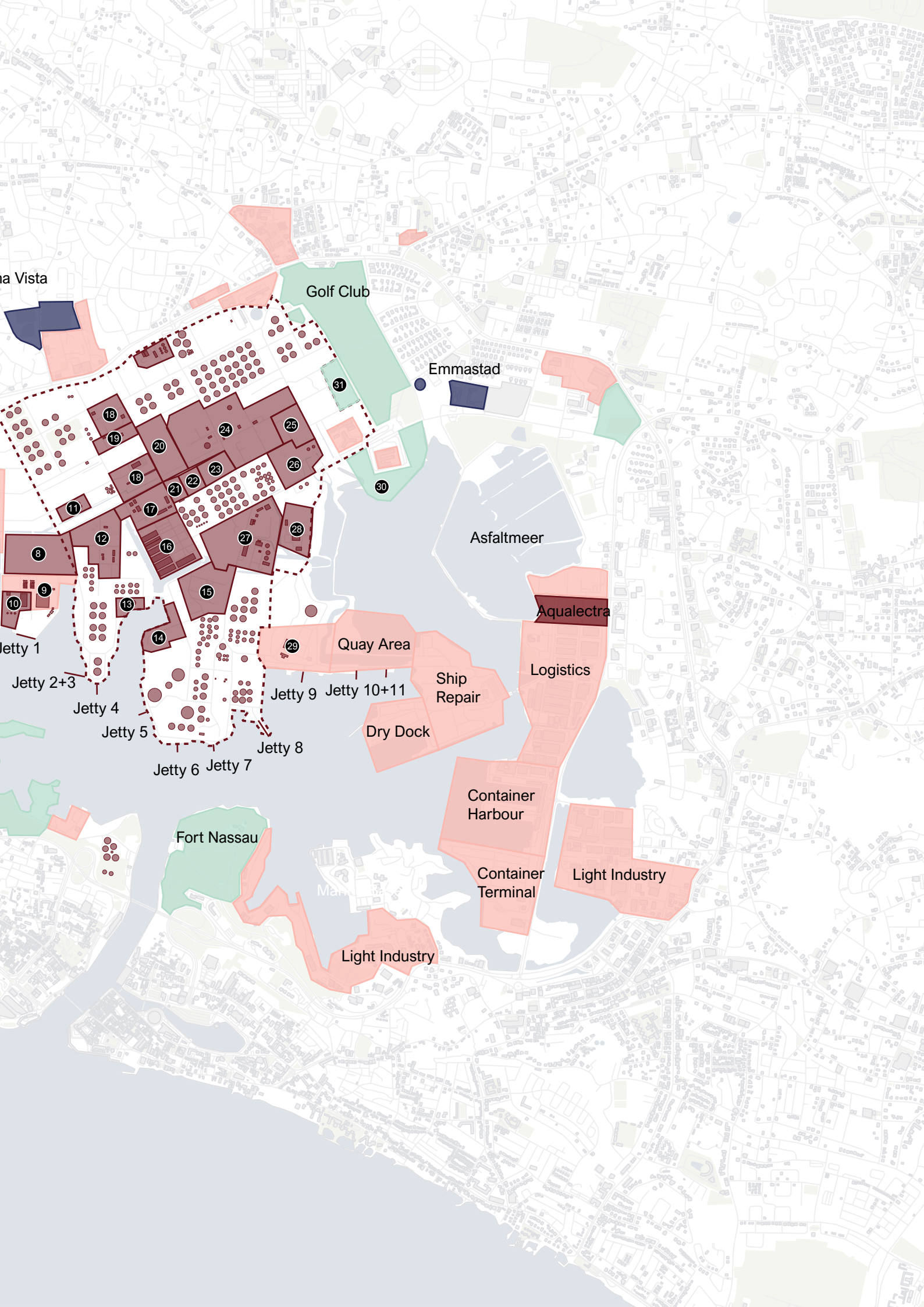


Figure 11: Land use map Schottegat, source: Author


Golf Club
Emmastad
Asfaltmeer
Aqualectra
Quay Area
Logistics
Ship
Repair
Dry Dock
Container
Harbour
Container
Terminal
Light Industry
Light Industry
Fort Nassau
Jetty 1
Jetty 2+3
Jetty 4
Jetty 5
Jetty 6
Jetty 7
Jetty 8
Jetty 9
Jetty 10+11
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3.1 Contexts

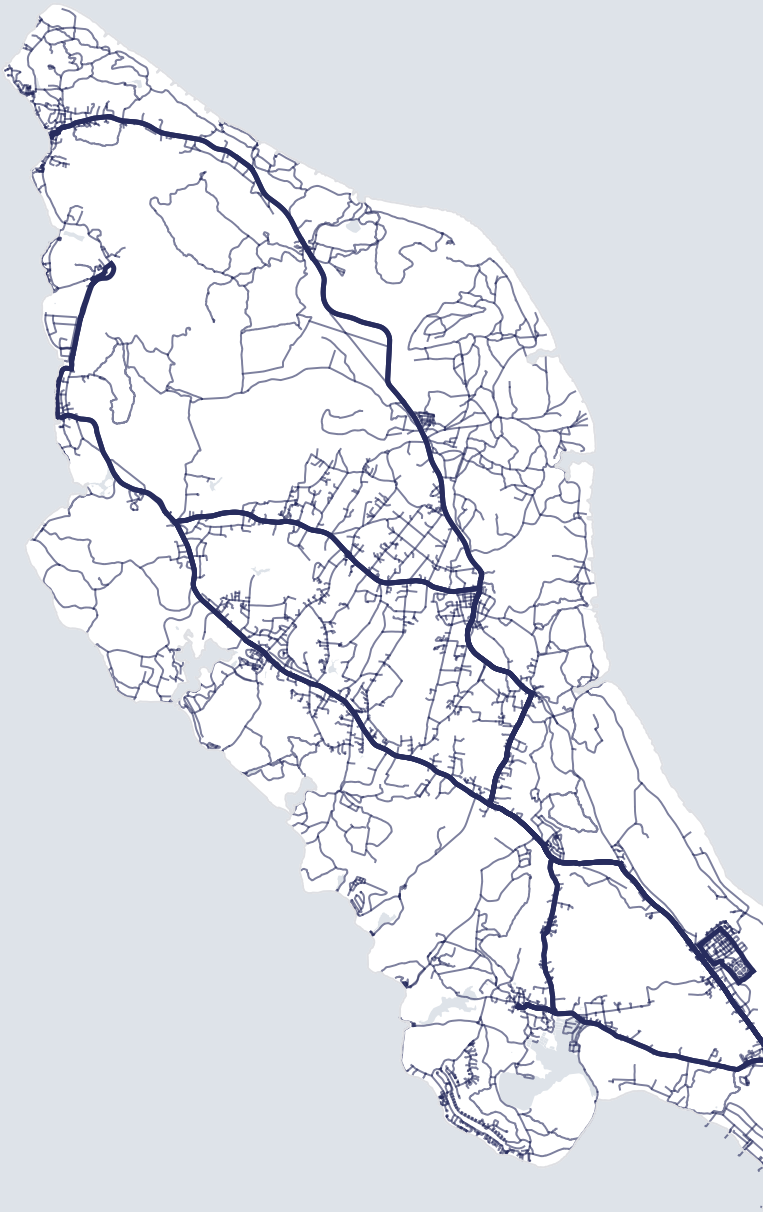
Infrastructure

The infrastructure connecting the refinery area to the surrounding areas and the rest of the island is mainly based on a road network. No infrastructure for trains or waterways exists.

The road network is developed from old country roads and currently the main road is a ring road around the Schottegat with a few main radial roads connecting the refinery area to this ring, On the refinery area is an extensive sub-road network.

Travel behaviour on Curaçao is largely dependent on cars. Almost 80% of all trips are made by car. Main reasons for this are relatively low-density housing, poor quality of public (autobus) transport and the distribution of employment, schools, and amenities. The spatial distribution of housing cause a strong east-west pattern of travel to and from the residential areas to the city centre. Traffic congestion is caused by bottlenecks in the existing infrastructure, particularly on Schottegatweg Noord and the Juliana Bridge.

Several mitigations are promoted to reducing the need for expensive road network expansions of the main ring road (Toelichting EOP, 1995). These mitigation options include promoting carpooling, ensuring that schools are of such high quality that parents can send their children to school in their own neighbourhoods, concentrating shops and employment in district centres and neighbourhood centres, densifying the urban area and significantly improving public transport (Toelichting EOP, 1995).



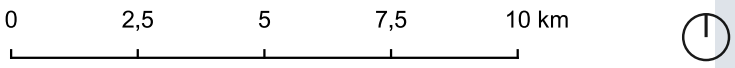
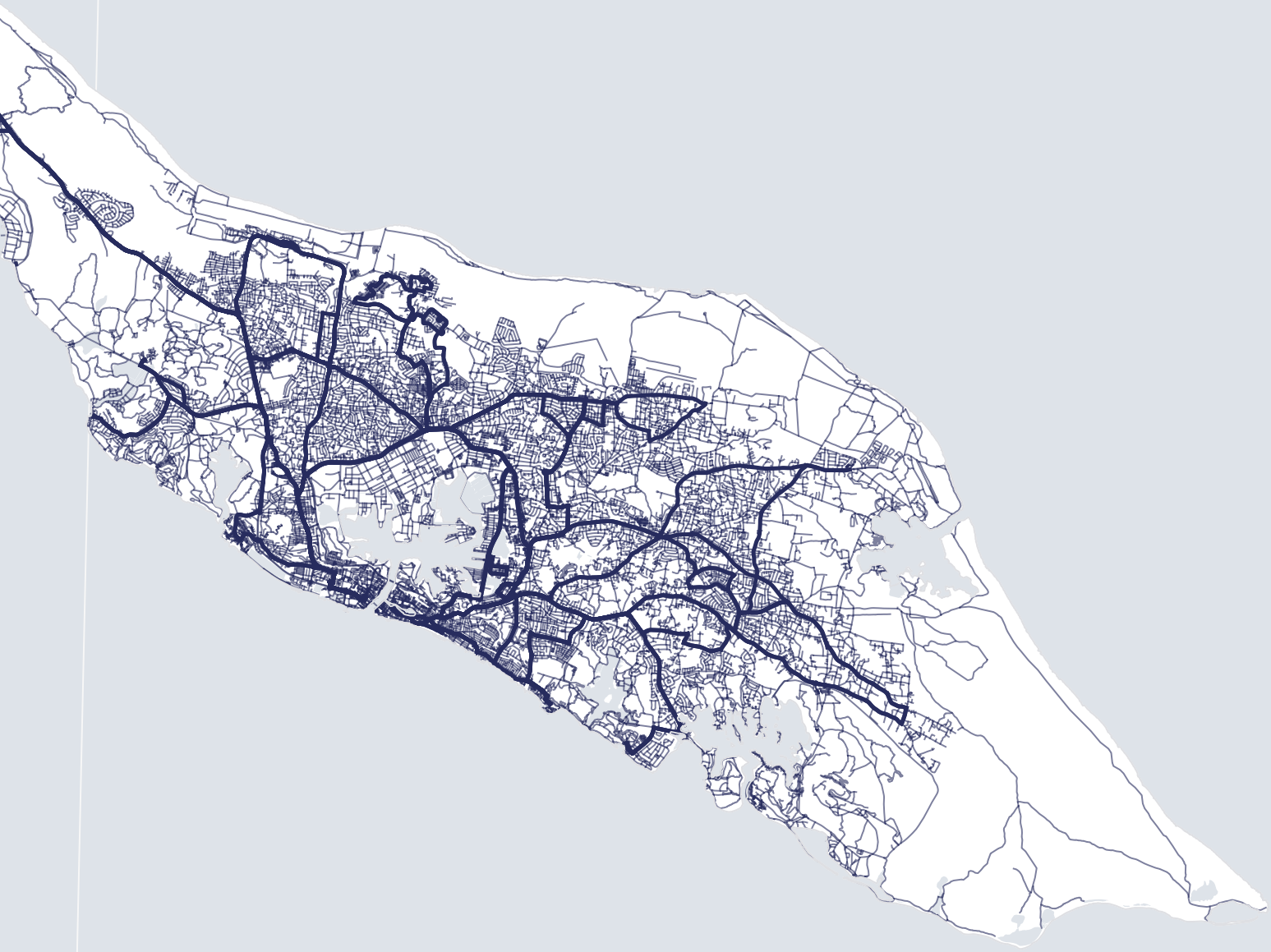


Figure 12: Infrastructure map, source: Author

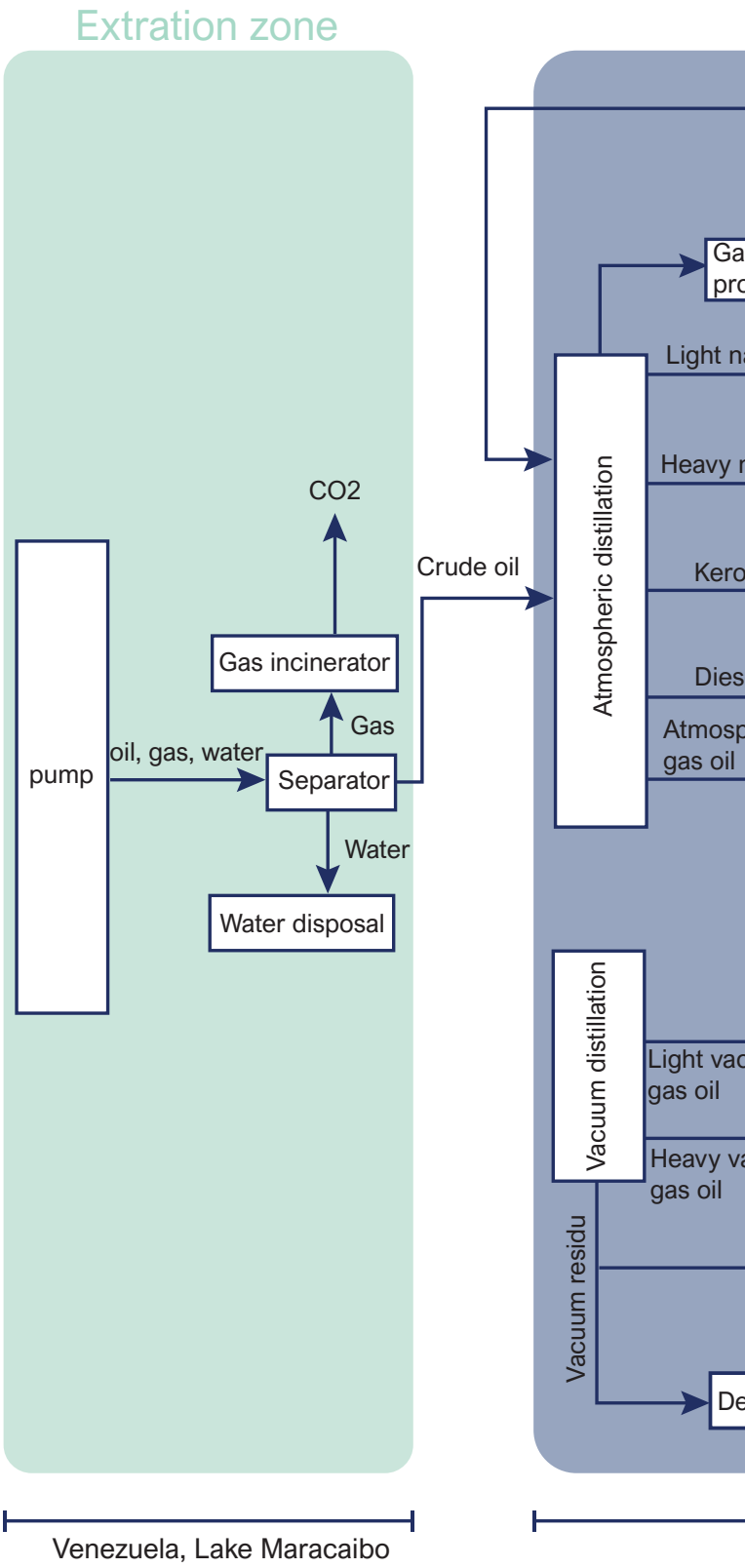


3.1 Context
Pollution analysis

Almost all pollution with hazardous materials on the island is originating from the refinery activities. To understand the pollution from the refinery, first the different activities on the refinery needs to be understood.

The refinery includes the crude oil processing facilities, a power station, crude oil and white spirit (the refined products) storage and the infrastructure in between. The main activity on the Schottegat site is the oil refinery. The figure on the right shows the activities in the crude oil refinery process. The process starts with the storage of crude oil that was (mainly) imported from Venezuela. Due to the large size tankers, the crude oil arrives at the deep-water harbour in Bullenbaai. The crude oil is then refined into white spirit products like; diesel, petroleum and kerosene, through separation and distillation processes, as described in the figure on the right. After completion of these processes, the products are stored in the designated storage tanks on the Schottegat site, until required for shipping to consumers like the USA (Interview A, 2025). Typically, the products are transported by much smaller product carriers that can moor to the quayside in the shallow water of Schottegat

During the production process, the greatest risk for contamination or spilling petroleum products occurs during the transportation between the different process facilities on the refinery. For the Isla Refinery site this means that most pollution is expected under/around the pipelines tracks and docking points for shipping. Moreover, due to the construction and reparation of multiple structures in the past, there is a high likelihood of asbestos contamination on and in the soil surfaces (Interview A, 2025).



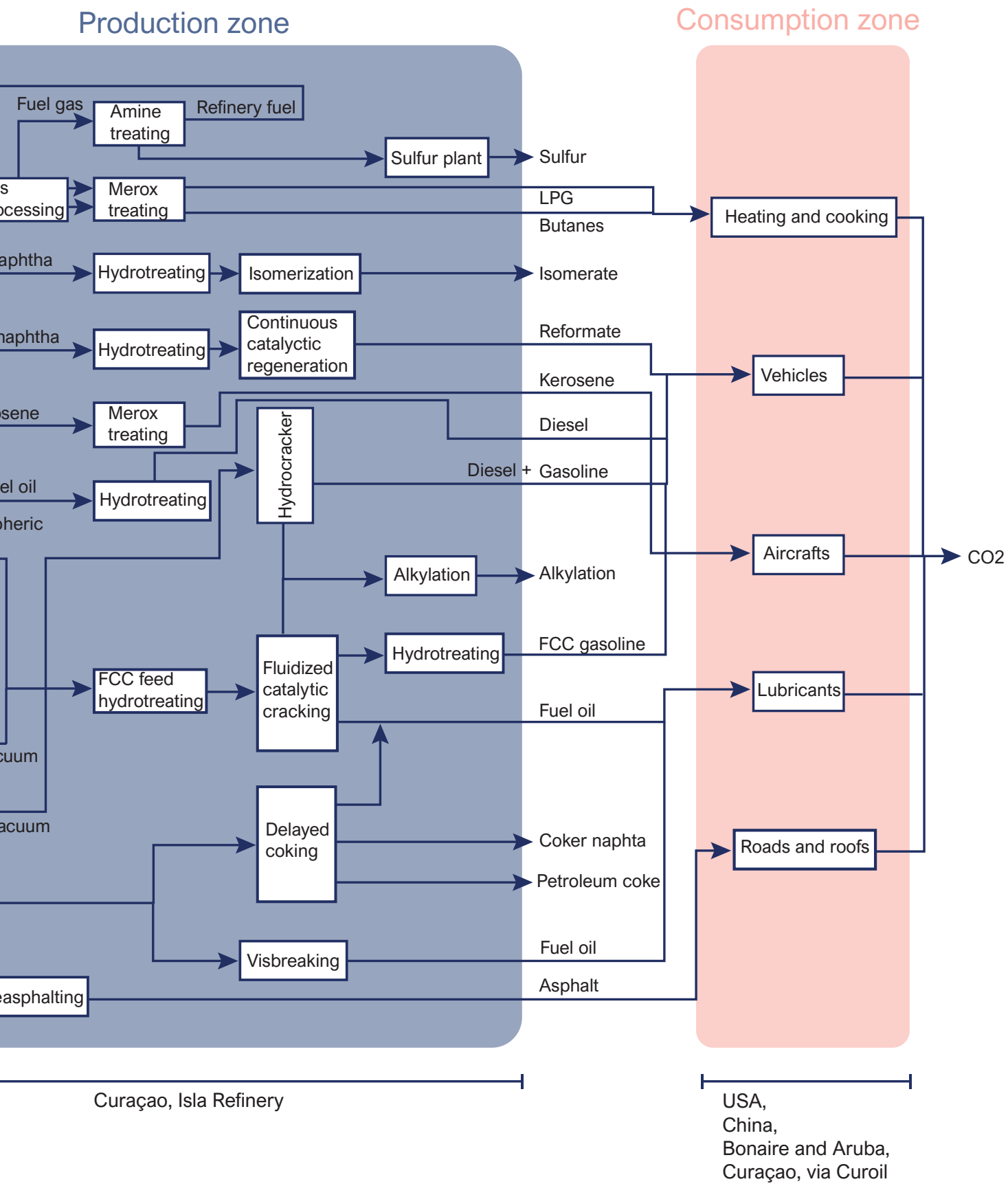


Figure 13: Refinery process diagram, source: Author

3.1 Context
Pollution analysis

The agreement in 1985 between Shell and the Netherlands Antilles and Curaçao stated that the buyers had to abstain irrevocably and unconditionally from existing and future claims for pollution or other environmental effects exerted by Shell's companies in the Netherlands Antilles. The most known pollution comprises the asphalt lake. During World War II, the Isla refinery produced a large quantity of gasoline and aviation fuel for the Allied forces. The market for these light oil products outperformed the market for heavy oil products. Thus, the remainder of the heavy Venezuelan oil (an estimated 1.5 million tonnes of asphalt) was dumped in the Buscabaai next to the refinery. Still, the lake is filled with about one million tonnes of asphalt (Jong, 2015).

According to Shell, during the period 1983-1985 a contractor has scooped 0.5 million tonnes of asphalt for use in the refinery on a financially sound basis. The contract with the contractor and the asphalt lake were included in the sale by Shell of its Curaçao assets in 1985. The estimate in 1985 was that in the next ten years everything would be cleaned up. The asphalt-sand mix at the bottom of the lake would eventually be burned in an incinerator. After Shell left, the clean-up/processing went on for a few years, but was then stopped. The discussions during the 1985 deal were never about cleaning up pollution, it was about exploitation of the lake. Later on, it turned out that the lake was too polluted, and that it was not economically justified to process it (Jong, 2015).

In 1992, the Dutch Ministry of Transport, Public Works and Water Management advised the Curaçao Ports Authority about the pollution of the Schottegat harbour. The ministry stated that the refinery site was saturated with crude oil, petroleum products, impurities in the crude oil, and substances used in the production process. The groundwater was thought to be severely polluted. Over large areas of the refinery site, a thick scum of oil was assumed to be present on the groundwater. Cruising along the quays of the refinery, a continuous flow of oil from the ground could be seen seeping through the quay structures, especially at the west-side of the Schottegat harbour. The refinery site also comprises ditches and canals, through which oil was expected to seep out (ter Meer et al., 2007).

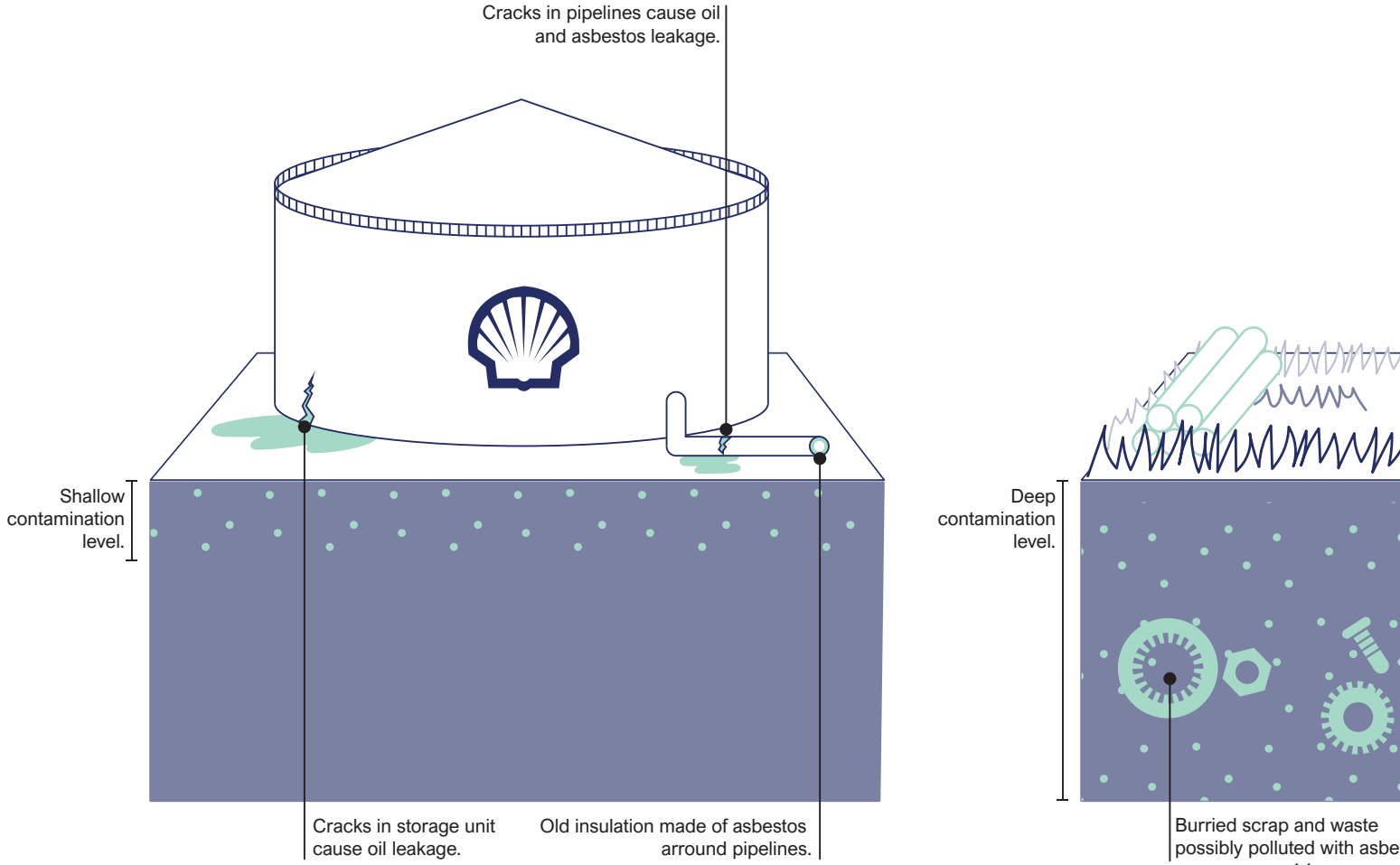


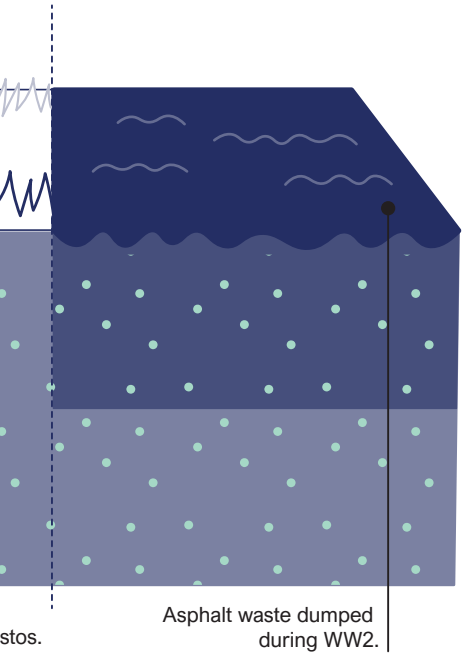
Figure 16: Pollution caused by leakage, source: Author.

In 1983, the Dutch governmental agency DCMR conducted an environmental study with regard to the refinery. At the time of ownership change in 1985, also an environmental audit has taken place. According to the Dutch Ministry of Transport, Public Works and Water Management, it could be deduced from these reports that there have been many direct discharges in the Schottegat harbour. These were caused by a large number of oil spills, leaking tanks, and an outdated refinery lacking facilities considered basic in the Netherlands. The discharge of cooling water (about 3,500 m3 per hour) at the west of the Schottegat harbour caused much pollution and stench. The sediment in the western part of the harbour was found to be severely polluted with oil. According to Dutch standards, the sediment sludge should be classified as chemical waste. Near the Valentijn bay, Shell has contaminated around four hectares of ground due to the dumping of barrels filled with sulphur, catalyst and other toxic substances. Similar waste was also dumped into sea at the south side as well as north side of Curaçao (Fact-Finding Missie Isla Raffinaderij Curaçao, 2004).

it was not possible to receive further detailed information about the status of pollution.

Figure 14: The Asphalt lake near Buskabaai, Source: Milieu Defensie (2021).

Figure 15: In 2005 pollution was buried on the Isla Refinery site, Source: Ton de Jong



17: Heavily polluted areas, source: Author.

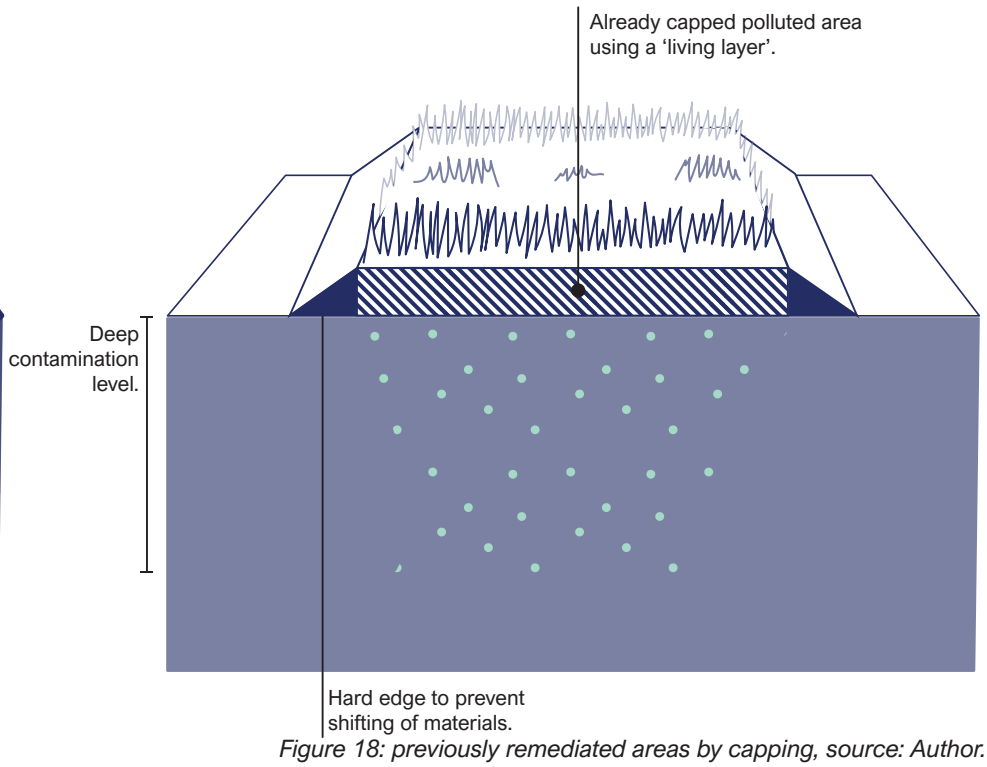


Figure 18: previously remediated areas by capping, source: Author.

3.1 Context
Pollution analysis

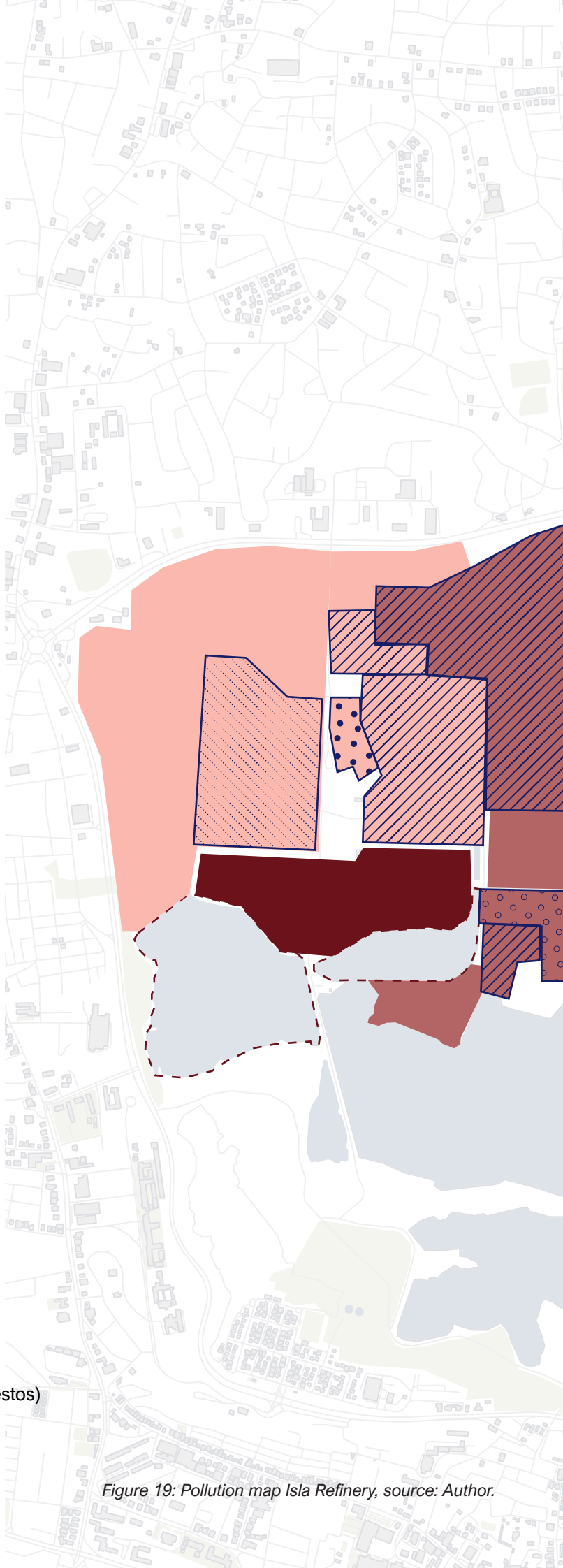
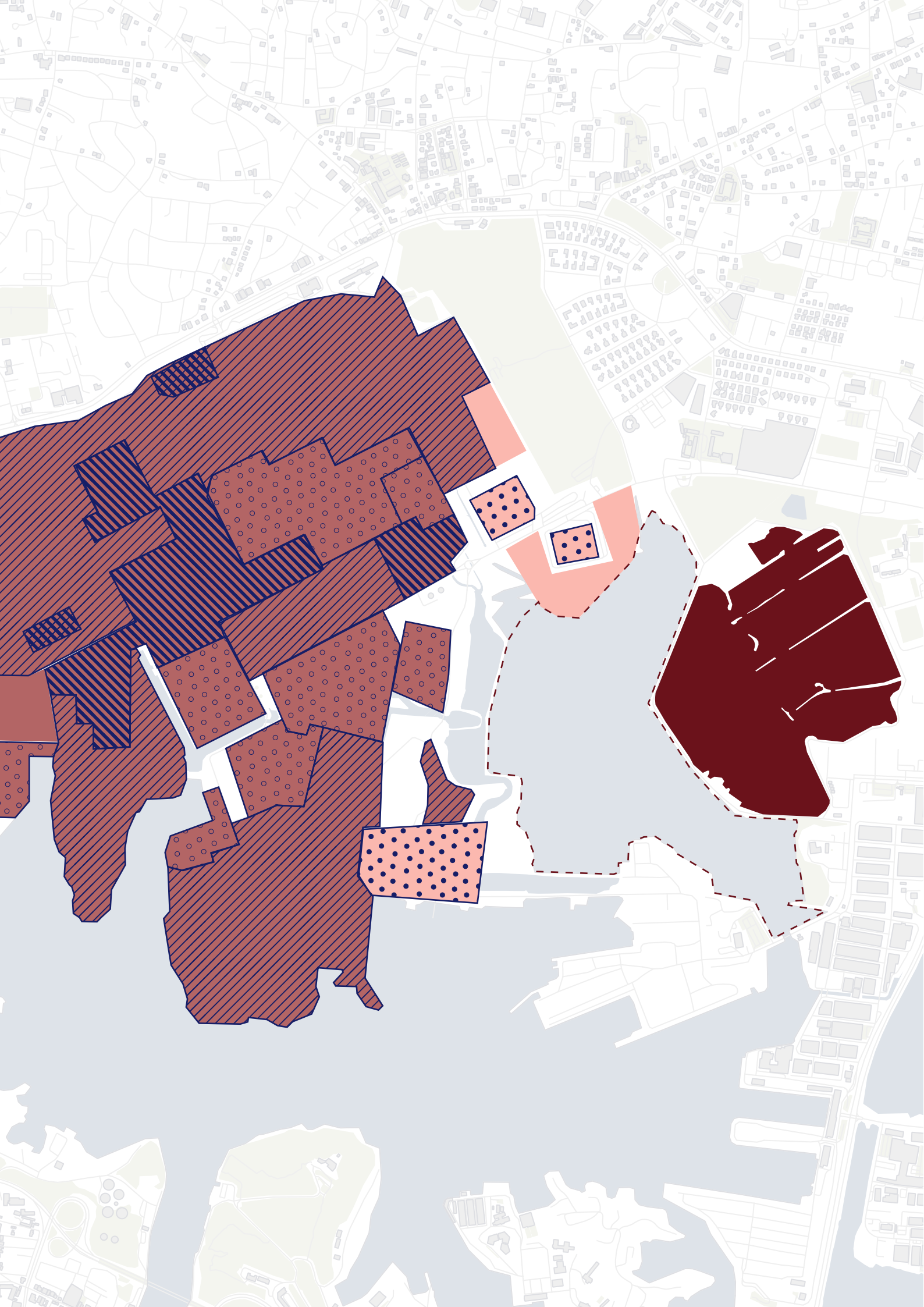


Figure 19: Pollution map Isla Refinery, source: Author.



3.2 Future trends
Climate change

In this paragraph the future trends are discussed that can be relevant for the refinery location. The following trends are expected to be relevant: Climate change, Brain drain, Import dependency and Over-tourism. These trends have been identified using the interviews conducted during the site-visit.

Global warming
Because of global warming, periods of extreme heat will become increasingly more frequent. This causes threats on people's health, the economy and Curaçao's nature.
Higher temperatures increase the demand for energy and drinking water, this could lead to higher prices and put pressure on inhabitants who already struggle financially. Moreover, extreme temperature could pose a threat to vulnerable people, making heat stress occur more frequently. This could also result in an increase of cardiovascular diseases, respiratory diseases, mental health problems and infectious diseases. The tourism sector could also be badly affected by increasing temperatures, influencing tourist behaviour and choice to go to cooler alternative destinations.
Global warming also poses a threat to nature, by increasing the risk of natural fires (in Koraal Tabak for example), increase algae growth, loss of biodiversity and pollution of natural water reservoirs. Increasing temperatures will increase agricultural crop failures (Kelder & Anker, 2024).

Extreme weather events
Global warming will cause more extreme tropical storms, hurricanes and other extreme weather events. Currently, Curaçao has no hurricane threat as the island is outside the Hurricane Belt. Global warming is providing more heat to the Gulf of Mexico, making hurricanes larger and more unpredictable, exposing a future higher risk for Curaçao. To date, tropical storms generate heavy but short rainfall, causing flash floods that lead to erosion and washout of (fertile) soils into the sea. (Kelder & Anker, 2024). Erosion can already lead to dangerous situations, for example by causing mud streams, landslides, and falling trees. The mud streams that flow into the sea impose a high risk for the health of coral reefs.
The tropical storms also generate wind gusts and higher waves, together with coastal flooding this can lead to the destruction of property and public infrastructure (Kelder & Anker, 2024).

Drought
Due to climate change, periods of drought will also become more frequent Long lasting droughts effect nature, economy and people. Droughts typically have a large impact on agriculture, as it leads to crop failures and the inability to grow certain crops. It can also cause a shortage of fresh water, which in turn makes adaptive strategies more difficult to implement, creates the risk of leakage in septic tanks polluting the soil and it could increase the costs for fresh water. Furthermore, drought poses a threat to nature, by increasing the risk of natural fires (in Koraal Tabak for example) (Kelder & Anker, 2024).

Warming and acidification of the sea
Global warming has effects on the health of the seas and oceans worldwide. The seawater temperature increases and the seawater becomes more acid, due to the increase of CO2 concentration. This has impact on sea life (reduce fish catch), threatening biodiversity and bleaching coral reefs (Kelder & Anker, 2024).The health of the coral reefs surrounding Curaçao have not only impact on biodiversity but also directly on the economy, the visits to these reefs are important for tourism.
Increasing the seawater temperatures also provides sargassum (a seaweed species) and algae the opportunity to grow exponentially, causing over-abundance of these species. Over-abundance is a threat for the biodiversity in the seas, but also in Schottegat, and especially for the coastal coral reefs. The tiny sea creatures that live in sargassum can cause skin rashes and blisters, which is a direct threat for the tourists. To date, already Sint Jorisbaai, Ascencion and the north coast of Bocca are struggling with this problem. Furthermore, high sea temperatures can destroy mangroves forests, that are protect the east coast of Curaçao against storms and floods (Kelder & Anker, 2024).

Sea-level rise
Global warming rises the sea level worldwide. Beaches, beach resorts and cultural heritage sites along the coastline can become flooded, negatively affecting the tourism industry. With a sea level rise of one

meter, approximately 30% of all beach resorts on Curaçao become (partially) flooded. Heritage sites that are especially vulnerable to the rise of the sea-level are Otrobanda and Punda, due to their proximity to the coast. Sea level rise can pose a threat to species that are dependent on sandy beaches for their survival, like the famous turtles (Kelder & Anker, 2024).
Seawater rise will also increase the salt ingress as fresh groundwater is displaced by seawater. An example already happening is the salinization of groundwater near Ronde Klip, Sint Joris and Pos Salu, making it more difficult to meet fresh water demands and near impossible to grow crops in these areas (Kelder & Anker, 2024).

Changing Passat wind
Curaçaos climate is heavily influenced by the almost constant and quite strong eastern Passat wind. Climate change can influence this wind by changing its direction, wind strength and amount of wind. Especially, a decrease in wind would make the perceived temperature higher, having a direct impact on the well-being of people and negatively impacting the tourism sector (Kelder & Anker, 2024).

3.2 Future trends
Brain drain

Attracting and retaining young talent is a key component of Curaçao's future development. However, in reality, many talented individuals leave the island (Economische Ontwikkeling 2023 Een Standhoudende Economie, 2024), as they see no future for themselves on the island. For this reason, the so-called "brain drain" is receiving increasing attention. An important "pull" factor for young people is a study abroad. The Netherlands and the US are popular destinations for these students (Braingain: Een Integrale Aanpak, 2025).

Reasons for studying abroad and staying there include (Braingain: Een Integrale Aanpak, 2025):
- Well-regarded universities and faculties abroad
- Opportunities for self-development outside the environment in which they grew up
- Higher salaries abroad
- Modern employer practices abroad, which promote inclusivity and a certain degree of autonomy

Furthermore, certain factors on the home island often hinder the retention of students and young professionals in Curaçao.

This includes the following factors (Braingain: Een Integrale Aanpak, 2025):
- The main reason is the often high student debt accumulated abroad, which is difficult to repay here due to a difference in salaries
- The perception that education in Curaçao is of inferior quality than abroad
- The lack of professional prospects due to an outdated job market
- Lack of suitable and affordable housing
- Lack of support upon return
- Exclusion from the job market due to lack of experience or overqualification

Although these reasons often outweigh the main reason for returning to Curaçao, namely the connection with the island and family, there are certainly opportunities to turn this brain drain into a brain gain. The Strategic Education Alliance (SEA) (2025) proposes an integrated approach to solve this problem in the future.

Starting with reducing the pressure to study in the Netherlands. While self-development abroad remains an important experience for young people, this should not weaken their ties to their home island. Therefore, it is necessary to involve young people early on in social engagement programs to foster a stronger sense of connection and responsibility with the community and the island. Furthermore, there is a need for improved guidance about opportunities on the island itself. Young people often receive signals that the best option for them is to study abroad, particularly in the Netherlands. This creates an imbalance, leading to a negative perception of studying on one's own island. Providing information about both the quality of higher education in Curaçao (which is often accredited according to the same strict requirements as programs in the Netherlands) and the potential obstacles associated with studying abroad, is needed. Furthermore, the current financing of studying abroad intensifies the brain drain. Students can currently apply for student financing to pursue a program abroad, even if the same program is offered locally. Furthermore, studying in the Netherlands should be more focused on the labour shortages in Curaçao. By subsidizing specific programs, students are encouraged to study in sectors such as healthcare, education, and ICT, where these shortages are acute (Braingain: Een Integrale Aanpak, 2025).
It will also be helpful to offer joint programs with educational institutions abroad. This makes studying in Curaçao more attractive and reduces the pressure to study abroad. This can take the form of jointly developing minors, exchange programs, and collaborations in the field of associate degrees, bachelor's degrees, and master's degrees (Braingain: Een Integrale Aanpak, 2025).

Secondly, there is a need for better support for students who drop out in the Netherlands. The prospect of completing the discontinued program on one's own island can be offered. This can be done by granting exemptions for subjects completed in the Netherlands. This is a particularly good option for programs with similar content (Braingain: Een Integrale Aanpak, 2025).

Thirdly, the island's educational infrastructure needs to be improved. This involves improving the image of education on Curaçao, diversifying the curriculum, and investing in the facilities of educational institutions. The image of education on Curaçao could be improved by strengthening ties with foreign educational institutions and businesses. This could be achieved, for example, through dedicated partnerships, allowing students to pursue part of their studies abroad. As mentioned previously, diversification and improved quality should primarily focus on educational programs that are directly related to the labour market challenges on Curaçao. Consider, for example, programs in tourism, maritime studies, sustainability, healthcare, and entrepreneurship (Braingain: Een Integrale Aanpak, 2025).

Finally, the return of graduates and young professionals must be encouraged. This includes maintaining their ties to the island, better matching job openings with job seekers, offering traineeships that provide a few years of exposure to working in Curaçao, offering remote work, fostering work-related connections with professionals in Curaçao, and, above all, providing good employment practices. This last point requires businesses, government, and civil society organizations to critically reflect on whether the labour market is sufficiently inviting young talent, knowing that they have many options to work on their terms in the tight global labour market (Braingain: Een Integrale Aanpak, 2025).

3.2 Future trends

Import dependency

Historically, Curaçao has never had a thriving agricultural sector, due to its dry climate. Nowadays, the agricultural sector in Curaçao still contributes only a small portion to its total economy. This can be seen in Table 4, where this sector's contribution to the GDP is shown. Agriculture, forestry, fishing and mining account for only 17,8 mln ANG. This amounts to less than one percent (0,33%) of the GDP in 2024. Moreover, the share of local production in the total consumption of agricultural products on the local market is 11% (Toelichting EOP, 1995).

Gross Domestic product (GDP) by industry, Curaçao (mln ANG)															
Isic 4		2011	2012	2013	2014	2015	2016	2017	2018	*2019	*2020	*2021	*2022	*2023	*2024
A+B	Agriculture, forestry and fishing; Mining	16,2	10,2	12,4	11,4	11,3	9,2	9,0	11,7	12,6	12,2	12,7	14,7	15,8	17,8
C	Manufacturing	393,6	406,0	438,4	443,9	470,7	501,8	476,9	338,1	275,5	125,4	128,9	138,1	159,4	186,1
D + E	Electricity, gas, steam and air conditioning supply; watersupply,	73,5	116,1	147,2	241,8	249,8	231,9	155,0	248,6	261,2	246,3	254,0	268,7	281,1	307,8
F	Construction	248,3	221,4	247,4	210,2	183,1	195,1	204,8	199,2	182,3	172,0	177,9	209,2	246,0	282,9
G	Wholesale and retail trade; repair of motorvehicles and motorcy	485,3	524,9	488,7	470,8	473,6	472,0	477,2	420,1	368,9	292,7	315,1	341,5	357,2	379,4
H	Transportation and storage	241,1	252,8	263,3	345,4	319,7	280,9	269,0	238,6	225,2	173,8	182,7	233,2	269,7	329,8
I	Accomodation and food service activities	190,0	168,0	157,4	156,4	174,9	163,1	188,1	183,1	195,5	158,1	249,0	368,8	424,4	510,2
J	Information and communication	253,6	238,4	239,5	227,3	240,2	207,6	154,6	226,6	213,9	165,0	192,1	201,8	213,4	212,2
K	Financial and insurance activities	805,5	922,3	856,6	813,6	797,1	803,5	855,4	973,2	1012,1	968,8	1025,8	1131,4	1206,0	1257,1
L	Real estate activities	651,3	660,4	576,4	614,0	579,0	588,6	609,2	620,0	641,6	448,8	515,5	520,7	564,5	593,2
M	Professional, scientific and technical activities;	151,6	138,7	138,7	148,4	146,1	141,3	138,2	148,8	153,9	109,0	103,6	105,6	119,1	127,8
N	Administrative and support service activites	126,2	125,9	130,5	135,2	145,6	141,3	147,6	139,5	144,3	102,3	102,1	141,0	150,3	162,1
O	Public administraion and defence; compulsory social security	355,3	376,9	366,9	350,8	358,8	382,8	391,6	394,2	394,7	397,0	370,9	356,5	359,4	383,9
P	Education	147,0	122,8	190,0	143,6	143,6	148,1	152,4	122,6	121,6	122,0	119,0	119,0	113,6	116,7
Q	Human health and social work	261,9	266,6	266,4	258,0	265,7	249,7	265,1	275,2	251,3	238,1	244,6	215,7	213,3	210,0
R	Arts, entertainment and recreation;	60,3	44,4	48,8	49,8	45,7	33,8	39,3	40,6	42,9	35,1	32,9	38,7	40,4	42,2
S+T	Other service activities; Activities of households as employers, p	228,4	224,0	235,4	233,1	232,7	213,6	236,6	226,6	237,4	195,7	203,1	265,3	274,6	283,9
	Gross value added	4689,1	4819,8	4803,6	4853,5	4837,4	4764,3	4770,2	4806,9	4734,8	3962,2	4229,9	4669,8	5008,2	5403,1
	plus Taxes less subsidies on products	555,8	573,2	626,4	622,8	637,9	649,9	659,6	646,1	681,9	574,2	674,0	834,8	865,5	971,4
	Domestic Product Gross, market prices	5244,9	5393,0	5430,1	5476,3	5475,2	5414,2	5429,8	5453,0	5416,8	4536,4	4903,9	5504,6	5873,7	6374,5
	Nominal GDP growth	3,0	2,8	0,7	0,9	0,0	-1,1	0,3	0,4	-0,7	-16,3	8,1	12,2	6,7	8,5
	Real GDP growth	0,6	-0,3	-0,6	-0,6	0,5	-1,1	-1,3	-2,1	-3,2	-18,4	4,2	6,9	4,2	5,0

* Estimated figures

Updated per June 2025

Table 4: GDP by industry in Curacao, source: CBS.

This lack of local production can also be seen in the difference between imports and exports of Curaçao. Table 5 shows a major difference between the total exported and imported goods, with a ratio of 1 to 12 in 2021. Meaning Curaçao is highly dependent on imported goods for sustaining its population and tourism sector.

Total Imports and Exports (Excl. Oil products)											
	2011	2012	2013	2014	2015	2016	2017 [3]	2018 [3]	2019 [3]	2020 [3]	2021 [3]
	Mln ANG										
Imports (cif)	2303	2512	2334	2449	2123	2442	2284	2469	2151	1795	1908
of which:											
Capital goods [1]	409	571	500	647	370	336	381	405	314	291	258
Consumer goods [2]	510	513	499	512	485	451	471	500	461	414	425
Exports (fob)	286	341	577	271	471	235	188	206	172	147	156
of which:											
Capital goods [1]	39	67	244	101	157	49	42	56	38	27	28
Consumer goods [2]	67	49	44	45	71	33	37	42	40	23	27
1) BEC: Capital goods (except transport equipment)											
2) BEC: Consumer goods nes											
3) Preliminary Results											
Source: Central Bureau of Statistics Curaçao											

Table 5: Total imports and exports Curacao, source: CBS.

The Covid-19 pandemic and the following global economic crisis in 2020 and 2021 have shown Curaçao's dependency on the USA and the Netherlands and how vulnerable and strongly related to economic growth its labour market is (Economische Ontwikkeling 2021 Een Economie Op Gang, 2022). This makes the island susceptible to international price fluctuations, which was confirmed by the sharp increase in energy and food prices, which resulted in record high inflation figures for the island in 2022 (Economische Ontwikkeling 2022: Een Rijzende Economie, 2023).
The hight import levels are a concern for the local economy, that can (only) be mitigated when Curaçao intensifies its own production industries, to become more self-sufficient. This can be done by promoting communication and knowledge-sharing between farmers and setting up education programs to implement new technologies that can improve crop harvests.

3.2 Future trends

Over tourism

Due to the arrival of the oil industry in Curaçao and the economic growth and employment it brought, other sectors in Curaçao remained underdeveloped for a long time. This includes the tourism sector, which has only recently experienced a growth spurt. In contrast, tourism in the rest of the Caribbean had been much more developed since the 1950s. However, since the 1980s, there has been a revival in tourism, partly because the government has clearly prioritized the development of this sector. In 1987, the Island Government announced its intention to develop tourism into one of the main pillars of the economy (Toelichting EOP, 1995).

They have succeeded in this. When looking at the contribution of the tourism sector to the economic growth of Curaçao, it can be seen that tourism has made an enormous contribution and experienced and exponential growth, especially in recent years (since the Covid-19 pandemic) (Economische Ontwikkeling 2023 Een Standhoudende Economie, 2024).

This sudden growth poses a threat to the local community and the island's unique identity, if current developments are not guided by clear policy. The current development approach jeopardizes this and local communities are under pressure due to the rise of vacation rentals and commercial developments for tourism.

Furthermore, new developments do not align well with Curaçao's visual identity, which is characterized by uniquely coloured houses, primarily consisting of low-rise buildings. Many new construction projects in the tourism sector consist of white high-rise towers with large glass facades, which therefore do not align well with the island's historical character.

Moreover, unregulated development also impacts the quality of life for local communities. For example, rising house prices are excluding local families from the housing market.
The commercialization and privatization of beaches is a growing problem. These public spaces, highly valued by the local population, are now made inaccessible. As a result, locals are no longer welcome in places they have been visiting for recreation for generations. There is therefore a need for more balance between tourism, economic growth and the needs of the local population, by actively involving locals in tourism projects (Hendriksen, 2024).

04 | Design and Strategy

Remediation
- Phyto-technology mechanisms
- Phyto-typologies and plant selection
- Phyto-remediation implementation strategy

Design and strategy
- Possible redevelopment in the Isla area
- Design site 2075 in 3 phases
- Effects on the island of Curaçao

In the design and strategy phase of the redevelopment, the following sub-questions will be answered and used for the redevelopment of the polluted Isla Refinery location:

- How can the pollution remediation in the redevelopment of the polluted Isla Refinery become sustainable?
- What are possible new redevelopments on the Isla Refinery area, both for different locations in the area as well as for different timelines
- How fair are the redevelopments to ensure their contribution to the value of People, Planet and Prosperity?
- What is the final result after the completion of the sustainable remediation for the Isla Refinery location?

4.1 Remediation

In this paragraph the different remediation techniques are discussed that can be relevant for the pollution on and in the soil and water at the refinery location.

Brownfield redevelopment projects typically consist of three phases; site assessment, site remediation and site redevelopment. During the remediation phase conventional methods are often used to clean-up contamination, including incineration, sealing/capping and disposal of soil contamination . However, these methods fail to destroy hazardous particles in the environment and instead either displace the problem, create a new one or stabilize it. By incinerating contaminated particles, new harmful gasses and carbon dioxide are created and blown into the atmosphere, causing air pollution and increasing global warming. Sealing or capping methods will stabilize the contamination by preventing it from leaking further into surrounding soil and water, yet the hazardous particles still stay intact. Disposal of contaminated soil is essentially removing the contamination from a brownfield site and storing it in another site, resulting in the creation of another brownfield site and failing to reduce the amount of contamination in the environment (Singer & Groeneveld, 1999).

This is the reason why the following chapter will start with an examination of sustainable remediation methods that are nature-based. These methods use plants and other micro-organisms to extract or stabilize the contaminant particles, making sure they are removed from the environment entirely. This is an environmentally friendly remediation method, that is more energy efficient, but also more cost efficient than conventional methods (Kafle et al., 2022; Singer & Groeneveld, 1999). For example, Singer & Groeneveld (1999) estimated that for cleaning up one acre of lead-contaminated soil to a depth of 50 centimetres the sustainable methods cost around $60,000 to $100,000 less than conventional methods, however the sustainable method takes about 10 years more to remediate the soil. The success of nature-based remediation methods is highly dependent on the sites characteristics to be suitable.

4.1 Remediation
Phyto-technology mechanisms

This paragraph explains the different currently available phyto-techniques. A selection of effective phyto-techniques will be selected that could potentially be used for the remediation of the polluted Refinery site.

Plant function, pollutant location and pollutant type
The nature-based phyto-techniques use sugars, oxygen and other root exudates that plants release into the soil, to break down contaminants and attract micro-organisms that support this process. The nutrient transfer from the soil to the plant will also capture contaminant particles that are absorbed by the plant. Especially pollutants that have a similar chemical structure as the nutrients that feed the plant can be absorbed easily by this plant. The plant has furthermore the ability to extract water from soil and create a hydraulic pull towards the plant, making the transport of some pollutants possible towards the plant roots. This is especially valuable for cleaning soil from pollutants that can dissolve in water, the transport to the plant roots also slows down the migration of pollutants in groundwater (Kennen & Kirkwood, 2015).

Pollutants can either be organic or inorganic. Meaning they either consist on a molecular level as a compound of bonds of carbon, nitrogen and oxygen, or they are an element found on the periodic table. The type of pollutant determines what phyto-technique can be effective to remediate the soil. Since organic pollutants are a compound, a plant is able to break it down into smaller particles, completely removing the hazardous particles from the environment. Inorganic pollutants, like heavy metals cannot be broken down into smaller particles. These pollutants can only be absorbed by the plant, which in turn can be disposed after harvesting the plants. The tables below shows the different pollutants and their typical source.

Pollutant	Typical Sources
Petroleum Hydrocarbons: Oil, Gasoline, Benzene, Toluene, PAHs, gas additive: MTBE: Methyl Tertiary Butyl Ether	Fuel spills, leaky underground or above-ground storage tanks
Chlorinated Solvents: such as TCE: trichloroethylene (most common pollutant of groundwater), Perc	Industry and transportation, dry cleaners
Pesticides: Atrazine, Diazinon, Metolachlor, Temik (to name a few)	Herbicides, insecticides and fungicides from agricultural and landscape applications
Explosives: RDX	Military activities

List of Common Organic Pollutants not Easily Degraded or Volatilized at Field Scale with Phytotechnologies

Pollutant	Typical Sources
Persistent Organic Pollutants: Including DDT, Chlordane, PCBs	Historic use as pesticides or in products such as insulation and caulking
Explosives: TNT	Military activities

Table 6: list of common organic pollutants, Source Kennen & Kirkwood (2015).

Pollutant	Typical Source
Plant Macronutrients: Nitrogen and Phosphorus	Wastewater, landfills, agriculture and landscape practices
Metals: Arsenic, Nickel, Selenium (shorter time frame) Cadmium and Zinc (longer time frame)	Mining, industry, emissions, automobiles and agriculture

List of Common Inorganic Pollutants not easily Extracted or Volatilized with Phytotechnologies

Pollutant	Typical Source
Metals: Boron (B), Cobalt (Co), Copper (Cu), Chromium (Cr), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Lead (Pb), Fluorine (F) Lead (Pb), Mercury (Hg), Aluminum (Al)	Mining, industry, emissions, automobiles, agriculture, and lead paint
Salt: Sodium chloride, Magnesium chloride	Road de-icing, gas fracking and oil drilling, fertilizers, herbicides
Radioactive Isotopes: Cesium, Strontium, Uranium	Military and energy production activities

Table 7: list of common inorganic pollutants, Source: Kennen & Kirkwood (2015).

4.1 Remediation
Phyto-technology mechanisms

The following section will investigate the different phyto-technology mechanisms found in literature. The mechanisms explained are based on the research by Kennen & Kirkwood (2015) , who describe seven main processes how a plant can remove a pollutant. Namely, by phyto extraction, phytovolatilization, phytodegradation, phytometabolism, rhizodegradation, phyto stabilization and phyto hydraulics.

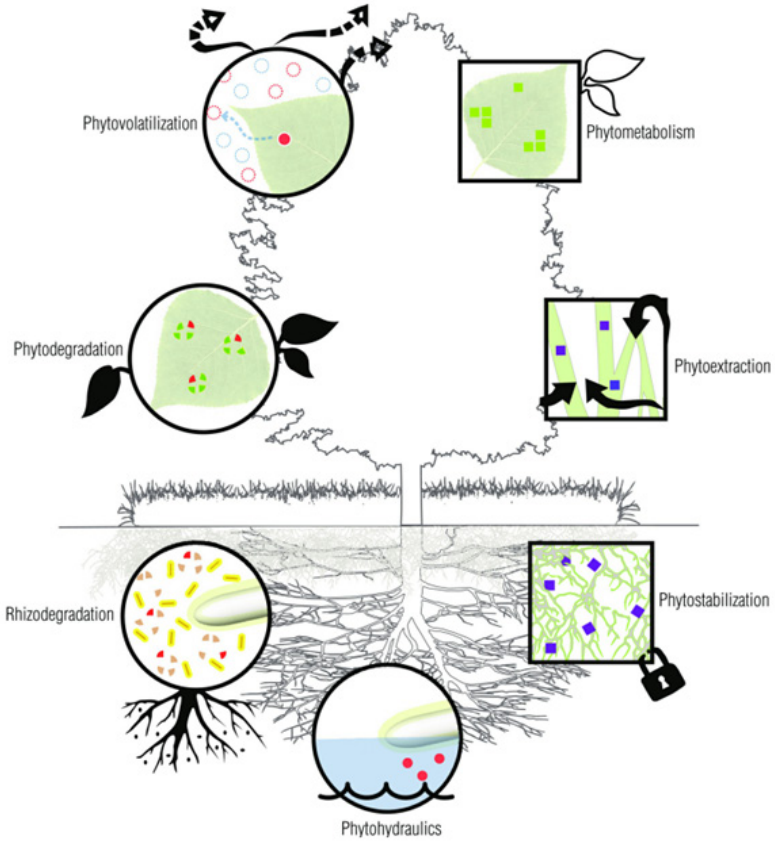


Figure 20: Phyto mechanisms summary diagram, Source: Kennen & Kirkwood (2015)

Phyto-extraction
Phyto- extraction uses the ability of a plant to extract pollutants from water and soil and turn it into plant matter. To fully remove the contaminant particles from the site, the plant can be harvested and burned or reused for biomass fuel (Kennen & Kirkwood, 2015). This process is called 'Phyto-mining', when heavy metals are caught during the burning process and reused as a resource. The type of pollutants that can be extracted can be both organic and inorganic. However, due to the need to harvest the plant, typically this method is only used for removal of inorganic pollutants, like heavy metals and asbestos (Kafle et al., 2022; Kennen & Kirkwood, 2015).

Phyto-volatilization
Pytho-volatization uses a series of steps in the plant. First, the plants absorbs the pollutants from the soil, next the plant transforms the pollutant into less harmful compounds, finally the plant transpires these compounds and release them as a gas into the atmosphere. This process removes the pollutants from the site (Kafle et al., 2022; Kennen & Kirkwood, 2015). Pytho-volatization works well when a volatilized contaminants become less harmful when its molecules are split into smaller compounds. This is usually the case for organic contaminants with large molecules, like heavy crude oil or asphalt (Kafle et al., 2022).

Phyto-degradation
Phyto-degradation uses the ability of a plant to absorb and break down contaminants inside the plant into less harmful substances, using enzymes or internal metabolism, either inside plant tissues or in the root zone (rhizosphere). In this process the broken-down pollutants remain in the plant, thus removing the pollutant from the environment (Kafle et al., 2022; Kennen & Kirkwood, 2015). This process is only possible for organic pollutants (like solvents, petroleum).

Phyto-metabolism
Phyto-metabolism uses the pollutants as nutrients for plant growth. Typically, inorganic elements such as nitrogen, phosphate and potassium are nutrients that are needed for plant growth. This process can also happens right after phytodegradation, when larger organic compounds are broken down and the N, P or K particles and are metabolized into the plant and turned into plant growth (Kennen & Kirkwood, 2015).

Rhizo-degradation
Rhizo-degradation uses the micro-organisms living near the plants root system to break-down the pollutant molecules. It is very similar to phyto-degradation. However, this process uses the naturally occurring micro-organisms and is often used as an accelerator for the phyto-degradation process. Since these organisms cannot break down inorganic particles, it can only be used for organic pollutants (Kennen & Kirkwood, 2015).

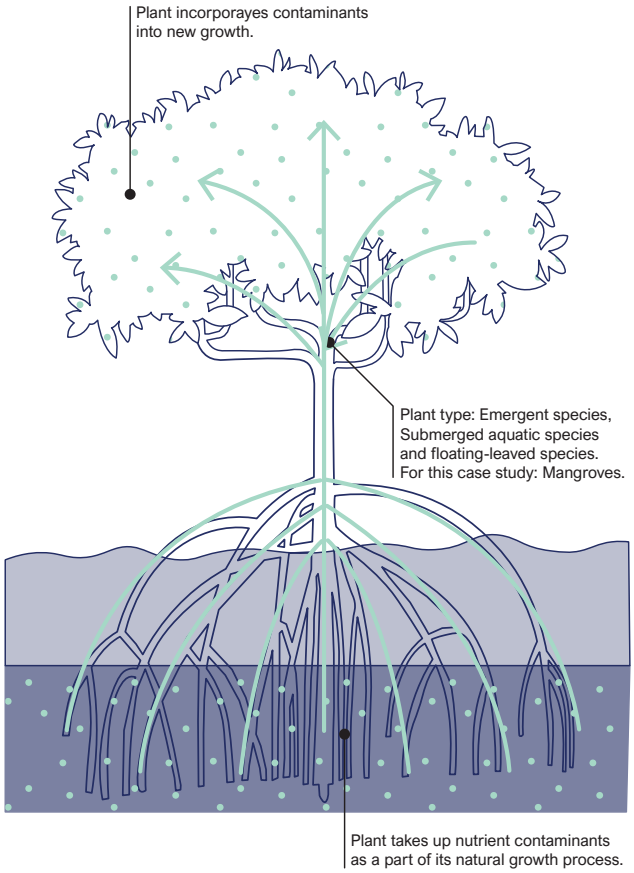
Phyto-stabilization
Phyto-stabilization uses the plant roots to hold the pollutants in place, making sure further spreading of contamination in the environment is prevented. The plant acts as a physical barrier, using similar mechanisms to the conventional remediation method of soil capping (Kennen & Kirkwood, 2015). This method can be used for all types of pollutants, as long as the deep-rooted plant can penetrate the contaminated soil and the plant is able to withstand the pollution levels of contamination in the area (Kafle et al., 2022).

Phyto-hydraulics
Phyto-hydraulics uses the strong ability of a plant to pull-up water from the soil to the plants aerial organs (the transpiration stream). This pulling force can be so strong that the flow of groundwater is stopped, preventing plumes of contamination from further migrating in the soil and groundwater. Usually, this method comes paired with other mechanisms, such as phytodegradation or phytovolatilization to completely get rid of the pollutants (Kennen & Kirkwood, 2015).

4.1 Remediation

Phyto-typologies and plant selection

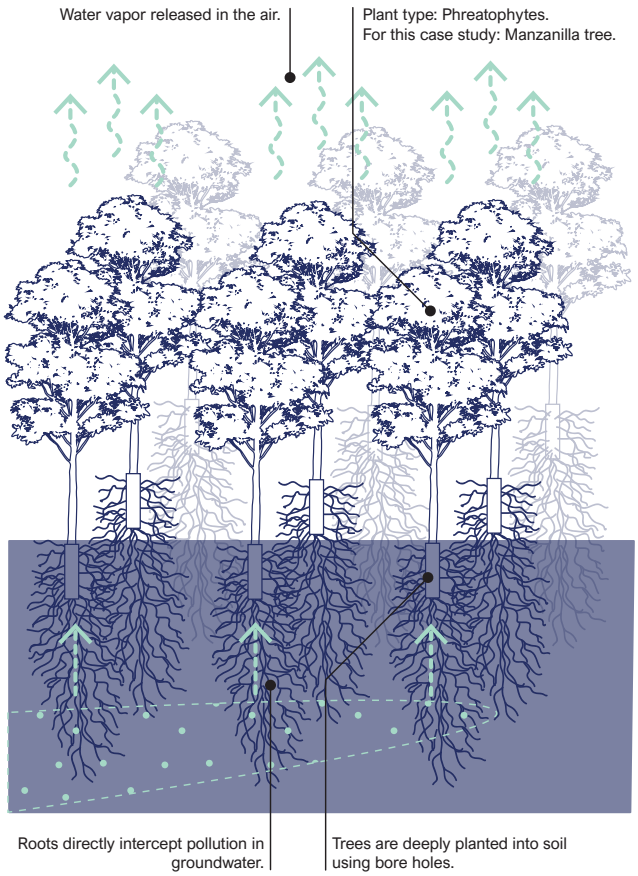
The following section describes six different phyto-typologies, in which the phyto-mechanisms can be used to remove the pollutants from the former refinery area. It should be noted that in practice, these typologies are usually combined to find the optimal remediation effect and monitoring is needed to track the progression of remediation in the areas. Based on the phyto-typology that is considered most optimum for a specific area in the refinery site, plant types are selected together with the required spatial and technical interventions.



Surface flow constructed wetland

Surface flow constructed wetlands have strong similarities to natural wetland habitats, where water saturates the soil and making the area a natural filters that improves water quality, reduces flooding, and provides habitats for diverse species. When water is moved through the system it uses the plants ability to filter out contaminants, thus remediation the water and soil (Kennen & Kirkwood, 2015). In the case of Curaçao there are already similar naturally occurring habitats, the mangrove forests at the coast of the island. These mangrove forests are indigenous species, equipped against the dry climate on the island. Moreover, they are able to withstand and degrade petroleum waste, making this plant type suited for use as Phyto-stabilization technique to avoid further spreading of contamination in the former refinery area (Ivorra et al., 2021).

Figure 21: Surface flow constructed wetland, Source: Author.



Groundwater migration tree stand

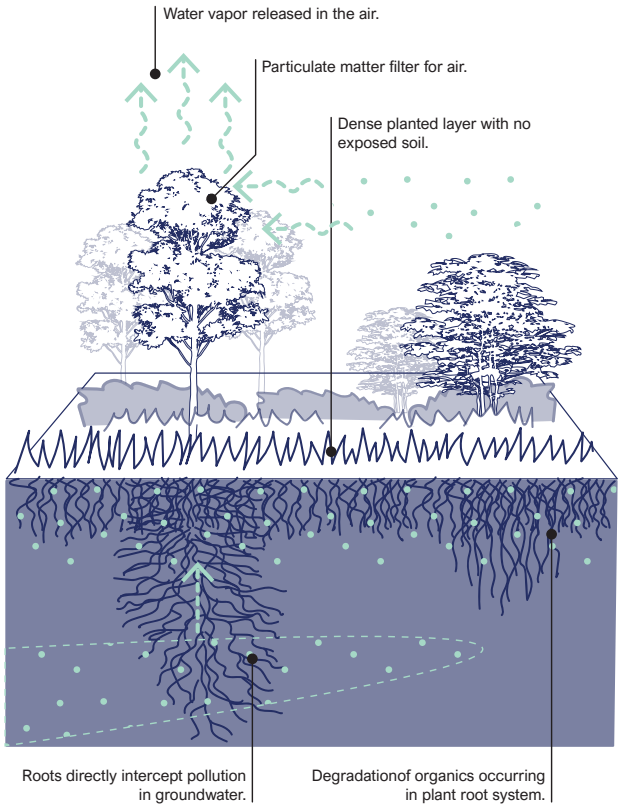
The mechanism of phyto-hydraulics is used, by planting a row of phreatophytes (deep rooted plant species) to stop the contamination plume from migration in groundwater and soil.
Groundwater migration tree stands act as a natural water pump, mimicking the conventional remediation method, where a series of wells is engineered to intercept the contaminated plume which is then pumped to the surface and treated with conventional filtration methods. As mentioned above, tree species with deep grounded roots must be selected to be able to create enough pulling force to reach the plume. In the case study area this could be achieved with the native Manzanilla tree, which is a drought tolerant phreatophyte species (Kafle et al., 2022; Kennen & Kirkwood, 2015).

Figure 22: Groundwater migration tree stand, Source: Author.

Multi mechanism buffer

A multi mechanism buffer utilizes the full potential that phytomechanisms have to offer, by providing a densely planted and diverse plant selection. This way, multiple phytomechanisms are at play on the same plot of land. This has the added benefit of increasing ecosystem services in the area, like increasing biodiversity, absorbing CO2 and adding liveability to surrounding neighbourhoods (Kennen & Kirkwood, 2015). Due to the complexity of this typology, there has not yet been made a plant selection to clean-up the pollutants on the former refinery. However, it is suggested to look at the native plants that thrive in the local climate, and if they are able to withstand and degrade the pollution particles in the case study area. For example, the Manzanilla tree or different species of cacti and aloe plants.

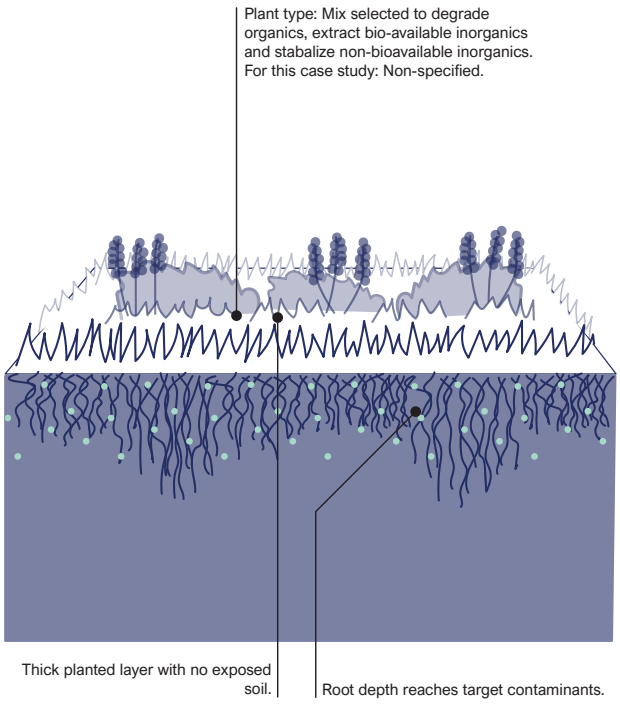
Figure 23: Multi mechanism buffer, Source: Author.



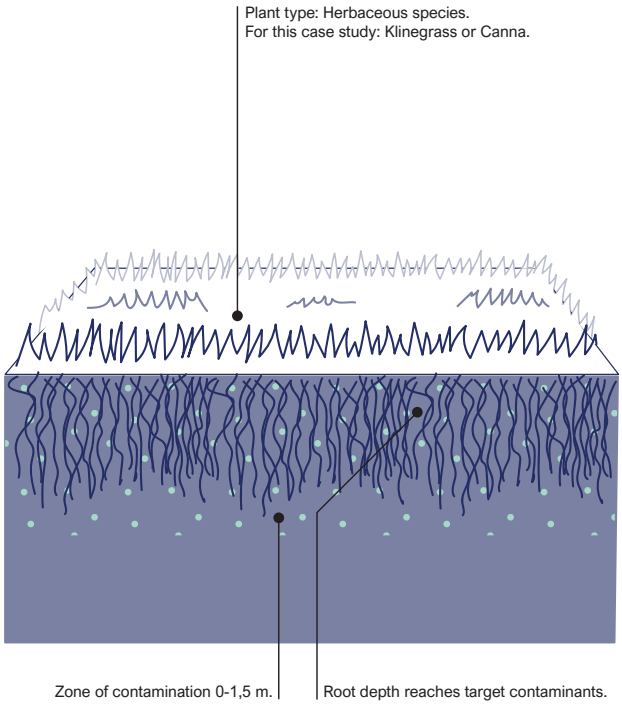
Multi mechanism mat

The multi-mechanism mat uses a similar principle to the multi mechanism buffer, in that it utilizes all of a plants potential to remediate a site. However, the multi mechanism mat only uses herbaceous plants, making it possible to also harvest these plants, for biomass production for example or for phyto-mining (Kennen & Kirkwood, 2015). Due to the complexity of this typology, a plant selection has not yet been made to clean-up the pollutants on the former refinery. However, to increase its potential to benefit liveability for surrounding neighbourhoods, most promising is a selection of native flowering plants, such as the “Fayalobi” (Ixora) or the “Stòki” (Capparis flexuosa).

Figure 24: Multi mechanism mat, Source: Author.

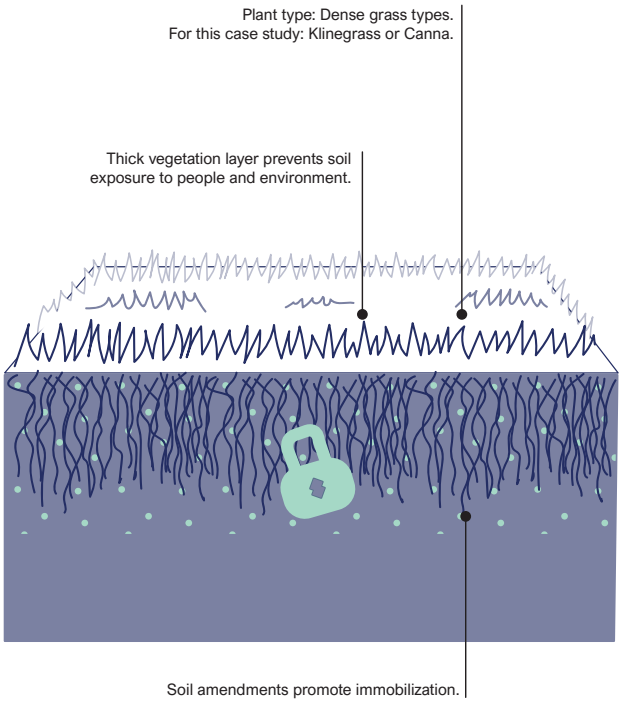


4.1 Remediation
Phyto-typologies and plant selection



Degradation cover
Degradation covers use thick and deep-rooted herbaceous plant types to remove pollutants from soils up to 1,5 meters deep. This typology is usually applied to large areas to speed up the natural break down of contaminants. Deep-rooted, drought-tolerant prairie grass type plants are usually used, due to their ability to reach pollutants deep in the soil (Kennen & Kirkwood, 2015). The use of Klinegrass or Canna is expected to be most promising, since these species are proved to work well against petroleum pollution in hot and dry climates like Curaçao (Kafle et al., 2022).

Figure 25: Degradation cover, Source: Author.



Stabilization mat
The planted stabilization mat offers a similar technique as the conventional remediation method of soil capping, by providing a thick protective cover made of plants to hold contaminants trapped on the site and prevent them from spreading and contaminating other locations (Kennen & Kirkwood, 2015). This has especially great potential for the locations on the former refinery where other phyto-mechanisms are not able to break down pollutants. Klinegrass or Canna are expected to be suitable as stabilization mat as well, since these plants are able to withstand Curaçao's local climate and they provide a thick vegetation layer, making sure no surface area is exposed (Kafle et al., 2022).

Figure 26: Stabilization mat, Source: Author.

4.1 Remediation
Phyto-remediation implementation strategy

To develop a successful phyto-technology strategy for removal of the pollutants on the former refinery site, it is necessary to understand the site's specific conditions, treatment mechanism and design layout. In the phyto-remediation strategy the following activities will be implemented, typically this implementation is an iterative process (ITRC, 2009):

- Site assessment
- Phyto-remediation selection
- Design
- Implementation
- Operation, maintenance, and monitoring (OM&M)

The site assessment need to provide answers to the following questions, as these will be used to make a proper selection of the most efficient phyto-technologies for the site (ITRC, 2009):

- What is the type and pollution level of contamination?
- Where is the contamination located?
- How is the contamination migrating?
- Which hazards to public health or environment is imposed by the contamination?

During the pollution analysis only a part of these questions could be answered. The pollution analysis was based on information from open literature, a site visit and interviews with local experts.
This information was sufficient to create a general overview of the type and location of the pollutants. Detailed information was not available or not made available for this thesis.

Detailed pollution information should include results from soil and (ground-)water samples. These samples should preferably be taken in a systematic manner over the whole polluted area and also at different depths in the soil. This detailed information is required to finally select which phytoremediation methods are most efficient to clean-up the pollutants on and in the soil of the site.

For now, the available pollution information about the site was used to provide a phyto-topology selection per pollutant. The table below shows per pollutant the most promising phyto-technology mechanism, phyto-typology and plant selection.

Pollutant type	Phyto-technology mechanism	Phyto-typology	Plant selection
Crude oil	Rhizo-degradation	Surface flow constructed wetland; multi-mechanism buffer; multi-mechanism mat; degradation cover	*Rhizophora mangle* *Avicennia germinans* *Laguncularia racemosa* *Panicum coloratum* *Miscanthus* *Capparis flexuosa* *Cereus repandus* *Hippomane mancinella*
White spirits (oil based products, like diesel, petroleum and kerosene)	Phyto-degradation and/or rhizo-degradation	Surface flow constructed wetland; multi-mechanism buffer; multi-mechanism mat; degradation cover	*Rhizophora mangle* *Avicennia germinans* *Laguncularia racemosa* *Panicum coloratum* *Miscanthus* *Capparis flexuosa* *Cereus repandus* *Hippomane mancinella*
Asphalt	Phyto-degradation and/or rhizo-degradation combined with excavation and processing of useful components	multi-mechanism buffer; multi-mechanism mat; degradation cover; stabilization mat	*Panicum coloratum* *Miscanthus* *Capparis flexuosa* *Cereus repandus*
Sulphuric acid	Rhizo-degradation	multi-mechanism buffer; multi-mechanism mat; degradation cover	Acid-tolerant species
Catalyst (typically heavy metals like: platinum (Pt), nikkel (Ni), palladium (Pd), ruthenium (Ru), rhodium (Rh), Nickel (Ni), Cobalt (Co), Molybdenum (Mo) and Tungsten (W)	Phyto-extraction and/or phyto-stabilization	multi-mechanism buffer; multi-mechanism mat; stabilization mat	*Panicum coloratum* *Miscanthus* *Capparis flexuosa* *Cereus repandus*
Asbestos	Phyto-extraction and/or phyto-stabilization	multi-mechanism buffer; multi-mechanism mat; stabilization mat	*Panicum coloratum* *Miscanthus* *Capparis flexuosa* *Cereus repandus*

Table 8: Overview phyto-remediation implementation strategy, Source: Author.

4.1 Remediation

Phyto-remediation implementation strategy

This information was then used to create a phytoremediation strategy for the Isla Refinery site. Image X shows the location where the different phytotypologies are implemented, giving an indication of how the design would look like in the future.
Image X2 shows what timeframe these implementations have, giving an indication of how long it will take before the polluted area is cleaned and these locations can be further developed.

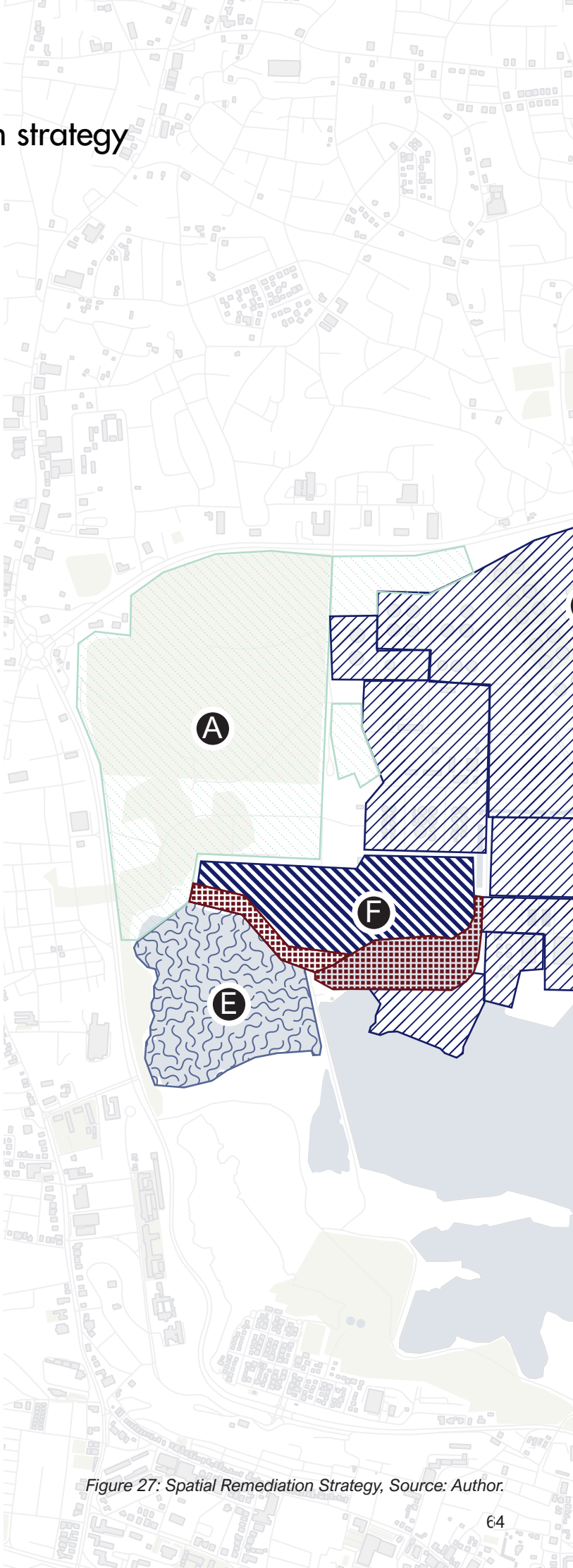
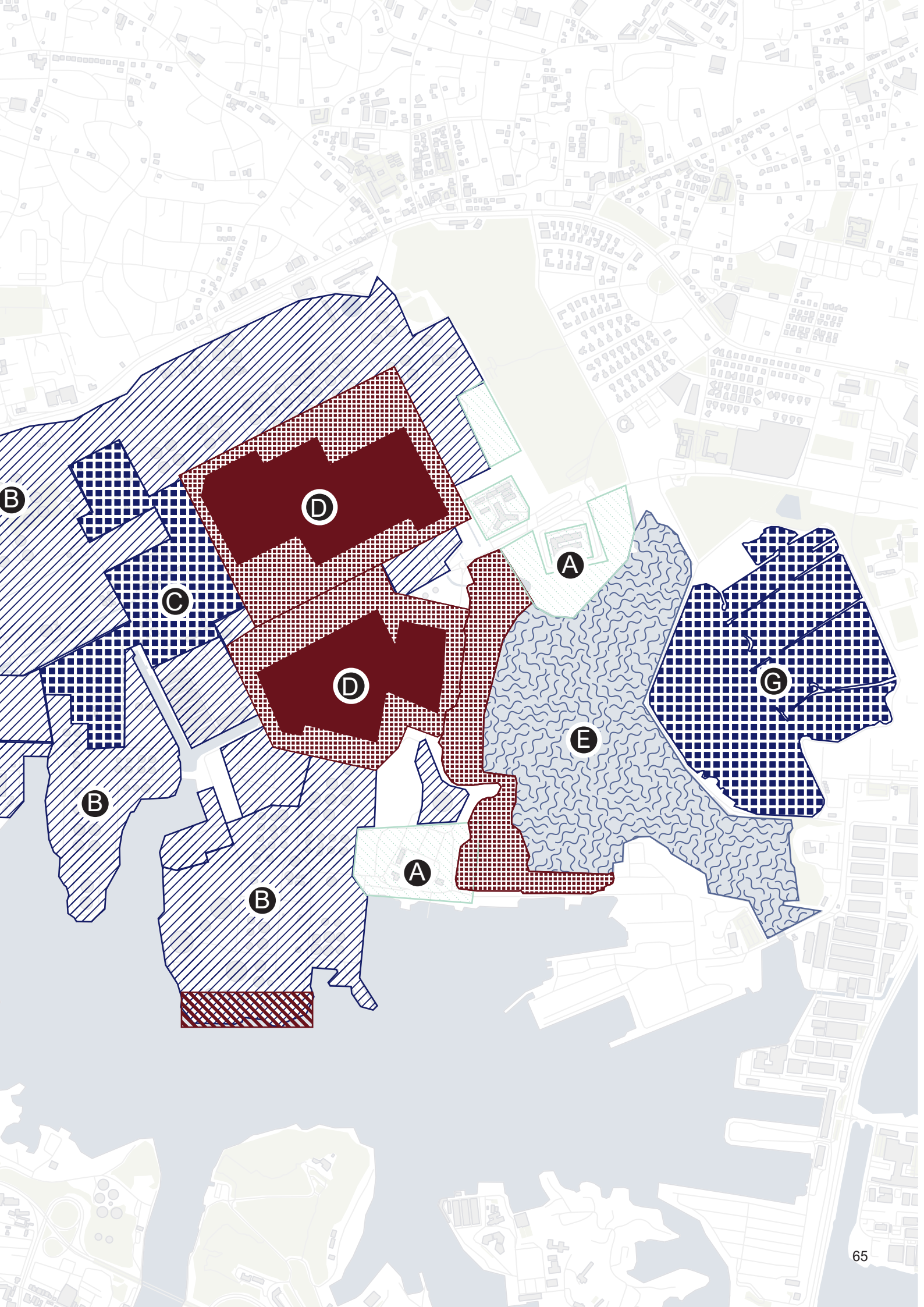


Figure 27: Spatial Remediation Strategy, Source: Author.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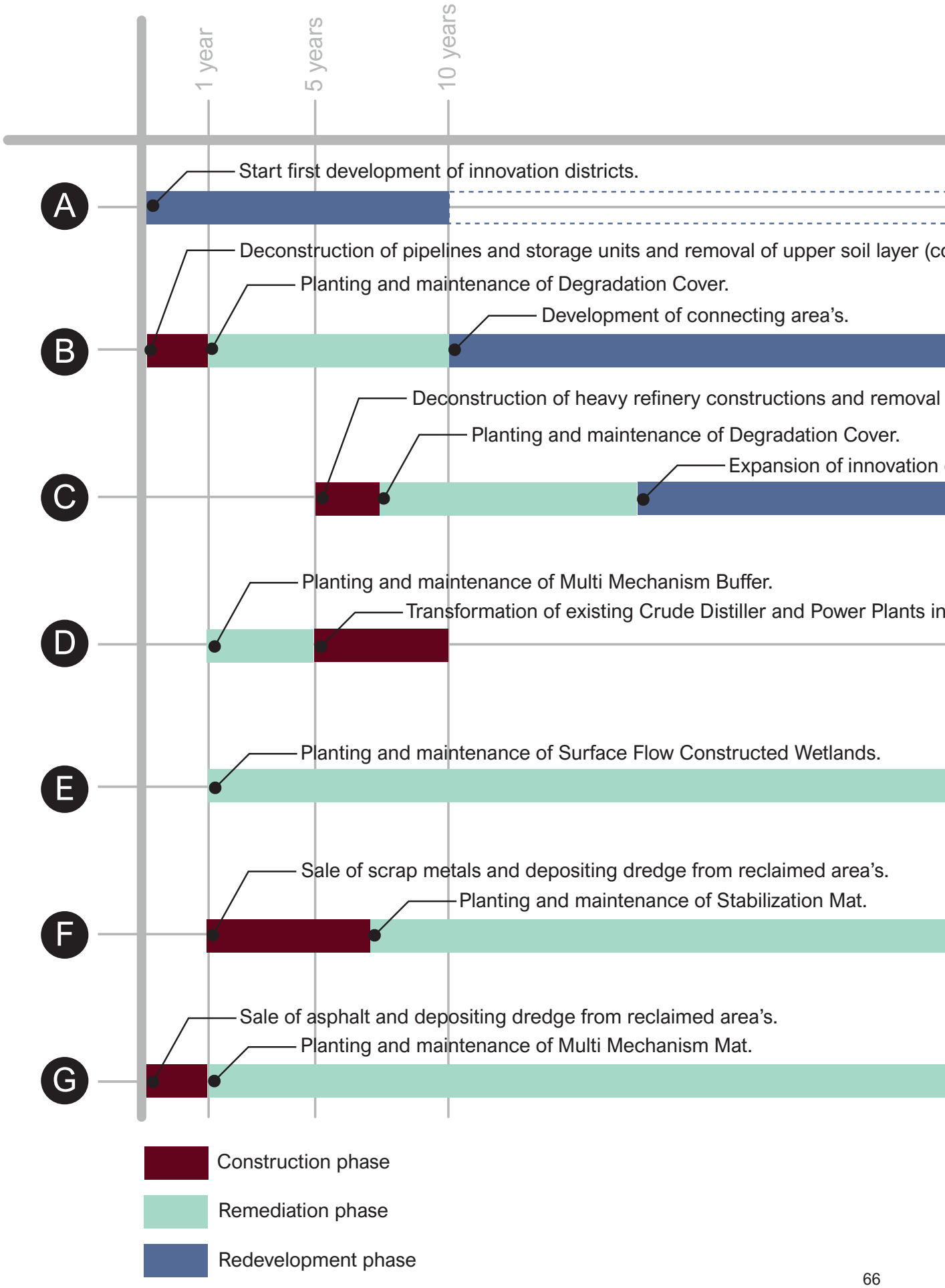
4.1 Remediation

Phyto-remediation implementation strategy



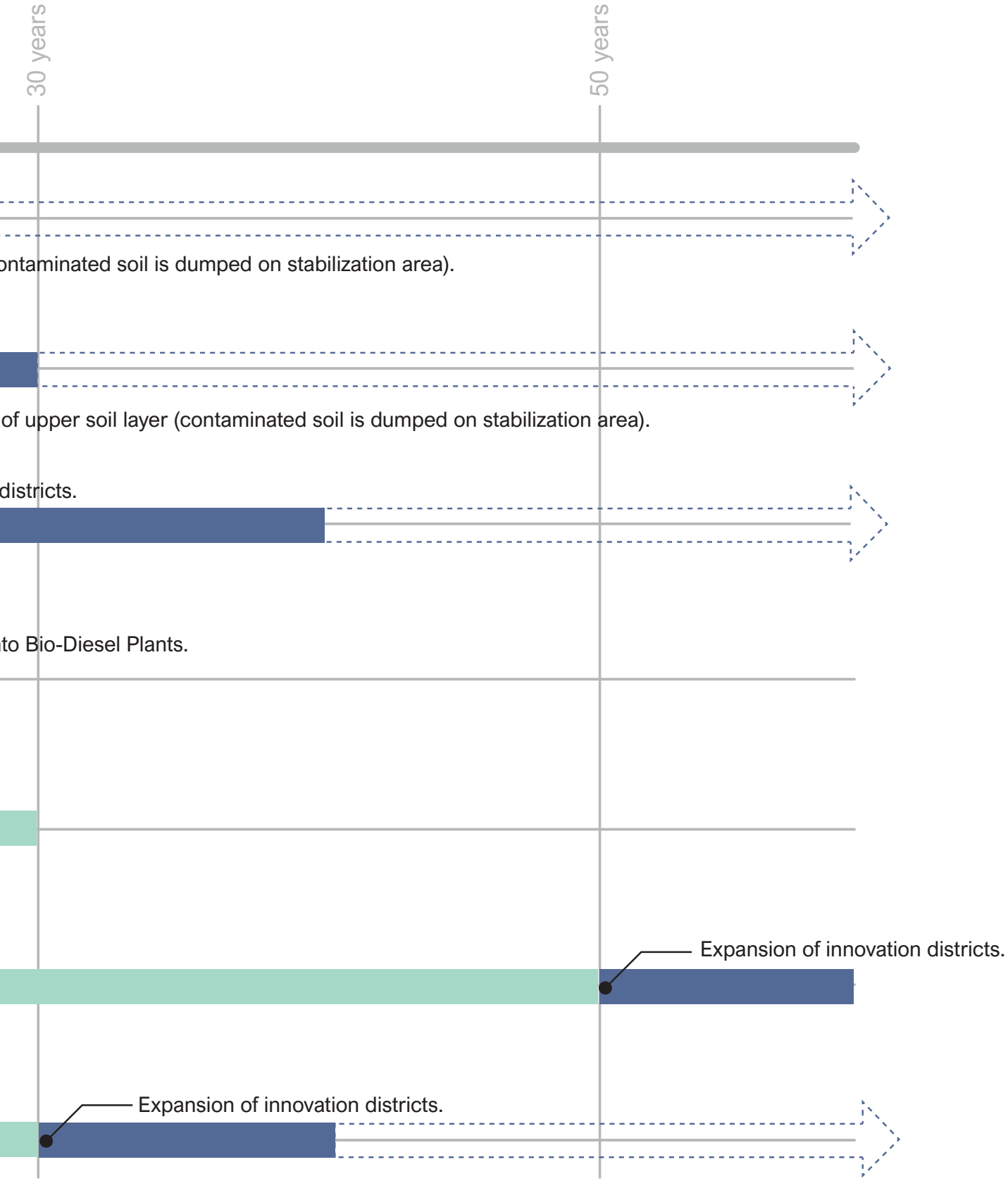


Figure 28: Remediation Strategy timeline, Source: Author.

4.2 Design and strategy
Possible redevelopment in the Isla area

In this paragraph the possible activities in the redevelopment are discussed given the to-date known pollution levels in the refinery location (now called Isla area) and potential of applied remediation techniques. The activities will be different for each location in the former refinery area as well as different over time, as pollution levels will decrease due to the remediation.

The design of the urban planning for the Isla redevelopment area needs to fulfil the principles, as indicated in the following diagrams:

- Maximize re-use of existing structures
- Maximize the connections with the surrounding neighbourhoods
- Continue ecological corridors
- Continue the urban fabric
- Diversify the program and economic activities
- Contribute to heritage

Maximize re-use of existing structures
Starting with the spatial grid, the redevelopment aims to keep most of the existing structures on the site, to support re-use, meaning that the infrastructure is largely based on the existing grid of the refinery. It is noted that this regular grid with straight roads has a high contrast with the surrounding neighbourhoods, which evolved organically. The site visit provided information about the different existing installations, buildings and infrastructure on the Isla area. Based on this information a selection is made which have potential to be reused, or which need to be demolished.

Maximize the connections with the surrounding neighbourhoods
Secondly, the importance of connecting the surrounding neighbourhoods with the site is addressed through creating passageways together with eco-ducts over the Schottegatweg, which is the main barrier between the site and these neighbourhoods. These connections are located on strategic intersections with the neighbourhoods and on the side of the Isla public spaces will be created, which have program supporting the program on the other side of the connection. Moreover, the connection does not stop at the intersection, but instead moves further into the neighbourhoods, improving the living conditions there as well.

Continuation of ecological corridors
Thirdly, the added vegetation to the site will have a positive effect on its surrounding areas as well. The so called ‘’natural-spill’’ describes the need for creating more connected natural spaces throughout the urban fabric of Willemstad. The base for this is laid during the remediation of the area, with the construction of a so-called ‘’Phyto-park” on the Isla site. This will form the base of the green identity of the redevelopment and will be connected to existing and potential new green areas in the surrounding neighbourhoods.

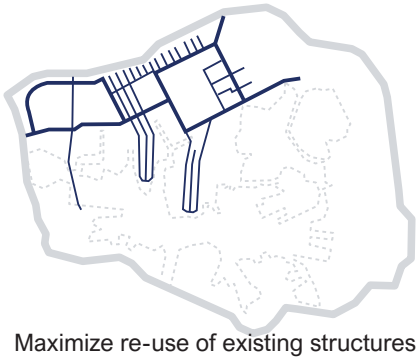
Continuation of the urban fabric
Next, the design will provide different urban densities throughout the site. Starting with a highly densified urban centre, which will provide many affordable houses with a vibrant character and many social amenities. This centre will mimic the bustling atmosphere and visual hight of the former refinery. Next to the Phyto park there come an intermediate density, which will flow into even lower densities throughout the entirety of the site.

Diversify the program and economic activities
Next, the program of the design will become a mix of four different districts. These districts overlap with each other and on certain points they have a strict barrier, to prevent them from clashing with each other’s needs. Starting with the innovation district on the western side, this district focusses on production and research, providing ample space for start-ups, large companies and diverse producing sectors. Secondly, on the eastern side will come an expansion of the UoF campus on the island. These new faculties will have a shared sports facility and will diversify the study programs offered on the island. Thirdly, the living areas at the centre of the site will have a mix of social, sports and cultural program. Binding people to the place, by providing qualitative public spaces, strengthening their connection to the new character of the Isla. Lastly,

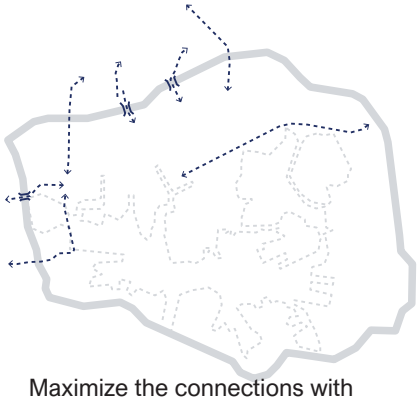
some industry will be kept alive on the site, for example the facilities of Aqualectra, which provide energy to the whole island.

Contribute to heritage

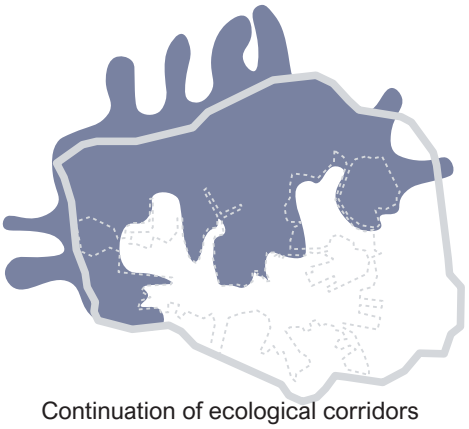
Lastly, an important part of the new identity of the site is to not ignore its past, but to incorporate it into the design. This will be done by preserving most of the heritage left behind by the refinery. For example, the old Director's home will be turned into a museum to commemorate the history of the Isla. Another example are the old oil storage tanks, which will be reused and turned into semi indoor-outdoor spaces for people to recreate or for local businesses to settle in. These spaces could also be used during festivities like Carnaval, strengthening peoples bond with the site even more. The typical round shape of the storage tanks will also be copied in the public spaces and parks, making their memory an integral part of the design. Moreover, some of the old refinery constructions will retain their space as a historic landmark in the area. These will be closed off to the public and eventually will overgrow with plants, changing their appearance through time. This remembrance of the passing of time and the Isla's past can be viewed throughout the site, as they are scattered throughout the design.



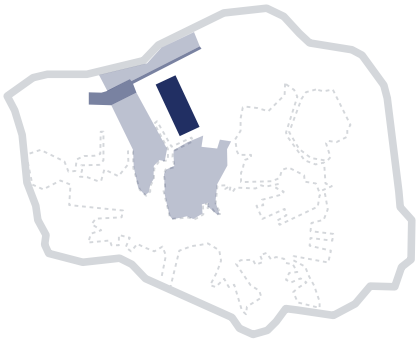
Maximize re-use of existing structures



Maximize the connections with the surrounding neighbourhoods

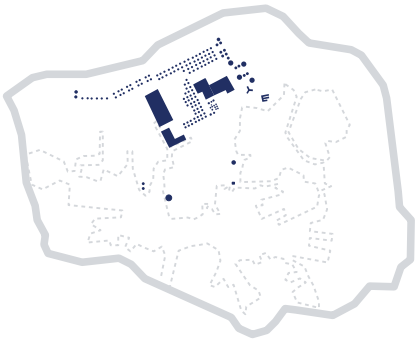


Continuation of ecological corridors



Continuation of the urban fabric

Diversify the program and economic activities



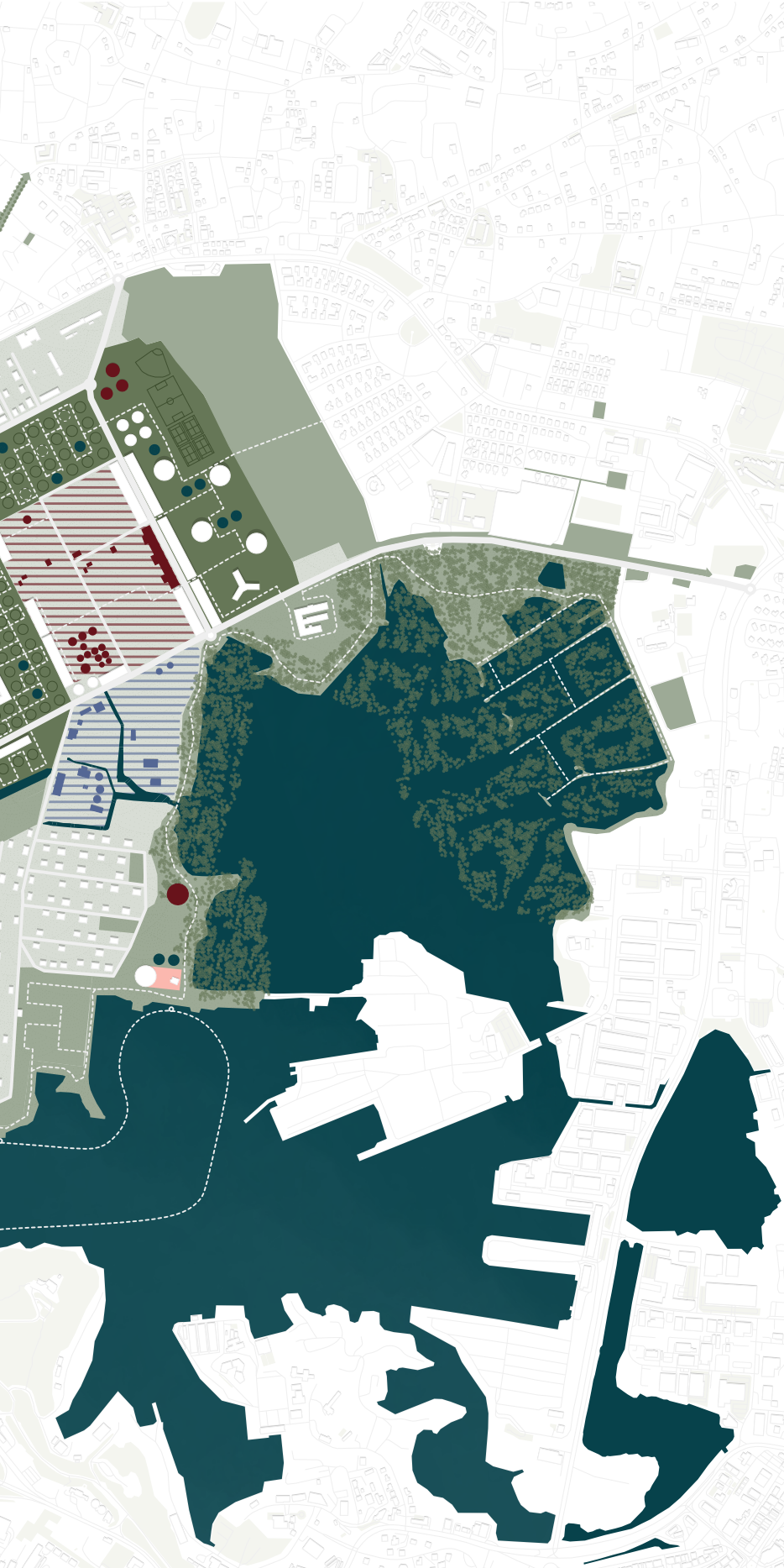
Contribute to heritage

Figure 29: Design Principles diagrams, Source: Author.

4.2 Design and strategy

Design site 2075 in 3 phases

Figure 30: Masterplan Isla area 2075, Source: Author.



4.2 Design and strategy

Design site 2075 in 3 phases

In this paragraph the phased approach for the remediation on the redevelopment is discussed and the impact of this on the possible (new) activities in the former refinery area. The remediation of the complete area is expected to be completed in 2075.

Implementation Phase 1

This first phase focuses on the first 5 to 10 years of the redevelopment. During this time the phytoremediation methods will be setup throughout the site, slowly cleaning up the pollution left behind by the oil industry. At the same time, the innovation district and campus will be developed, slowly expanding. Also the base for the new infrastructure is put in place and the first connections with the surroundings are made, connecting the neighbourhoods with the Phyto- park, where local artists van display their work and visitors can get a glimpse of the plans for the future of this site using informative panels along the path.

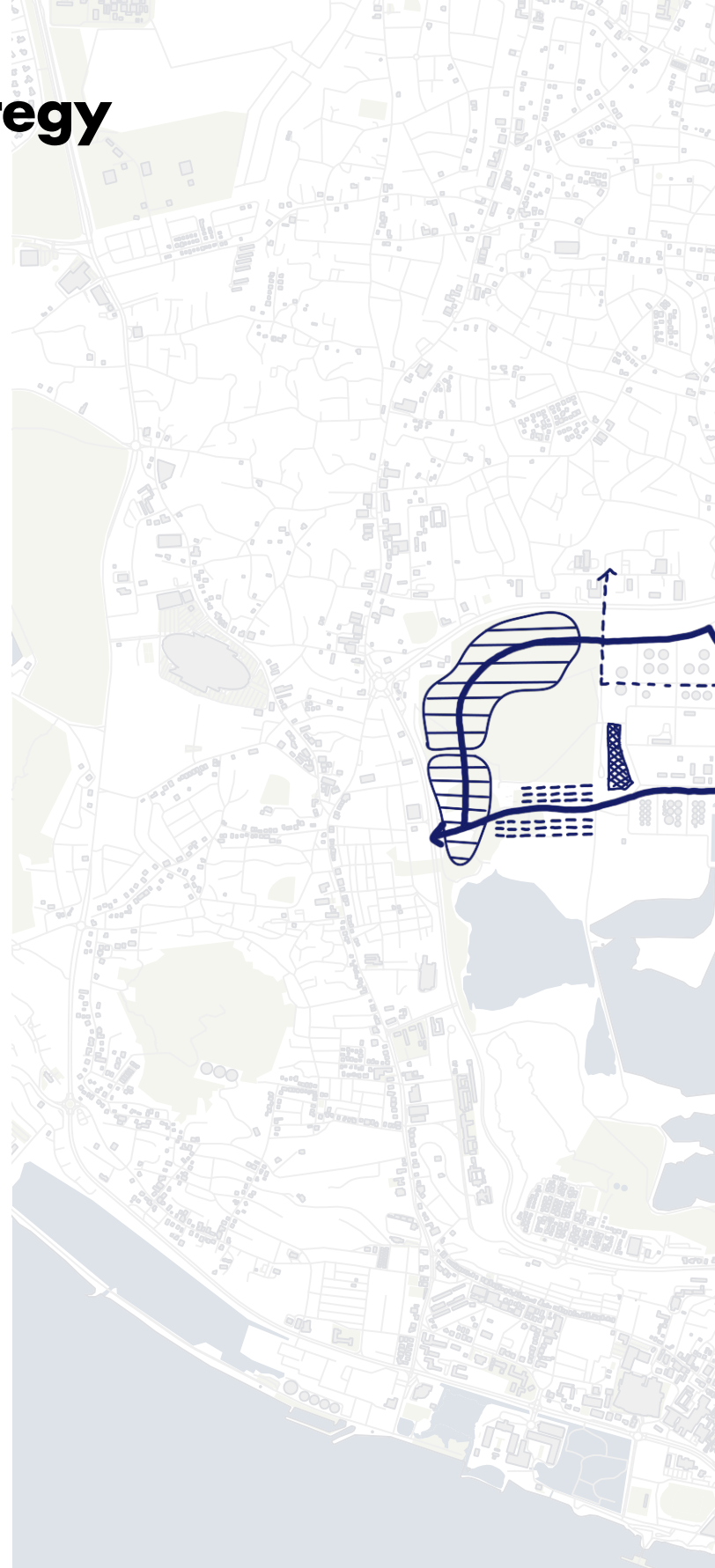
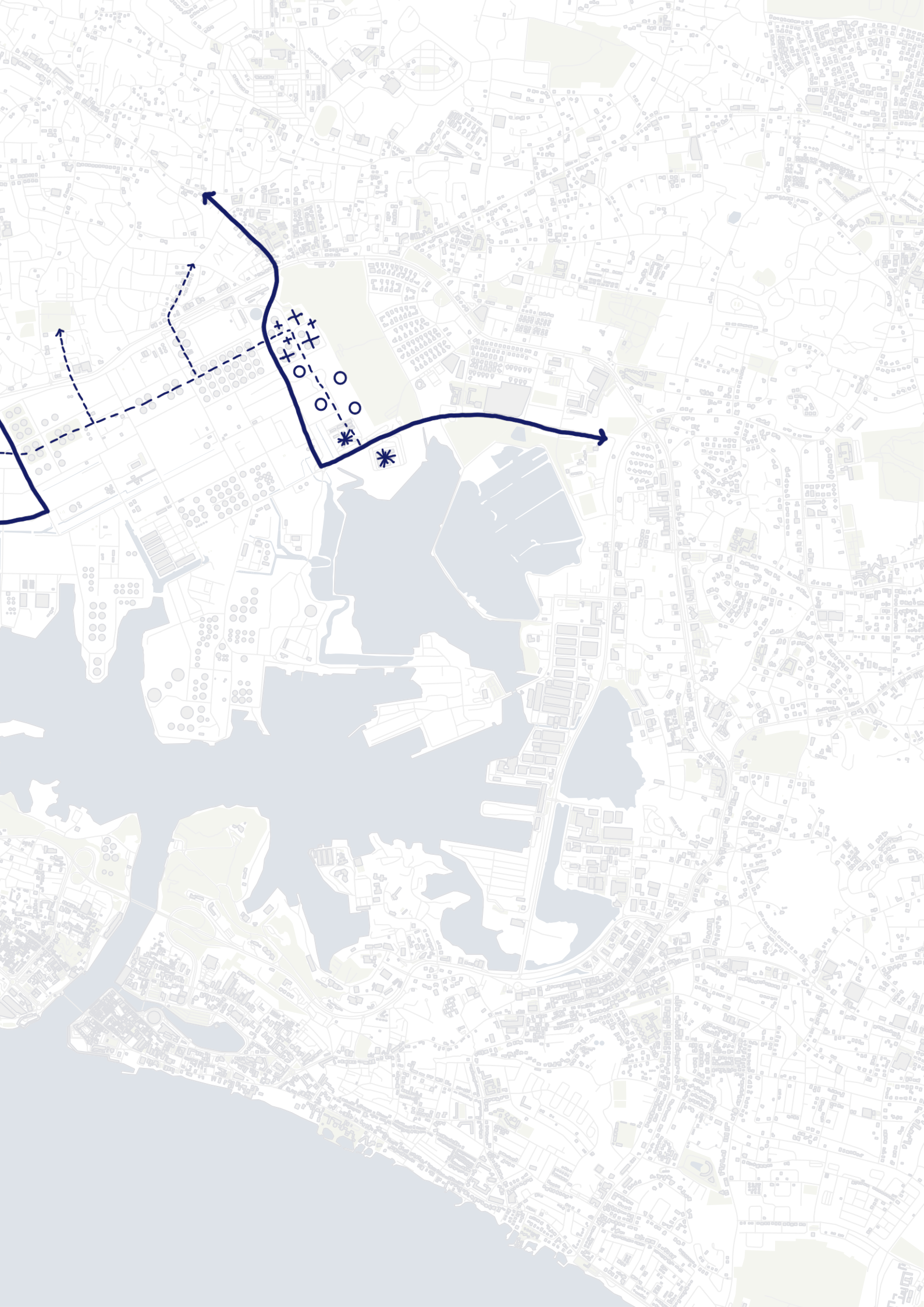


Figure 31: Implementation phase 1, Source: Author.



4.2 Design and strategy

Design site 2075 in 3 phases

Implementation Phase 2

In the second phase, from 10 to 30 years into the redevelopment, it is estimated that most locations have been successfully remediated by phyto-technologies. This creates opportunities for new development to happen in the centre of the site. The focus for these developments lay in creating places to live for new residents. These developments happen more organically, with self-built plots, mimicking the development of Otrobanda in the past. This makes these parts of the project flexible for future demand.

Different development forms will be implemented, for example the high-density city centre will be mostly developed by investors, making sure the centre gets built fast and social amenities like super markets and restaurants can settle there. The other developments happen more organically with self-built plots, mimicking the development of Otrobanda in the past. In this more flexible development form, people can choose the location and size of their plots. These developments follow one basic rule: the industrial character of the site and the natural character of the phytoremediation should be protected. Moreover, the connections with the surrounding neighbourhoods are expanded and made more attractive for the inhabitants as well as for fauna using green corridors.

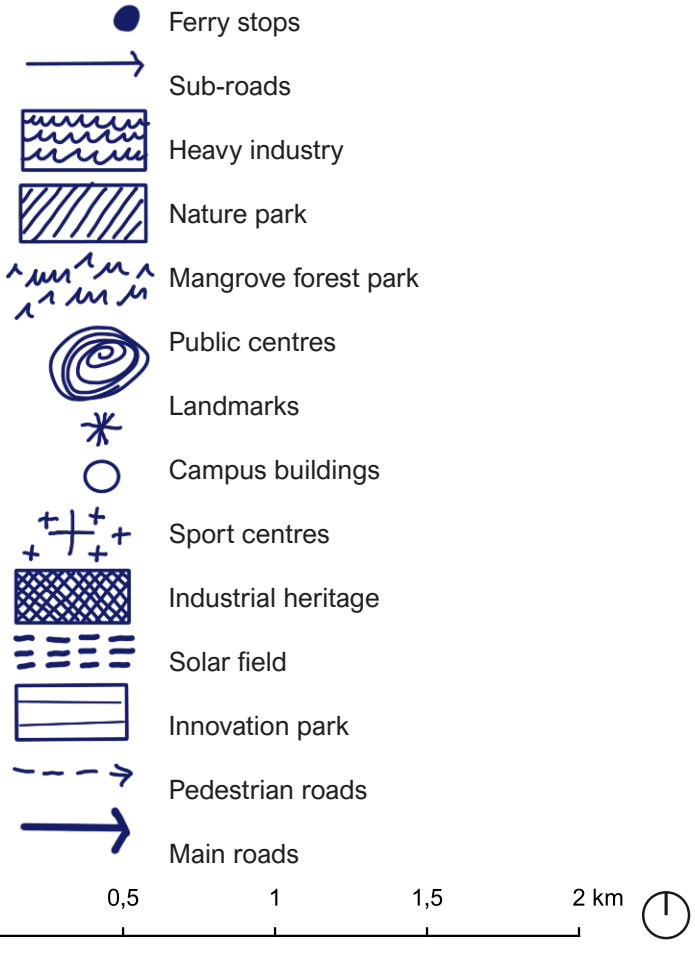
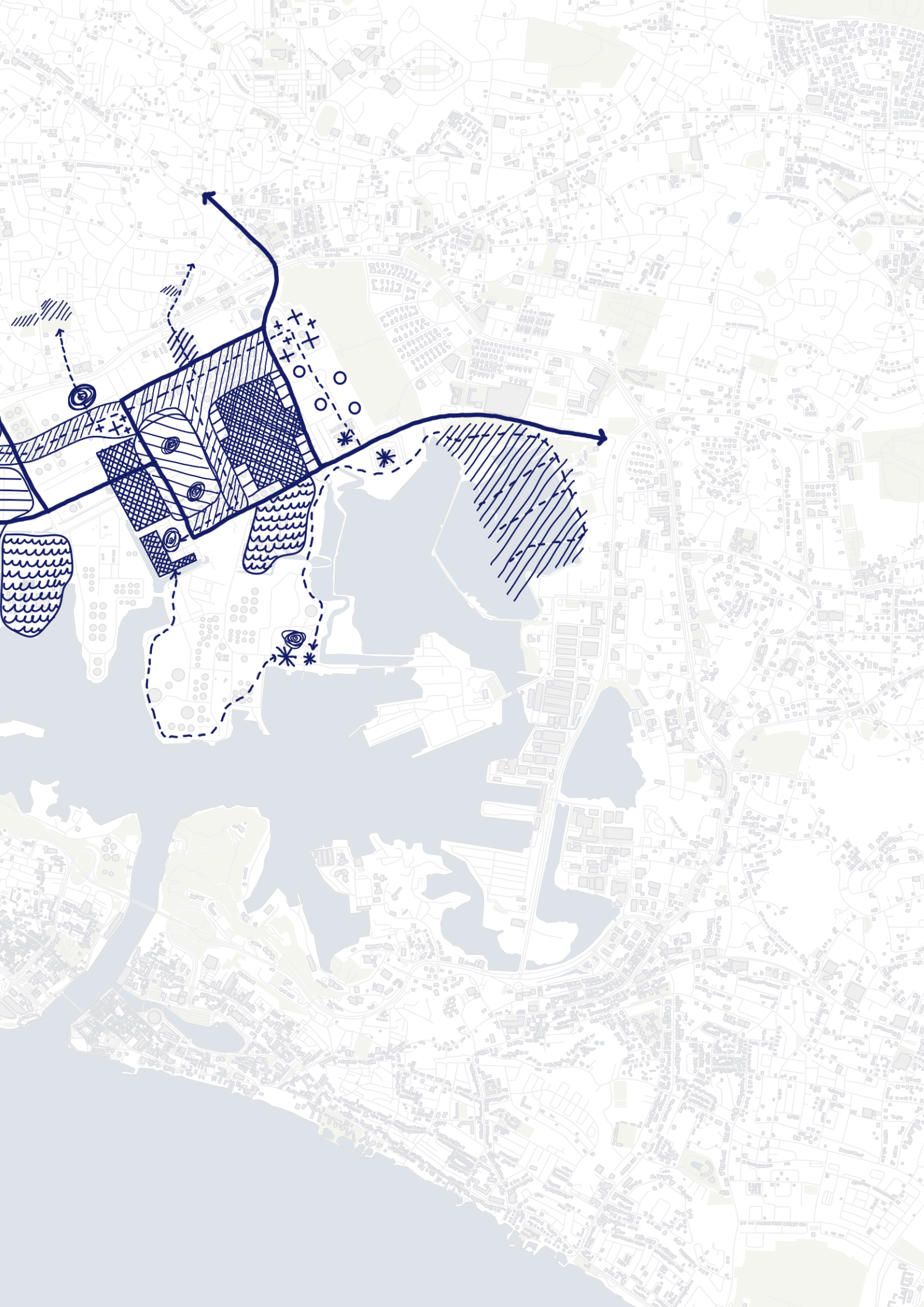


Figure 32: Implementation phase 2, Source: Author.



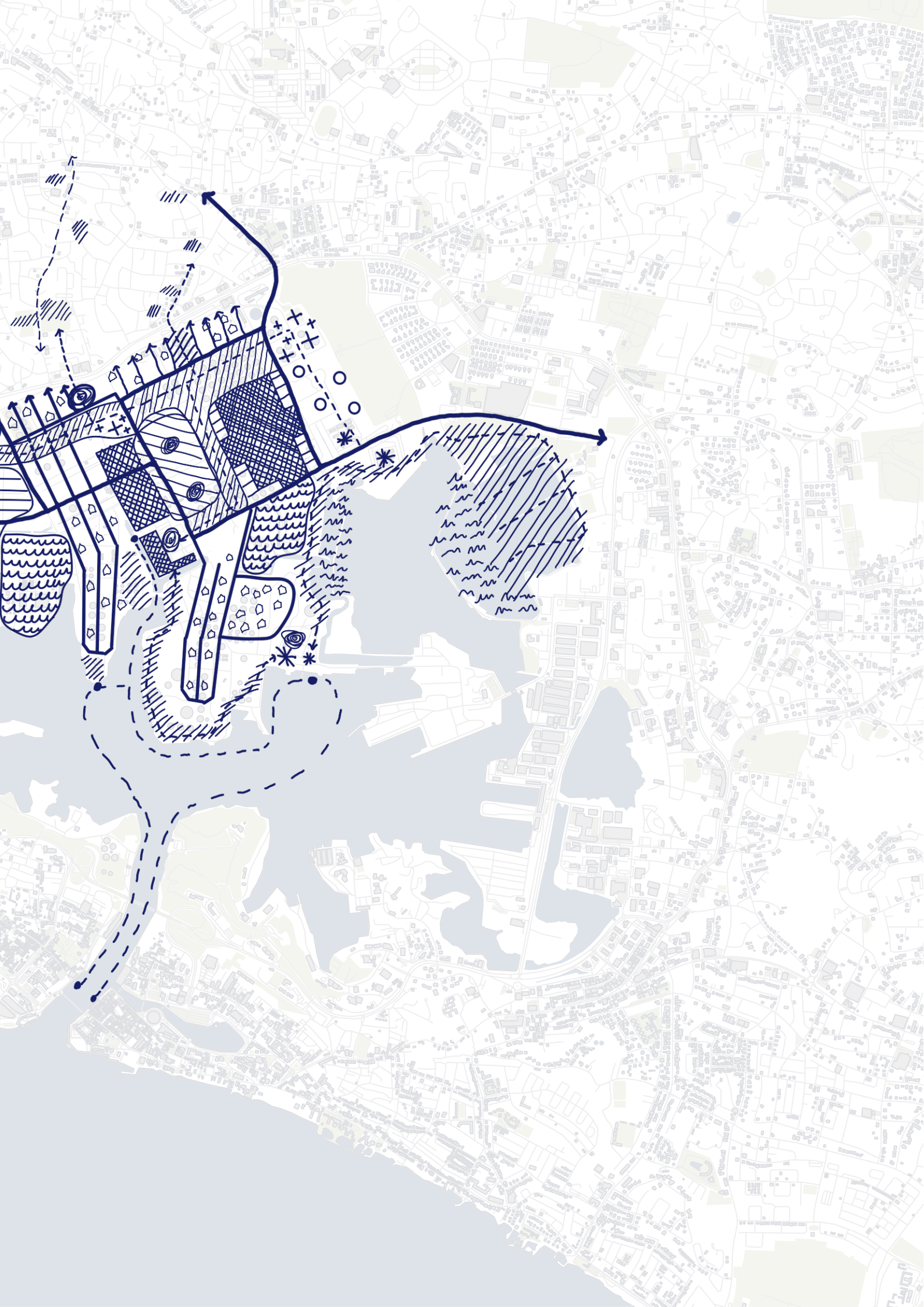
4.2 Design and strategy

Design site 2075 in 3 phases

Implementation Phase 3

This last phase describes the changes made during the final years of development, 30 to 50+ years into the redevelopment. During this last phase, more space gets filled in by the organic development of the site. It is seen how the different neighbourhoods each get their own identity through the communities living there. The innovation district and campus have become crowded with students and businesses, strengthening the island's economy. The effect of the changes made to the Isla are seen throughout Willemstad and the effect of time is seen on the remaining industrial landmarks. The Isla has changed drastically, but its history has not been forgotten.

Figure 33: Implementation phase 3, Source: Author.



4.3 Evaluation on sustainability

Effects on the island of Curaçao

The aim of the redevelopment is design is to create a sustainable future for the Isla area, benefitting people, planet and prosperity.

After the final phase of the redevelopment, the impact of the developments are expected to be seen throughout the entire island. Due to the increase and diversification of economic sectors, other parts of the island have also been able to expand and further develop. For example, the industrial sites near Bullenbaai and Hato (the airport) have expanded. Another example is the improved public transport, which runs from Willemstad all the way to West-Point. Moreover, the increase in energy demand has been covered by the expansion of (floating) wind turbines on the north and possibly east side of the island and the research done in this industry has made it possible for local communities and the tourism sector to become more self-sufficient. The local production of food has become more efficient, making it possible to also use it as an export product of high quality, strengthening Curaçao's trading position within the region. Due to the changes made at the Isla, the island's citizens, economy and environment have become more resilient to the uncertainties of the future.

Effect on improving the future trends.
The redevelopment will focus on improving the current challenges for local citizens and environments, namely climate change, brain drain, import dependency, overtourism and pollution. This will be done by building on opportunities associated with sustainable development projects:

- Increase flexibility
- Use local solutions
- Work community centred
- Implement resilience

These opportunities will be used in deciding upon new program for the future of the site. This program will be divided into four specific categories/perspectives:

- Learn & work
- Live & play
- Produce & research
- Inspire & connect

Learn & work, this perspective is focused on improving the educational system on Curaçao and adding work opportunities that fit the island's labour market. This will make the island a more attractive study and workplace for young talents, solving the current challenge of a brain drain. Examples include, the diversification of the study programs, improving connections with universities abroad, facilitating shared startup resources and connecting young professionals with the labour market of Curaçao by creating traineeship opportunities and by fostering networking opportunities. An innovation district is an example where these goals spatially come together. These districts are characterized by the presence of multiple educational institutions, like a combination of vocational education and the University of Curaçao (UoF), and the presence of big and small companies that companies that connect with the education provided.

Live & play, is a perspective focussing on recreation and affordable housing for local citizens. Currently, due to the challenge of over tourism, local people have trouble entering the housing market, due to inflated real estate prices caused by the presence of foreign investors. Moreover, overtourism claims large areas of public spaces, for example the continued privatization of beaches near the south coast. This design will take a community centred approach, by trying to solve these problems in two ways. Firstly, by adding new affordable housing and high-quality public spaces to the design. And secondly, by going beyond the scope of the redevelopment location and also implementing improvements to the neighbourhoods surrounding the case study site.

Produce & research, is focussed on improving the self-sufficiency of the island. Due to its dependency on imported goods, the island is vulnerable to unregulated price fluctuations, caused by global uncertainties. This creates a non-resilient future for the local people on the island. To tackle this problem, this design will create space for the production of resources like energy, water and food. Moreover, it will encourage

research into innovation of these producing sectors, in the previously proposed innovation district. Program considered for these goals are, solar fields, hydrogen storage, high tech farming, indoor fish farming and keeping some of the existing industry alive.

Inspire & connect, provides for local citizens opportunities to create a more sustainable future for themselves. This is done through proper education and by connecting the surrounding neighbourhoods with the redevelopment area. This will be done as early on as during the remediation phase, where recreational paths connect the neighbourhoods on strategic intersections with the ''Phyto park'', making sure citizens are aware of the change in their environment and the possibilities the future will have for them. This connection is further implemented on a larger scale, where the site becomes a public transport hub for the rest of the island and internationally by creating a good connection to the airport.

Challenges	**Opportunities**	**Perspectives**	**Contribution to vision**
Climate change	Flexibility	Learn & work	People
Brain drain	Local solutions	Live & play	Planet
Import dependency	Community centred	Produce & research	Prosperity
Overtourism	Resilient	Inspire & connect	
Pollution	Diverse		

Table 9: Recommendations framework, Source: Author.

05 | Conclusion

Conclusion
Reflection

5.1 Conclusion

To answer the main research question of this thesis, first the sub-research questions have to be answered.

1. What is the current context and what future trends are expected of the case study and how will this context interact with the redevelopment?

During the analysis the context of the Isla site and its surroundings were examined. From this analysis multiple challenges were uncovered, related to the redevelopment of the Isla site, namely;

- Reopening the refinery is generally seen as the preferred future scenario, because of the past reliance of the economy of Curaçao on the refinery
- Past polluters like Shell and PdVSA cannot be financially held accountable for the costs for cleanup
- The EOP, the official National Ordinance that determines how the space on Curaçao may be used is outdated
- The main means of transportation on Curaçao is the car, pedestrian and public transport infrastructure is lacking
- The Schottegatweg forms a rigid barrier between the Isla site and the surrounding neighbourhoods
- The pollution on the Isla area is diverse and information about this is not publicly accessible, making the clean-up process complex

Moreover, during the analysis multiple future trends on Curaçao were found. The development of the Isla area can mitigate these trends in the future, for example;

- Climate change; can be mitigated by making the area climate resilient and due to its central location the Isla area can become a safe haven for the people and fauna in the surrounding neighbourhoods
- Brain drain; the redevelopment can attract young talent to Curaçao and bond local students to their home island by providing opportunities for education, work and houses
- Import dependency; can be countered by making Curaçao more self-sufficient by producing (green) energy, water and food on the Isla area
- Over-tourism; and its negative effects can be countered by creating affordable housing for and by local people in a self-built process

2. How can the pollution on the case study site be sustainably remediated?

This thesis explored the possibility to use phyto-technologies to clean the Isla Refinery site.
During the pollution analysis only a part of the information needed to successfully design a phyto-remediation strategy could be found. The pollution analysis was based on information from open literature, a site visit and interviews with local experts.

This information was sufficient to create a general overview of the type and location of the pollutants. Detailed information was not available or not made available for this thesis.

For now, the available pollution information about the site was used to provide a phyto-topology selection per pollutant. The pollution on this site consists of a mix of crude oil, white spirits, asphalt, sulphuric acid, heavy metals and asbestos. To remediate these pollutants six different phyto-typologies were suggested and different plant selections were made.

The phyto-typologies are Surface flow constructed wetland, Groundwater migration tree stand, Multi-mechanism buffer, Multi-mechanism mat, Degradation cover and Stabilization mat. The plant selection used information about the plants ability to survive the local climate and pollution type and levels, and if the plant was either native to Curaçao or non-invasive. Examples of used species are; mangroves, Klein grass, Manzanilla trees and local flowering bushes.

3. What are possible new activities in the case study area, during and after remediation, and how fair are these developments to ensure their contribution to the value of People, Planet and Prosperity?

Possible activities in the redevelopment of the Isla Refinery were found given the to-date known pollution levels in the refinery location and potential of applied remediation techniques. The activities are different for each location in the former refinery area as well as different over time, as pollution levels will decrease due to the remediation. To contribute to the existing context of the site, these activities fulfil the following principles;

- Maximize re-use of existing structures
- Maximize the connections with the surrounding neighbourhoods
- Continue ecological corridors
- Continue the urban fabric
- Diversify the program and economic activities
- Contribute to heritage

Moreover, these new activities contribute to the people, planet and prosperity of Curaçao by focussing on the next four perspectives;

- Learn & work
- Live & play
- Produce & research
- Inspire & connect

4. What will a sustainable future look like for the case study?

The completion of the remediation phase is expected to be 2075. Before this moment three different phases were designed to show how the Isla area can evolve alongside the phyto-remediation. Important to these phases are the following design principles;

- Maximize re-use of existing structures
- Maximize the connections with the surrounding neighbourhoods
- Continue ecological corridors
- Continue the urban fabric
- Diversify the program and economic activities
- Contribute to heritage

5.2 Reflection

Relation between the project, master track and master programme

The master track Urbanism consists of four different studio's, each focussing on different aspects of the urban planning field.

Within the MEP studio this project would focus on creating a circular economy for the island and on soil and water reclamation through pollution clean-up. The clean-up method I would like to explore within this studio is phytotechnology. The research would focus on ecosystem services and it would explore new services for the site, creating a more abundant ecosystem. The different flows of the island: food, energy, water, waste, etc. will have to be analysed to create said circular economy.

Within the TT studio this research would focus on the effect of the global transitions and crisis on the site. Especially the energy transition, climate crisis and transition towards self-sufficiency, would be important to this research. The site's specific history and context would need to be analysed to create a future vision appropriate for the island.

Within the DUF studio this research would focus on designing a new urban fabric for the site after the clean-up phase has been finalised. The research would explore the form language present on the island and try to create a cohesive design, fitting in with the context of the site. It will answer the question: What will this area look like in the future?

Within the PCC studio this research will focus on governance related issues in the area. Moving through different governmental scales, from geopolitical to citizen participation. It will test the current plans of the local government on sustainability, inclusivity, transparency and justice. The conflicts of interest between civil society and private parties will be brought to light and the role of the government within this will become clear. This research will become more focussed on planning and less on designing within this studio.

Iterative research & design process

- The site analysis influenced the design process by giving input for the different challenges that needed to be addressed
- The phytoremediation strategy design process influenced the analysis, by giving input on what information needed to be gathered about the site
- The remediation strategy also influenced the design process by giving restriction, these were restrictions in time and space. As the remediation strategy made it impossible to redevelop certain areas and on other areas it would take time before those could be developed.

Research approach and limitations

- The EOP (1995) is an important source, since this is the only available planning tool in Curacao, However this source is dated and it is advised to the local government to revise this tool, to make planning more accurate
- The lack of information available about the specific contamination levels, type and locations made the research less detailed and accurate. In the future, a much more comprehensive research int this subject is needed as a base for the design of a phytoremediation strategy

Project's relevance and ethical considerations

In this research efficient pollution clean-up is key to achieve the research aims stated earlier. Phytoremediation could be a more cost-friendly alternative to conventional methods for clean-up. Multiple researchers have looked into this method and have proven its effectiveness (Kafle, 2022; Kennen & Kirkwood, 2015). However, the implementation of this method in the context of brownfield redevelopment and in the tropical climate of Curacao has not yet been researched.

This thesis project will close this knowledge gap by doing a site specific research and design, providing knowledge about the feasibility of this remediation method and highlighting the possibilities during this relatively long clean-up process. The research will take a phased approach to this clean-up process which typically takes five years but may take up to 50 years, depending on the type of phytotechnology used (Kennen & Kirkwood, 2015). During that time the project area will have different levels of pollution throughout time. Meaning, the area will have different possible functions during the different clean-up phases. Researching when which functions are possible, will generate economic value to the area during the whole clean-up process, making the project more feasible. This will make future brownfield regeneration projects more likely to use phytoremediation.

Democracy in decision making and participation of local residents are key success factors in brownfield regeneration projects (Glumac, 2020). This is also the case for the Isla Refinery site. However, decision

makers in this case study are focussing on economic benefits by attracting new investors to the area. it lacks transparency towards the civil society. This neo-liberal approach to redevelopment lacks transparency towards local residents and makes it more difficult for them to get involved and accept the project.
My project aims to make a more holistic sustainable future vision for the area, where people, planet and prosperity are equally important. Moreover, the project will ensure transparency for all stakeholders involved. Making sure that local citizens, that have been negatively affected by the pollution from the refinery, will experience the positive effects of the project. This will reduce inequalities on the island and promote environmental justice.
The first priority of the local government and the state owned company 2Bays is the re-purposing of the refinery area to new economic activities (Beumer, 2012; Mordt, 2018; Reijmer, 2024). This should be done within acceptable Health, Safety and Environment (HSE) criteria. Meaning the contamination levels in soil and water should be according to international standards for HSE . This should be an independent governmental responsibilities, which includes setting criteria, monitoring and enforcement of said criteria. This project will facilitate the local government with a set of possible new functions and a sustainable clean-up method that fits international HSE criteria.
Secondly, the rebranding of RdK to 2Bays was required for them to reposition themselves and attract new businesses and industries towards the area. However their plans for sustainable development lack concreteness and transparency. Moreover, their wish to reopen parts of the refinery will conflict with the goals of this project. This research will have to examine how reopening parts of the refinery will affect the goals of this project, to see whether these plans of 2Bays can coexist with the plans found in this project. The main question here is: How does partly reopening the refinery fit into the plans suggested by this project?
Thirdly, the conflict between health and job opportunities regarding prosperity should be considered in this research. Main consideration would be; how can this project provide compensation to the citizens that are negatively affected by the pollution in the area and how can job losses be kept to a minimum. Important is to keep in mind the vulnerability of these two groups and their conflicting needs. If done right, these two interests will not be conflicting in this project. As it will generate new job opportunities through the introduction of new industries.
Lastly, the historical background regarding migration in the area should be considered in this research. It is apparent that the island has gone through major immigration and migration flows throughout history. One of the events associated with this, was the arrival of the refinery to the island (Jong, 2015). The influence of changing job opportunities on the composition of society on this island, will be an important aspect to look at during this research.

Transferability

- Remediation strategy can not be directly implemented elsewhere, since the site specific characteristics are very important to make phytoremediation viable.
- The use of industrial heritage in the project could be replicated in other projects
- The future program ideas could inspire other redevelopment projects

Effect on Curaçao

After the final phase of the project, the effects of the design are seen throughout the entire island. Due to the increase and diversification of economic sectors, other parts of the island have also been able to expand and further develop. For example, the industrial sites near Bullenbaai and Hato (the airport) have expanded. Another example is the improved public transport, which runs from Willemstad all the way to Westpunt. Moreover, the increase in energy demand has been covered by the expansion of wind turbines on the north side of the island and the research done in this industry has made it possible for local communities and the tourism sector to become more self-sufficient. The local production of food has become more efficient, making it possible to also use it as an export product of high quality, strengthening Curaçao's trading position within the region. Due to the changes made at the Isla, the island's citizens, economy and environment have become more resilient to the uncertainties of the future.

Personal reflection

- Difficulties with a lack of available data
- I got more aware of the iterative process of design and research, in the future I would use this to my advantage and start designing almost right at the start of a project, during this thesis project I waited until most of the research was done, in fear of designing something that is not accurate
- Time management

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Appendix
Historical analysis (full)

Pre-historic and Spanish colonial periods

Before the Spanish conquest, Curaçao was inhabited by Amerindians who arrived in canoes from the South American mainland. Although it is unclear whether they always lived in permanent settlements, evidence of this has been found in the form of graves at the foot of Sint Michielsberg, dating from approximately 2000-1650 BC (Dr. R. M. Allen et al., 2020a).

From 1499, Curaçao was under Spanish rule, following the discovery of Alonso de Ojeda. During this period, the island was used as a trading post, hacienda and several unsuccessful attempts were made to establish agriculture. During this period, the island was depopulated by the Spanish, when in 1513 a labour shortage required the local Amerindians of Curaçao to work as enslaved labourers on Hispaniola (present-day Haiti and the Dominican Republic). About a decade later, Juan de Ampués, Governor of Venezuela, was granted Curaçao as a fief and was tasked with repopulating it. During his governorship, the population grew to approximately 150 people. In 1634, the island was conquered from the Spanish by Johan van Walbeeck. Since then the island has been connected to the Netherlands, with short interruptions in 1800-1803 and 1807-1816, when the British ruled Curaçao (Dr. R. M. Allen et al., 2020b).

Dutch colonial period

Since its conquest in 1634 by the WIC (West Indian Company) Curaçao developed differently from a traditional plantation economy, as natural resources were quite limited. The island initially served only as a military base during the Eighty Years' War, using Fort Amsterdam on Punda (the peninsula on the eastern side of the entrance to St. Anna Bay) as its main defence. However, a trade economy emerged from the mid-17th century onward due to the investment of the WIC into the growing global slave trade (Dr. R. M. Allen et al., 2020c; Toelichting EOP, 1995).

During this time, a settlement grew north of Fort Amsterdam, which evolved into a walled city called Willemstad. In the 18th century Willemstad further developed into the city it is today. Starting in 1700, when the walled city was becoming over-populated. People began living outside the city walls, this led to the development of the neighbourhoods Pietermaai, Scharloo, and Otrobanda (Dr. R. M. Allen et al., 2020f; Toelichting EOP, 1995).

Starting with Pietermaai, which emerged on the strip of land between the Waaigat and the sea, which was much narrower then than it is now. Houses were built on both sides of the road that ran to the eastern part of the island. The city wall was demolished between 1861 and 1866, resulting in the expansion of both Punda and Pietermaai towards the north and in the empty areas between them (Dr. R. M. Allen et al., 2020f; Toelichting EOP, 1995).

Secondly, in the second half of the 19th century Scharloo emerged. Large, scattered houses were built along the north side of the Waaigat, on the former Scharloo plantation. This neighbourhood grew exponentially and within a few decades, Scharloo developed into a prominent residential area (Dr. R. M. Allen et al., 2020f; Toelichting EOP, 1995).

Lastly, during this period the development of Otrobanda (meaning on the other side) started on the opposite side of St. Anna Bay. This new neighbourhood initially developed similarly to Pietermaai along the two sides of a road, the one that ran to the west of the island. Because Otrobanda was never walled, meaning people didn't have to build within a limited space, the buildings here were initially spacious. Houses stood on large plots with lots of open space around them. Small, adjoining houses were built on the edges of these often walled 'kura's'. Otrobanda grew rapidly, and by the mid-eighteenth century, it was already larger than Punda (Dr. R. M. Allen et al., 2020f; Toelichting EOP, 1995).

During this period the number of plantations on the island also increased, these were situated all over the island. These were primarily intended to supply the local population and slave depots with food and not for extensive export, due to the low harvest yields caused by Curaçao's dry climate. On these plantations

so-called kas di pal'i maishi (small clay houses with corn cob roofs) were built for the enslaved population. These village centres generally remained, even after the abolition of slavery, particularly in Bandabou (the western part of the island). In the 19th century additional village centres emerged initiated by the Roman Catholic Church, starting with Barber, then Santa Rosa and Santa Maria and later San Willibrordo and Montagne were made. Besides these church initiatives, there were also settlements made by free people in Westpunt, San Pedro, Seru Fortuna, and Boka Sami (Dr. R. M. Allen et al., 2020c, 2020g; Toelichting EOP, 1995).

The population at this time consisted primarily of Dutch and Jewish colonists, enslaved Africans, and the indigenous population. This society developed into a segmented one, splitting the population into groups with similar birth, origin, skin color, religion, and socio-economic position. Members of certain segments had more rights than others, ranging from the high-ranking white Protestant merchants and WIC officials with extensive rights and power, to the enslaved Africans who had no rights whatsoever. In between these two groups moved the Jews, low-ranking white Protestants and the so-called colored people, who emerged from (often forced) relationships between white men and black women (Dr. R. M. Allen et al., 2020d, 2020c).
Emancipation and pre industrial period

Despite the oppression of the enslaved population, they repeatedly rebelled against their inhumane treatment. Organized slave uprisings occurred in 1716 in Sint Marie, in 1750 on the Hato plantation, and in 1795 the major slave uprising led by Tula took place (Dr. R. M. Allen et al., 2020e).

However, it wasn't until 1863 that slavery was abolished in the Dutch colonies. Life after emancipation was not easy for the formerly enslaved. It was difficult to obtain land for growing food and building a house, since most fertile land was already in the hands of the plantation owners. For this reason, some freedmen remained living with the shons (plantation owners) based on a so-called Paga Tera system, in which they were obligated to work unpaid for the plantation owners for a number of days each year in exchange for land. In the city, the freedmen could find work as porters in the harbour, loading and unloading ships. After 1875, some found work in phosphate mining on Tafelberg near Nieuwpoort. Women could work as servants on the plantations or in the city and they could work as hat weavers. However, in the period following emancipation, the economy was not doing well, and poverty was widespread, particularly among the newly liberated (Dr. R. M. Allen et al., 2020h).

This poor economic situation served as the main incentive for emigration in Curaçao in the period following the emancipation. Workers left for surrounding areas such as Venezuela, Costa Rica, Colombia, and the Dominican Republic in search of employment. Some even found employment during the construction of the Panama Canal. Even after the arrival of the oil company in 1915, the migration of Curaçaoan workers to countries in the Caribbean continued. This continued situation until around 1923 (Dr. R. M. Allen et al., 2020i).

Industrial period till now

Industrialization began in Curaçao in the 20th century. This began with the establishment of an oil refinery by Shell. In 1912, Shell had acquired a concession in the Mene Grande oil field, east of Lake Maracaibo in Venezuela. When it became clear in 1915 that the Mene Grande oil field was rich in oil, the decision was made to establish a refinery in Curaçao. The reason for building it here, rather than in Venezuela itself, was the oil field's poor accessibility for large ships and Curaçao's more stable government (Dr. R. M. Allen et al., 2020j; Toelichting EOP, 1995).

In the refinery's early years, it employed approximately 300 people, a number that quickly grew to over 10,000 in 1929. Besides many Curaçaoan and Dutch employees, the workforce consisted primarily of migrant workers from the Dutch Antilles, Suriname, Venezuela, Colombia, the British and French islands in the Caribbean and even from Madeira. During this period of economic progress not only migrant workers came to Curaçao, but also small traders from Lebanon, Central and Eastern Europe (particularly Ashkenazi Jews), India, and China were attracted to the island (Dr. R. M. Allen et al., 2020k; Toelichting EOP, 1995). Shell had not only a significant influence on the composition of Curaçao's population but also on its urban development. Over the course of 25 years the company built entire neighbourhoods for employees at various locations near the refinery, such as Julianadorp, Rio Canario, Groot Kwartier, Suriname Dorp, and Suffisant. This was followed by many low density developments, resulting in the large urban area consisting

of many different districts now known as Willemstad (Toelichting EOP, 1995).
This expansion was reinforced by the increased mobility provided by the car, because it made it possible to live further away from your workplace. By 1938, there were already 1,500 cars and more than 400 buses on the island. Developments continued with housing projects for lower incomes in Steenrijk and Marie Pompoen between 1947 and 1951. More such projects followed in 1954 in Brievengat, in 1957 in Buena Vista, and later (in the 1960s and 1970s) Koraal Specht, Brievengat (phase 2), Ceru Domi and Ceru Fortuna. During the Shell's reign the population had grown from 32,000 in 1920 to 125,000 by 1959 in its peak. Approximately 90% of the population lived in Willemstad or in the suburbs.

To date, this process of urban sprawl has continued uninterrupted. The construction of new low-density residential neighbourhoods on the outskirts is rapidly urbanizing the island. Meanwhile, the centre of Willemstad is becoming increasingly depopulated (Toelichting EOP, 1995).

Appendix
Stakeholder analysis abbreviations

Description of Abbreviations:

R1, PdVSA, Venezuelan oil company
R2, Stichting GreenTown, NGO concerned about the future development of the area
R3, CPA, harbour company of Curacao
R4, KTK, ship towing company of Curacao
R5, CRU, Curacao's refinery utilities
R6, 2BAYS, Isla Refinery operator
C1, SMOC, Stichting Schoon Milieu Curacao, NGO concerned with clean air on Curacao
C2, Clean Air Everywhere, NGO concerned with clean air globally
C3, MOTE, Marine laboratory researching pollution in the area
C4, Former workers Refinery
C5, Local Residents
C6, Schools
C7, Healthcare facilities
U1, Justitie, ministry of justice
U2, Financiën, ministry of finance
U3, Algemene zaken, ministry of general affairs
U4, GMN, ministry of Health, Environment and Nature
U5, Economische Ontwikkeling, ministry of economic development
U6, OWCS, ministry of Education, Research, Culture and Sports
U7, VVRP, ministry of Traffic, Transport and Spatial planning
U8, BPD, ministry of Governance, Planning and Civil service
U9, SAW, ministry of Social development, Labor and Welfare
U10, Minister van Koninkrijke relaties, NL
U11, USA
U12, EU, European Union
U13, 1e Kamer, NL
U14, Venezuela

Appendix

Informed consent template (interviews)

Informed Consent Form

Opening statement:

Dear participant,

You are being invited to participate in a research study that is preliminarily titled *Reclamation of the Isla Refinery - A phased approach to brownfield redevelopment.* This research is being done by Annika van der Nat (main researcher and corresponding researcher, Master student), Ir. Francesca Rizzetto (supervisor and responsible researcher, researcher), and Prof.Dr Arjan van Timmeren (secondary supervisor, full professor) from the Faculty of Architecture and the Built Environment, department Urbanism, at TU Delft.

About the research:

The study is a Master Thesis. The thesis focusses on sustainable brownfield redevelopment by using a phased approach, using the Isla Refinery site on Curacao as a case study to test this approach.
Brownfield redevelopment projects typically consist of three phases; site assessment, site remediation and site redevelopment. Conventional remediation methods are used during these projects, which take a relatively short amount of time to clean-up the soil and water in these areas. However, a growing demand for nature based solutions in the urban planning field is challenging this paradigm. Phyto technologies are remediation methods that use plants to extract or stabilize pollution particles in soil and water. These less invasive remediation methods need a longer amount of time to clean-up the pollution compared to conventional methods. This changes the typical timeline of brownfield redevelopment projects drastically, meaning the remediation phase will be significantly longer.
This thesis will research how this longer remediation phase can be best approached to increase sustainability during brownfield redevelopment projects. This is done by focusing on increasing the value of people, planet and prosperity (triple bottom line concept) in the case study area. The aim of this study is to create a toolbox, which helps decision makers choose a suitable remediation method and create a sustainable vision for brownfield remediation projects.

Your participation:

Your participation is sought because you have been identified as an expert in Curacao, and/or the Isla Refinery and/or sustainable brownfield redevelopment. Your participation will be in the form of an in-depth interview regarding your expertise relating to this. This interview will take approximately one hour, up to one and a half hours, to complete. The data will be anonymised and used in a written master thesis report, which will be published on the TU Delft repository. Further publication of a journal article based on the master's thesis is not out of the question. Questions that could be asked during the interview will relate to your job and specific role in the development of the Isla Refinery site and governance, Curacao’s urban planning practice, the governance systems at place in Curacao, the Isla Refinery site’s role in Curacao’s economy and pollution in the area and Curacao’s economy, ecology and culture. The interview will be semi-structured. If preferred, a list of questions can be sent by email beforehand, however, additional questions could be asked during the interview.

Data type and management:

As with any online activity, the risk of a breach is always possible. To the best of our ability, your answers in this study will remain confidential. We will minimise risks by storing data in the protected TU Delft OneDrive environment, deleting any data that is unnecessary (such as recordings after transcription), anonymising all data that is used in the research output, and deleting all data upon completion of the project. Besides contact information for any potential follow-up questions, no personal data will be collected. Data will be anonymised before publication

of the research output. Names and official job titles will be removed. A profile with categorised information, such as age group, generalised job position (designer, policy-maker, moderator etc.), and sector (civil, public, or private) might be added to create context to the data if necessary.

Your risk:

Whilst all efforts for safe and secure data management are being made, risk always remains. It is important to realise that the topic of the research, sustainable brownfield redevelopment of the Isla Refinery, can be a politically loaded topic. Unauthorised publication or re-identification of anonymised data might pose a risk to your job position and reputation.

Voluntary participation:

Your participation in this study is entirely voluntary, and you can **withdraw at any time**. You are **free to omit any questions**. It is also possible to **remove data up to a three-month period from the day of the interview** (so, if the interview takes place on June 1st, the last day to remove any data is September 1st).

Contact information:

For any questions regarding the research or your data, concerns, or complaints, you can reach out to the corresponding researcher, Annika van der Nat. For any complaints that cannot be shared with the corresponding researcher, you can reach out to the responsible researcher, Ir. Francesca Rizzetto.

Main researcher and corresponding researcher: Annika van der Nat

Responsible researcher: Francesca Rizzetto

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated 26 May 2025, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves: An audio and/or video recorded interview, these recordings will be transcribed as text, after which the recordings will be destroyed	☐	☐
4. I consent to participating in: - An in-depth semi-structured interview in which I will be answering questions concerning my professional expertise on Curacao, and/or the Isla Refinery, and/or sustainable brownfield redevelopment; - Where my answers will be audio recorded and written notes will be taken during the interview; - and the audio recording of the interview will be transcribed as text upon which the audio recording will be deleted;	☐	☐
5. I understand that the study will end in January 2026, when the Master Thesis has been graded sufficient.	☐	☐
6. I consent to the use of data generated from my participation in the publication of the master thesis, which is expected in January 2026.	☐	☐
7. I consent to voluntary participation in this research study with no financial or other compensation.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
8. I consent to taking part in the study which could involve the following risks: - A data leak containing my personal data and answers to (potentially politically sensitive) questions; - Re-identification of anonymised data and answers to (potentially politically sensitive) questions. I consent to a Data Management Approach where these risks will be mitigated by - Safe data management and storage in the secure TU Delft OneDrive; - Anonymisation of my data and answer - - Deletion of my data and answers as soon as the data is made redundant or the project is completed	☐	☐
9. I understand that taking part in the study also involves collecting specific personally identifiable information (PII), such as my name, job description and place of residence with the potential risk of my identity being revealed.	☐	☐
10. I consent to the collection of associated identifiable data knowing that some of this PIRD is considered sensitive data within GDPR legislation, such as my political views on the governance of Curacao.	☐	☐
11. I consent to the following steps being taken to minimise the threat of a data breach, and to protect my identity in the event on such a breach:	☐	☐

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
- Data is stored on the protected TU Delft OneDrive - Any unnecessary data is destroyed - Data is anonymised before publication of the research output - Access to data is limited to the main researcher, the responsible researcher, and the secondary supervisor only.		
12. I understand that personal information collected about me that can identify me, such as my name or where I live, will not be shared beyond the study team.	☐	☐
13. I consent to the collection and storage of the (identifiable) personal data I provide until completion of the projector before if made redundant due to transcription, anonymisation, or irrelevance to the project topic, upon which it will be destroyed.	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
14. I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐
15. I agree that my real name can be used for quotes in research outputs	☐	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
16. I give permission for the de-identified transcript that I provide to be archived in the TU Delft repository so it can be used for future research and learning.	☐	☐
17. I understand that access to this repository is unrestricted.	☐	☐

Signatures

_____ _____ _____

Name of participant [printed] Signature Date

I, as legal representative, have witnessed the accurate reading of the consent form with the potential participant and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

_____ _____ _____

Name of witness [printed] Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____ _____ _____

Researcher name [printed] Signature Date

Study contact details for further information: Annika van der Nat, (+31) 6 29039644, a.f.p.l.vandernat@student.tudelft.nl

Appendix
Data Management Plan (interviews)

Plan Overview

A Data Management Plan created using DMPonline

Title: Reclamation of the Isla Refinery: A phased approach to brownfield redevelopment

Creator: Annika van der Nat

Contributor: Francesca Rizzetto

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2025)

Project abstract:

The thesis focusses on sustainable brownfield redevelopment by using a phased approach, using the Isla Refinery site on Curacao as a case study to test this approach.

Brownfield redevelopment projects typically consist of three phases; site assessment, site remediation and site redevelopment. Conventional remediation methods are used during these projects, which take a relatively short amount of time to clean-up the soil and water in these areas. However, a growing demand for nature based solutions in the urban planning field is challenging this paradigm. Phyto technologies are remediation methods that use plants to extract or stabilize pollution particles in soil and water. These less invasive remediation methods need a longer amount of time to clean-up the pollution compared to conventional methods. This changes the typical timeline of brownfield redevelopment projects drastically, meaning the remediation phase will be significantly longer.

This thesis will research how this longer remediation phase can be best approached to increase sustainability during brownfield redevelopment projects. This is done by focusing on increasing the value of people, planet and prosperity (triple bottom line concept) in the case study area. The aim of this study is to create a toolbox, which helps decision makers choose a suitable remediation method and create a sustainable vision for brownfield remediation projects.

ID: 178819

Start date: 10-02-2025

End date: 30-01-2026

Last modified: 23-05-2025

Reclamation of the Isla Refinery: A phased approach to brownfield redevelopment

0. Adminstrative questions

1. Provide the name of the data management support staff consulted during the preparation of this plan and the date of consultation. Please also mention if you consulted any other support staff.

Francesca Rizzetto, the thesis supervisor and responsible researcher on the project has reviewed this DMP.

2. Is TU Delft the lead institution for this project?

- Yes, the only institution involved

I. Data/code description and collection or re-use

3. Provide a general description of the types of data/code you will be working with, including any re-used data/code.

Type of data/code	File format(s)	How will data/code be collected/generated? *For re-used data/code: what are the sources and terms of use?*	Purpose of processing	Storage location	Who will have access to the data/code?

Written signed informed consent forms	.docx/.pdf files	The physical or digital consent forms will be signed prior to online or in-person interviews with urban planning experts. Physical copies will be digitised and subsequently destroyed as soon as possible.	To ensure participants are well informed about the purpose of the research and their role in it. To ensure the participants understand their participation is voluntary and they can withdraw from the research at any moment.	TU Delft OneDrive	Annika van der Nat (researcher) and Francesca Rizzetto (supervisor).
Administrative information of interviewees	.xlsx file	A list of administrative information such as dates, names, occupation, interview location and contact information of interviewees will be kept.	The list of administrative information will be kept for the purpose of project administration. By keeping one list of administrative information, physical research notes of interviews can be coded and anonymised right away, minimising risk of data breaches.	TU Delft OneDrive	Annika van der Nat (researcher) and Francesca Rizzetto (supervisor).
Written notes from interviews	.docx/.pdf files	Notes will be taken on the researcher's personal laptop during in-person or online interviews after informed consent is provided.	Anonymised notes will be used as the main data source in the research output.	TU Delft OneDrive	Annika van der Nat (researcher), Francesca Rizzetto (supervisor) and Arjan van Timmeren (secondary supervisor)

Audio and/or video recordings of interviews	.mp4 files	Audio will be recorded by the researcher's personal mobile device during in-person interviews or by the researcher's personal laptop during on-line interviews with experts after verbal informed consent is provided. Audio will be transcripted into digital anonymised notes as soon as possible, after which the audio and/or video files will be destroyed.	Anonymised notes will be used as the main data source in the research output.	TU Delft OneDrive	Annika van der Nat (researcher), Francesca Rizzetto (supervisor) and Arjan van Timmeren (secondary supervisor)
Pictures of public spaces and people in public spaces	PNG/JPEG files	Pictures will be made by digital camera during the fieldwork trip in public spaces.	Pictures of locations can be used in the research output to create visual supporting material to illustrate the current context of the site.	TU Delft OneDrive	Annika van der Nat (researcher), Francesca Rizzetto (supervisor) and Arjan van Timmeren (secondary supervisor)

II. Storage and backup during the research process

4. How much data/code storage will you require during the project lifetime?

- < 250 GB

5. Where will the data/code be stored and backed-up during the project lifetime? (Select all that apply.)

- TU Delft OneDrive

III. Data/code documentation

6. What documentation will accompany data/code? (Select all that apply.)

- Data – Methodology of data collection

IV. Legal and ethical requirements, code of conducts

7. Does your research involve human subjects or third-party datasets collected from human participants?

If you are working with a human subject(s), you will need to obtain the HREC approval for your research project.

- Yes – please provide details in the additional information box below

Yes, the research involves human subjects (experts on the site) and a HREC application has been filled out

8. Will you work with personal data? (This is information about an identified or identifiable natural person, either for research or project administration purposes.)

- Yes

Yes, the research will work with personal data, such as information concerning occupation.
All information in the research output will be anonymised and unneccessary personal identifiable data will
be destroyed as soon as possible, as stated in the data description table.

9. Will you work with any other types of confidential or classified data or code as listed below? (Select all that apply and provide additional details below.)

If you are not sure which option to select, ask your Faculty Data Steward for advice.

- No, I will not work with any other types of confidential or classified data/code

10. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question.

Collected and produced data will not be shared with any external institutions or organisations. The project will be published as a masterthesis and will be posted on the TU Delft repository, where it falls under the property rights of TU Delft.

11. Which personal data or data from human participants do you work with? (Select all that apply.)

- Proof of consent (such as signed consent materials which contain name and signature)
- Audio recordings
- Video materials
- Telephone number, email addresses and/or other addresses as contact details for administrative purposes
- Names as contact details for administrative purposes

All personal data is for administrative purposes only and will be anonymised as soon as possible.

12. Please list the categories of data subjects and their geographical location.

Interview participants are expert on the Isla Refinery site on curacao, employed by either NGO's, managing companies, universities, or government bodies.

13. Will you be receiving personal data from or transferring personal data to third parties (groups of individuals or organisations)?

- No

16. What are the legal grounds for personal data processing?

- Informed consent

17. Please describe the informed consent procedure you will follow below.

Written informed consent: a written informed consent form will be signed before the interview takes place. This can be by hand or digitally.

18. Where will you store the physical/digital signed consent forms or other types of proof of consent (such as recording of verbal consent)?

TU Delft OneDrive (see data type description table).

19. Does the processing of the personal data result in a high risk to the data subjects? (Select all that apply.)

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data in your research project.

If any category applies, please provide additional information in the box below. Likewise, if you collect other type of potentially sensitive data, or if you have any additional comments, include these in the box below.

If one or more options listed below apply, your project might need a DPIA. Please get in touch with the Privacy team (privacy-tud@tudelft.nl) to get advice as to whether DPIA is necessary.

- None of the above apply

23. What will happen with the personal data used in the research after the end of the research project?

- Anonymised or aggregated data will be shared with others

Anonymised data will be used in the research output. Personal data will be destroyed upon finishing the research project or during the research project when the data has become irrelevant or unnecessary due to adequate anonymised backups

24. For how long will personal research data (including pseudonymised data) be stored?

- Personal data will be deleted at the end of the research project

25. How will your study participants be asked for their consent for data sharing?

- In the informed consent form: participants are informed that their personal data will be anonymised and that the anonymised dataset is shared publicly

V. Data sharing and long term preservation

27. Apart from personal data mentioned in question 23, will any other data be publicly shared?

Please provide a list of data/code you are going to share under 'Additional Information'.

- No other data/code can be publicly shared – please explain below why data/code cannot be publicly shared

VI. Data management responsibilities and resources

33. If you leave TU Delft (or are unavailable), who is going to be responsible for the data/code resulting from this project?

My supervisor Francesca Rizzetto, researcher and teacher at the department environmental technology and design: f.rizzetto@tudelft.nl

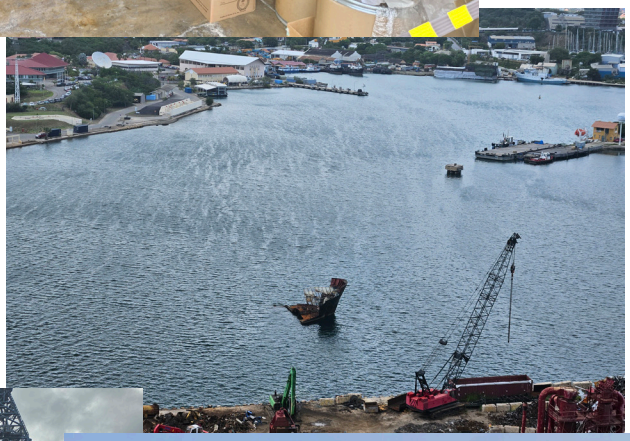
34. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

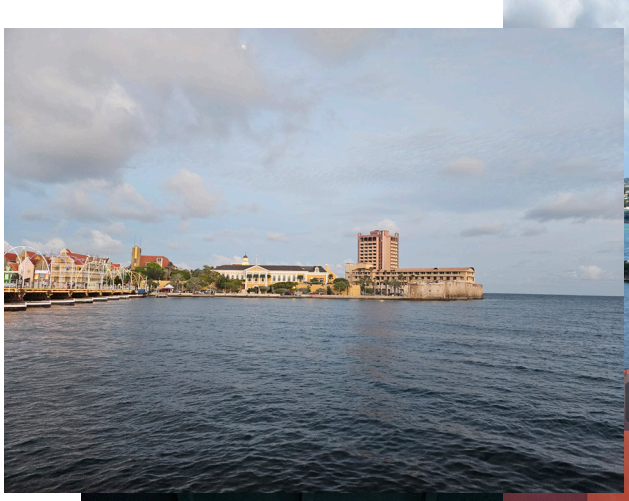
Research data are only shared within the MSc thesis: no additional resources are required.

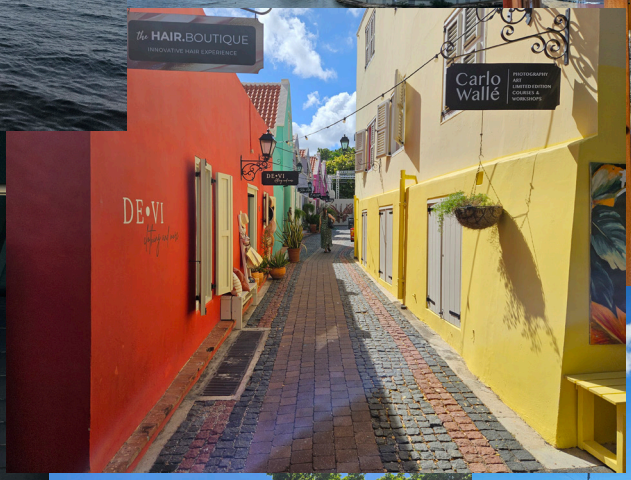
35. Which faculty do you belong to?

- Faculty of Architecture and the Built Environment (ABE)

Appendix
Fieldtrip



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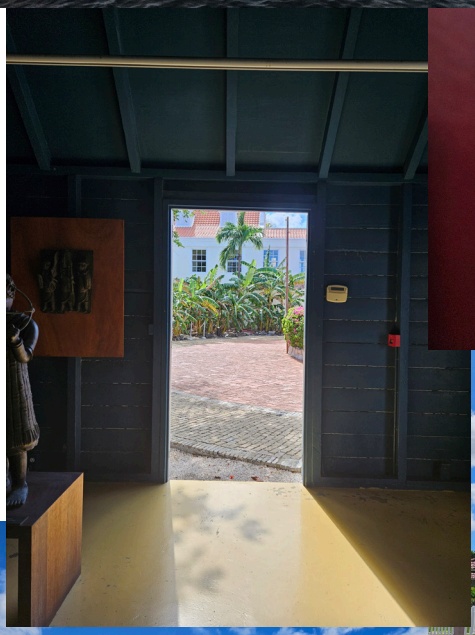
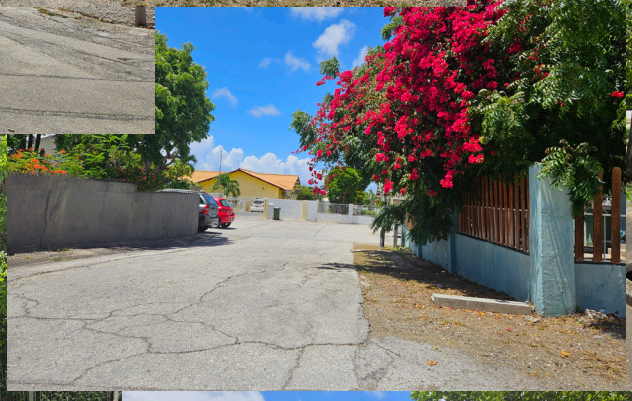
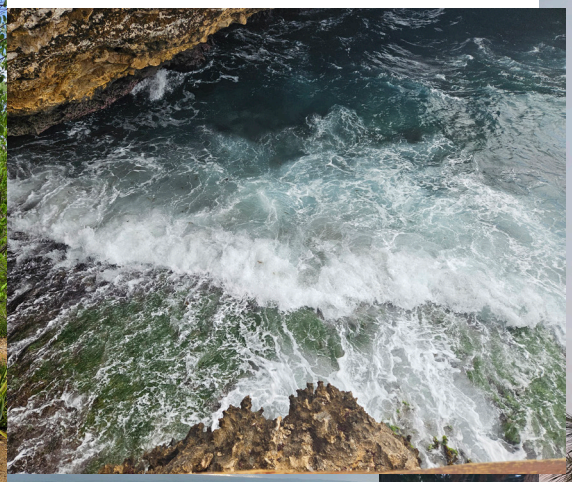
DE•VI




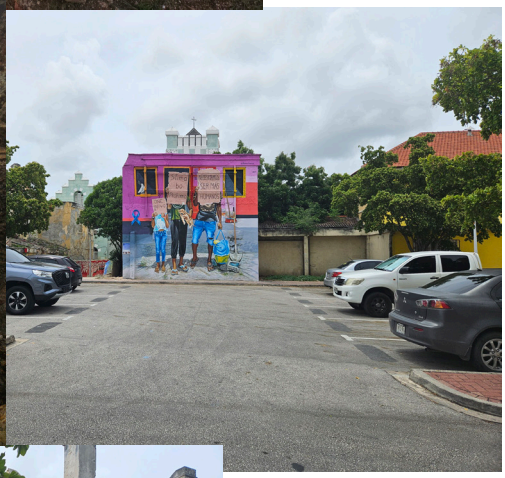


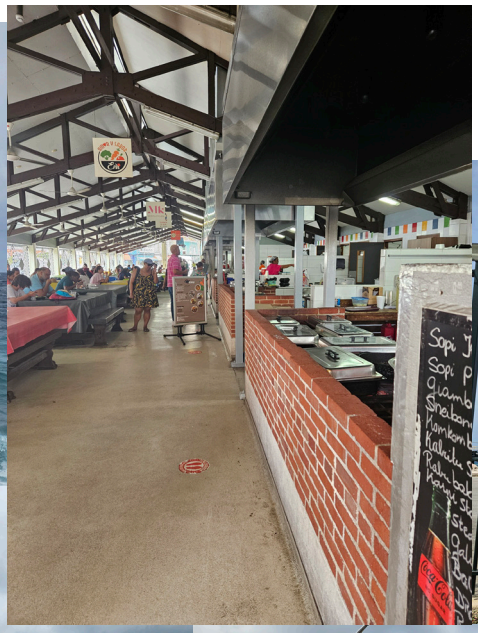











THIS FACILITY IS A
RESTRICTED AREA