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Expanding the new Ambon port

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PREFACE

This graduation thesis is written as the finishing part of the Bachelor Civil Engineering at the Rotterdam University of Applied Sciences and is conducted with the assistance of PT Witteveen+Bos Indonesia. During this graduation project I've conducted a research to explore the possibilities to expand the new Ambon port in Waai, Ambon. This research is embodied in a design assignment for a port expansion, which is sought within the given to a design that met the requirements and needs of the involved stakeholders.

Many civil engineering works throughout the islands of Indonesia have Dutch roots; a result from the long historical connection between the Republic of Indonesia and the Kingdom of the Netherlands. One of the regions where this can be seen the most is the Maluku Province in eastern Indonesia. That is one of the main reasons that the Dutch embassy and the provincial government have jointly decided to explore the possibility of a new port on the island of Ambon. This port, which is designed by a consortium of both Dutch and Indonesian engineering firms, aims to improve the economy and welfare of the inhabitants of the island Ambon. It is my task, as a graduate student at the Rotterdam University of Applied Sciences and a graduate intern at PT Witteveen+Bos Indonesia, to explore the possibility to expand the port in capacity and functionality. This thesis aims to contribute to this future scenario.

I've spend a period of five months, under the supervision of Witteveen+Bos, in the Indonesian capital Jakarta. During this time, I've worked on the research with a lot of pleasure and motivation. The development of a port is versatile and challenging, but above all it is interesting and captivating. During this period, I've had the pleasure of working with a lot of great minds. I would like to thank my university supervisor, ir. E.A. Schaap, his positive attitude and experience have been of great assistance in this challenging period. Furthermore, I would like to thank my Witteveen+Bos supervisor, ir. T. Wilms. His guidance has reshaped this document and thought me a long list of lessons I'll take with me into my further career. And finally, I would like to thank; ir. S. Meijer for his detailed assistant. With over thirty years of experience regarding port development, he has been a key player in the creation of this document.

I hope, with this thesis, to have contributed to the development of the port in Ambon and thus to the development of economy and wealth in the region. It is a beautiful island with a rich history and an unwritten future.

Jaimy ten Dam

Jakarta, 12th of January 2017

SUMMARY

A consortium of engineering firms from the Netherlands and Indonesia, is developing a new port on the Indonesian island of Ambon commissioned by the Embassy of the Kingdom of the Netherlands and the Maluku Government. The design of this port is based on the market study conducted by the Port of Rotterdam. The Port of Rotterdam provided three different scenarios based on a 3%, 6% and 8% growth in GDP. The consortium designed a port based on a 6% growth in GDP, called the "optimistic scenario". However, the government of Maluku indicated that they prefer a port development based on an 8% growth in GDP, called the 'boldly optimistic' scenario.

This thesis functions as the feasibility study for the expansion of the port, in order to fit the 8% growth in GDP, this scenario is called the "boldly optimistic" scenario. And to verify the recommendations provided by the Port of Rotterdam regarding the surface area requirements. To do so, the following research question is used: "*What is the most feasible location for the expansion of the new Ambon port in order to handle the trade capacities as predicted for the 'boldly optimistic' scenario from the market positioning study conducted by the Port of Rotterdam?"*. The location is not only selected based on port recommendations, but also on the physical characteristics present on the location.

In order to answer the research question, several methods of research are used. A field survey is conducted on the project location in the north eastern parts of the Indonesian island of Ambon. As well as literature study related to the new Ambon port project and port development in general. First the basis of design was created by summarizing the requirements from all involved stakeholders. Then using this data, the project location was analysed in order to create several different expansion variants. By using a multi-criteria analyses, an expansion to the south, southwest and west was selected as the most feasible variant. As a follow up, the area requirements based on the predicted cargo quantities where verified. Concluding that the original area requirements are over dimensioned, and can be further reduced by upgrading the container cargo handling equipment and liquid bulk storage. This reduction is so severe that by upgrading the container handling equipment, an expansion of container storage is no longer required to reach the capacity predicted in the 'boldly optimistic' scenario.

Based on these conclusions, it is recommended to conduct a cost-benefit analyses to determine the cost differences between upgrading the port and the costs of land acquisitioning. It is also recommended to conduct a new market positioning study or to verify the current market positioning study to ensure the numbers predicted and recommended are accurate enough to further design the new Ambon port.

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LIST OF ABBREVIATIONS

GDP	=	Gross Domestic Product
TEU	=	Twenty Feet Equivalent Unit
FEU	=	Forty Foot Equivalent Unit
PoR	=	Port of Rotterdam
BoD	=	Basis of Design
WiBo	=	Witteveen+Bos
RHDHV	=	Royal HaskoningDHV

NOMENCLATURE

A_{gr}	=	Required floor area	[0.65 to 0.70]
C	=	Yearly general cargo throughput across the terminal	[t/yr]
c_b	=	Throughput per berth	[t/yr] or [TEU/yr]
f_{area}	=	Ratio gross over net surface accounting for traffic lanes	[-]
f_{bulk}	=	Bulking factor due to stripping and stacking etc.	[-]
f_{TEU}	=	TEU factor	[-]
h_s	=	Average height in the storage	[m]
L_f	=	Free zone for safety and mooring	[m]
L_s	=	Vessel length	[m]
L_q	=	Quay Length	[m]
m_b	=	Berth occupancy rate	[-]
m_c	=	Acceptable average occupancy rate	[0.65 to 0.70]
$N_{20'}$	=	Number of TEU's per time period	[-]
$N_{40'}$	=	Number of FEU's per time period	[-]
N_c	=	Total tonnage handled annually	[t/yr]
N_{cb}	=	Number of berths per crane	[-]
N_{gs}	=	Number of gangs per ship	[-]
n_{hy}	=	Number of operational hours per year	[hrs/yr]
P	=	Average gang productivity	[t/hr]
r_{st}	=	Average/nominal stacking height	[0.6 to 0.9]
$\bar{t_d}$	=	Average dwell time	[days]

DEFINITIONS

A-biotic object	=	Not natural object
Bathymetry	=	The measurement of the depths of oceans, seas, or other large bodies of water.
Berth	=	A space for a vessel to dock or anchor
Biotic object	=	Natural object
Break-Bulk	=	Individual pieces of cargo transported in bigger quantities
Consortium	=	An association of businesses for the purpose of engaging in a joint venture.
Dwell Time	=	The time cargo spends at the port without moving.
Jetty	=	A wharf or landing pier
Modalities	=	Mode of transport, such as road (trucks), air (planes), river/sea (ships), rail (trains)
Socioeconomic	=	The combination or interaction of social and economic factors:
Topography	=	The measurement and mapping of the features of an area, district, or locality.
Volumetric flow rate	=	The volume of fluid which passes per unit time

1

INTRODUCTION

On the eastern Indonesian island of Ambon, an integrated fishery and container cargo port is being developed by a consortium of engineering firms and government parties. The goal of this port is to develop and stimulate the economy on the island. However, the government of the Maluku province wants to develop the port based on the 'boldly optimistic' scenario; which is has a bigger, more optimistic scale then currently the 'optimistic' scenario currently used by the consortium. In case the 'boldly optimistic' scenario becomes a feasible market option, Witteveen+Bos wants to have a preliminary feasibility study about this option ready. This leads to the main research question of this thesis:

"*What is the most feasible location for the expansion of the new Ambon port in order to handle the trade capacities as predicted for the 'boldly optimistic' scenario from the market positioning study conducted by the Port of Rotterdam?*"

In order to answer the main research question there are several sub-questions considered:

- *What are the requirements and boundaries for the development of the port based on the 'boldly optimistic' scenario?*
- *What are the possible locations for an expansion of the port and what are the current physical, socioeconomic and environmental conditions of those locations?*
- *What are the minimum dimensions of the surface area and quay wall minimum requirements for the expansion based on the predicted vessels and cargo quantities?*
- *How can the required surface area and quay wall of the total port be minimized?*

The main research question will be answered by combining the answers of the sub-questions. The sub-questions will be answered based on a combination of; field research on the island of Ambon, a port focused literature study, analysing the documents of the new Ambon port project, analysing relevant ports, and consulting with experts on the field of port engineering. Since this thesis will conduct a preliminary feasibility study; where there is little to no precise data of the location and market available, a large margin of error has to be taken into account.

Each chapter in this thesis is concluded with a paragraph containing the conclusions drawn within that chapter. Chapter two explores the background of the new Ambon port and the different development scenarios used for the development of the port. Chapter three contains the boundary conditions based on the Basis of Design. In chapter four the location of project is analysed based on a field survey and selects five possible expansion locations based on the boundary conditions. Chapter five describes the different layout variants that have been designed based on the possible expansion locations. In Chapter six the most feasible layout variant is selected by using a multi-criteria analysis. Chapter seven verifies the required dimensions of the container terminal. Chapter eight verifies the required dimensions of the container terminal. In chapter nine the land requirement is minimized by adjusting the port design. Chapter ten contains the conclusions and recommendations of this thesis. The appendices are added in a separate folder.

2

PROJECT BACKGROUND

This chapter will explore the background of the new Ambon port and the development scenarios that led to the current new Ambon port and this thesis.

2.1 Goal of the new Ambon port

The Embassy of the Kingdom of the Netherlands and the provincial government of Maluku jointly developed a plan to develop an integrated fishery and container cargo port on the Island of Ambon. This port will replace the current ports on the island. The current container port on the Island of Ambon is located in the centre of Ambon City and will reach its maximum handling capacity in 10 to 15 years while already suffering from congestion problems. The current fishery ports on Ambon are spread across the islands' coastline. Equipment is often outdated and the logistics often lack the capability to store and process fish; which limits the trading capacity and market opportunities since most of the fish can only be sold to the island and its direct surroundings. The current liquid bulk port on Ambon operates without direct threats [Lit. 1]. Furthermore, the development of a port is a key stimulant for the growth of the GDP in an area [Lit. 14].

2.2 Development Scenarios

Commissioned by the Embassy of the Kingdom of the Netherlands, the Port of Rotterdam has conducted a market positioning study for a new port on the island of Ambon. This study presents three scenarios for the market development of the island up to 2040: 'business as usual', 'optimistic' and 'boldly optimistic', see figure 2-1. Based on this study, a consortium consisting of; PT Witteveen+Bos Indonesia (WiBo), PT Royal HaskoningDHV Indonesia (RHDHV) and PT Bita Bina Semesta (BITA); conducted a feasibility study to assess the most feasible location, conceptual layout and operating system for a new port on the Island, under the project name: '*new Ambon port*'. A full list of the involved stakeholders can be found in [Appendix I].

Table 2-1 summary of the development scenarios in 2040 [Lit. 2]

Scenario	Cargo Types	Total area requirement	Peak Cargo
Business as Usual (3% growth in GDP)	• General- and Container	6 ha	1,315,000 tons
	• Fish/Food	6 ha	10,000 tons
	• Other	8 ha	-
	Total:	20 ha	1,325,000 tons
Optimistic (6% growth in GDP)	• General- and Container	15 ha	2,870,000 tons
	• Fish/Food	20 ha	100,000 tons
	• Other	8 ha	-
	• Shipyard	5 ha	-
	Total:	48 ha	2,970,000 tons
Boldly Optimistic (8% growth in GDP)	• General- and Container	20 ha	3,799,000 tons
	• Fish/Food	20 ha	100,000 tons
	• Other	15 ha	-
	• Shipyard	5 ha	-
	• Liquid Bulk	30 ha	625,000 tons
	Total:	90 ha	4,524,000 tons

During the stakeholder meeting held in Ambon City on the 25th of August, 2016, the Vice Governor of Maluku decided to develop the port based on the 'boldly optimistic' scenario [Lit. 13]. However, based on the feasibility study, the consortium overturned this decision and continued the feasibility study on the port based on the 'optimistic' scenario. The 'business as usual' scenario is never considered as an option by any of the stakeholders and will therefore not be further discussed or analysed in this document.

The feasibility study conducted by the consortium concluded that the best location for the realization of a port, based on the development requirements and location characteristics was a location near the village of Waai in north east Ambon, see figure 2-1.

Figure 2-1 location of the Waai village on Ambon, Indonesia

As a part of the feasibility study, the consortium developed a preliminary layout and design for the new Ambon port, based on the 'optimistic' scenario. Figure 2-2 shows the aerial view of the ports boundaries directly south of Waai. Figure 2-3 shows an artist impression of the port layout as conceived in 2040.

Figure 2-2 outline of the new Ambon port

Figure 2-3 artist impression of the new Ambon port

2.3 Conclusions

Based on this chapter, the following conclusions are drawn:

- *There is a significant difference in required surface area and predicted cargo quantities between the three proposed scenarios.*
- *The port developed by the consortium is based on the 'optimistic' scenario while the provincial government prefers the 'boldly optimistic' scenario. The development of a port based on the 'boldly optimistic' scenario, a bigger amount of cargo can be expected as well as the expansion with a liquid bulk terminal.*
- *The project is located on a remote location relative to Jakarta, where most stakeholders are stationed. The distance between; the offices of the consortium and the project location makes it more difficult to collect data and lowers the availability to visit the area.*

3

BOUNDARY CONDITIONS

This chapter will clarify the key criteria, assumptions, boundaries and conditions related to the feasibility study. All data is bundled together in the basis of design, which is added in appendix II.

3.1 Method of Data Collection

The data for the boundary conditions of thesis is gathered by conducting a literature study on the documents related to the previous feasibility study of the new Ambon port based on the 'optimistic' scenario. The literature study also includes literature provided by both the Delft University of Technology and the Rotterdam University of Applied Sciences. Besides a literature study, missing information was added by consulting; [redacted]; a port engineer from Witteveen+Bos.

3.2 Basis of Design

All collected data is then combined to form the basis of design which functions as a guideline for the feasibility study conducted for this thesis. At the start of this thesis, all related information was scattered over different documents, companies or was incomplete since it was not required for the development of new Ambon port in the 'optimistic' scenario. The collected data contains physical restrictions, functional requirements and cliental preferences. All aspects regarding the fishery terminal in the new Ambon port are left out of consideration in this thesis since there are no changes required. The following paragraphs summarize the key criteria from the basis of design. The full basis of design is presented in [Appendix II].

3.2.1 General Guidelines

The safety measurements and general design requirements are primarily based on the following international codes, standards and guidelines are shown in table 3-1. These are references are based on the recommendations of port engineers from Witteveen+Bos and Royal HaskoningDHV during general consultation and stakeholder meetings.

Table 3-1 applied design and safety guidelines

design aspect	code, standard or guideline	Literature
Berth Requirements	Mooring – do it safely (SEAHEALTH)	[Lit. 3]
Berth Requirements	Mooring Equipment Guidelines (MEG3)	[Lit. 4]
Terminal Requirements	International Safety Guide for Oil Tankers and Terminals (ISGOTT)	[Lit. 5]
Terminal Requirements	PIANC report no. 116 - 2012	[Lit. 6]
Terminal Requirements	PIANC report no. 153 - 2016	[Lit. 7]

However, since the feasibility study does not include exact measurements, these guidelines are only used as reference documents. The guidelines can be used further during the detailed engineering phases.

3.2.2 Functional Requirements

Table 3-2 presents the summary of the functional requirements for the new Ambon port in the 'boldly optimistic' scenario. These requirements are based on the documentation presented in the basis of design.

Table 3-2 summary of the functional requirements

Criteria	Details		
Commodities	The port will handle four types of commodities (ICT is not taken into account)	- Fish - Container Cargo - General Cargo - Liquid Bulk	
Modalities	The port will handle two types of modalities	- Sea Vessels - Road Transport	
Total Surface Area (including the current new Ambon port surface area)	Fishery General- and container cargo Liquid Bulk Other (businesses, infrastructure etc.)	$- 20\ ha$ $- 20\ ha$ $- 30\ ha$ $- 15\ ha$	
Storage Capacity	The required storage capacity is not available, therefore, the measurements provided by the port of Rotterdam will be used as preliminary area requirement		
General- and Container Cargo Storage	- General cargo is stored in both sheltered storages as on open yards - Container Cargo is stored on a concrete container yard, reefers require electricity supply		
General- and Container Quay	Suitable of handling the cargo quantities and maximum vessel size in predicted in 2040	- Container Cargo: - General Cargo: - Ship Class: - Ship Length:	$3.799.000\ tons$ $242.000\ tons$ 'Panamax' class. Up to $294\ m$
Liquid Bulk Quay	Suitable of handling the cargo quantities and maximum vessel size in predicted in 2040	- Liquid Bulk: - Ship Class: - Ship Length:	$625.000\ ton$ 'Handysize' class Up to $183\ m$

3.2.3 Equipment Requirements

Table 3-3 presents the summary of the equipment requirements for the new Ambon port in the 'boldly optimistic' scenario. These requirements are based on the documentation presented in the basis of design.

Table 3-3 summary of the equipment requirements

Terminal	Equipment type		
General- and container	- Fork Lifts	- Reach Stackers	- (Mobile) Harbour Crane
Liquid Bulk	- Transport by pipeline	- Mooring system to be determined	

3.2.4 Physical Requirements

Table 3-4 presents the summary of the physical requirements for the new Ambon port in the 'boldly optimistic' scenario. These requirements are based on the documentation presented in the basis of design.

Table 3-4 summary of the physical requirements

Criteria	Details		
Topography	On-shore a flat surface area is required. A location with a minimum in height variety compared to the sea level is preferred in order to minimize the costs of land preparation		
Bathymetry	Minimum required water depth in order for ships to dock safely (incl. 1m safety margin)	- Panamax Vessels: - Handysize Vessels:	$13\ m$ $12\ m$

3.2.5 Cliental Preferences

Besides requirements and boundaries determined by engineering and international guidelines, some of the stakeholders have stated to have several preferences regarding the development of the port. These preferences are summarized and presented in table 3-5. The cliental preferences are based on the basis of design.

Table 3-5 summary of cliental preferences

Stakeholder	Preference	Source
Tentara Nasional Indonesia - Angkatan Laut (TNI-AL)[1]	A colonel of the Indonesian navy (TNI-AL) requested to minimize the amount of inhabitants that will be relocated in the interest of port development.	[Lit. 25]
Government of Maluku	The government of Maluku stated they prefer the development of the port southwards in the direction of the Tulehu port.	[Lit. 13]

3.3 Conclusions

Based on this chapter, the following conclusions are drawn:

- *The cargo quantities as predicted by the port of Rotterdam, contain uneven patterns, which indicate inaccurate predictions in cargo quantities. For example, see table 3-6 and appendix II. While container and fish quantities vary per scenario, general cargo has the same quantities predicted; regardless of the scenario type. If other values are created with the same accuracy; this might result in inaccurate measurements. (Port of Rotterdam was not available for explanations regarding these numbers and referred back to the project leader of Witteveen+Bos when asked about an explanation for these numbers)*
- *Based on the market study conducted by the port of Rotterdam, the 'boldly optimistic' scenario will require an increase of approximately 42 ha. This area consists primarily of the liquid bulk terminal.*
- *To reach the 'boldly optimistic' scenario, an 8% annual growth in GDP is required.*
- *Cargo can only be transported via seas and roads.*
- *The recommended cargo handling equipment exists of basic and relatively inefficient equipment.*

Table 3-6 predicted general cargo quantities by the port of Rotterdam [Lit. 2]

	Scenario	2020	2025	2030	2035	2040
General Cargo	Business as Usual	153,000 tons	172,000 tons	193,000 tons	216,000 tons	242,000 tons
	Optimistic	153,000 tons	172,000 tons	193,000 tons	216,000 tons	242,000 tons
	Boldly Optimistic	153,000 tons	172,000 tons	193,000 tons	216,000 tons	242,000 tons

[1] Navy of the Republic of Indonesia

4

LOCATION ANALYSIS

This chapter will explore the location analysis that has been conducted on the new Ambon port project location south of Waai. The analysis was conducted by both a field survey and a literature study, the full analysis is presented in appendix V.

4.1 Aerial Image

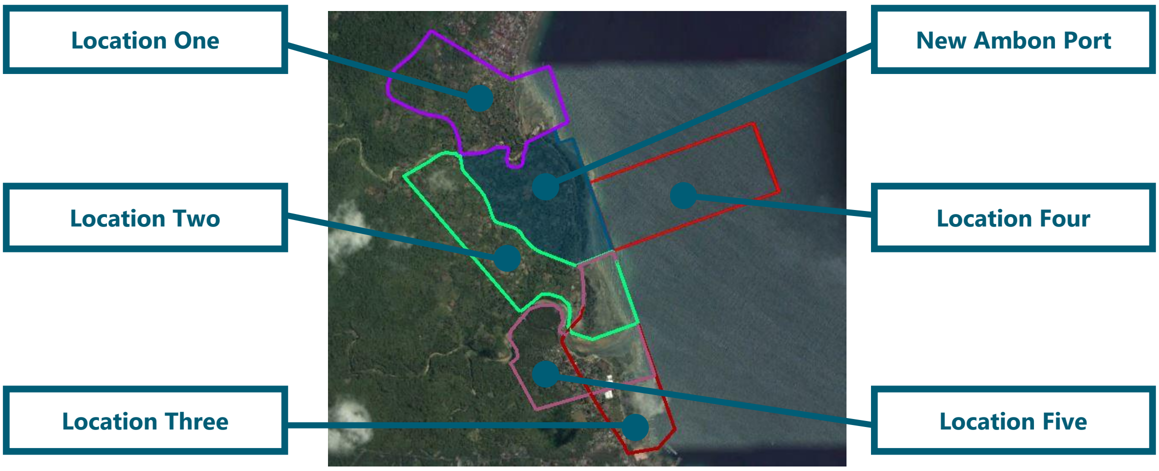
On the 14th of June, 2016, the consortium visited the project location south of Waai and created an aerial image by using a drone, see figure 4-1. This image is the most recent and accurate aerial view available. The Waai village and the location of the new Ambon port are pointed out as a location reference.

Figure 4-1 image of the project location, made on the 14th of June, 2016

4.2 Expansion locations

Based on the area requirements set in the basis of design and in consultation with coastal engineers from Witteveen+Bos; five expansion locations where selected, see figure 4-2. Each of these locations contains a minimum of $42\ ha$ in order to suit a $30\ ha$ liquid bulk terminal, $5\ ha$ container terminal and $7\ ha$ for other activities. In the following paragraphs, these five locations are further analysed.

Figure 4-2 boundaries of the five expansion locations



4.3 Analysis summary

From the 18th of October to the 20th of October, a field survey was held in the area surrounding Waai. The goal of this survey was to analyse the presence of both biotic and a-biotic obstacles and filter out possible locations that might hinder the expansion of the port. The survey took place in the area between Tulehu and Waai with a focus on the areas directly surrounding the new Ambon port.

During the survey in the area data was collected by taking photographs of objects and talking with the local inhabitants regarding the social socioeconomic aspects in the region, as well as the current spatial planning. The imagery and conclusions that resulted out of the site survey are combined with a previous site survey held by Witteveen+Bos and by the aerial images made on the Waai location. The following paragraphs contain a summary of the conclusions based on the field survey.

Interviews

Interviews with local inhabitants are challenging due to a language barrier and their suspicious attitude towards foreigners. The inhabitants explained that the fishing industry is the main business for these villages along the shoreline. This is partially caused by the absence of suitable land for farming grounds due to hills and forest. Other businesses in the area were focussed on selling and processing of food sold in the villages. There were few to none bigger businesses operational in the area.

Infrastructure

During the field survey, the main roads have been measured and the available modes of transportation have been analysed. Based on the analysis it is concluded that the only modes of transport in the area exist of either road transport, or sea shipping. There is no train rail present and the rivers do not carry enough water for inland shipping.

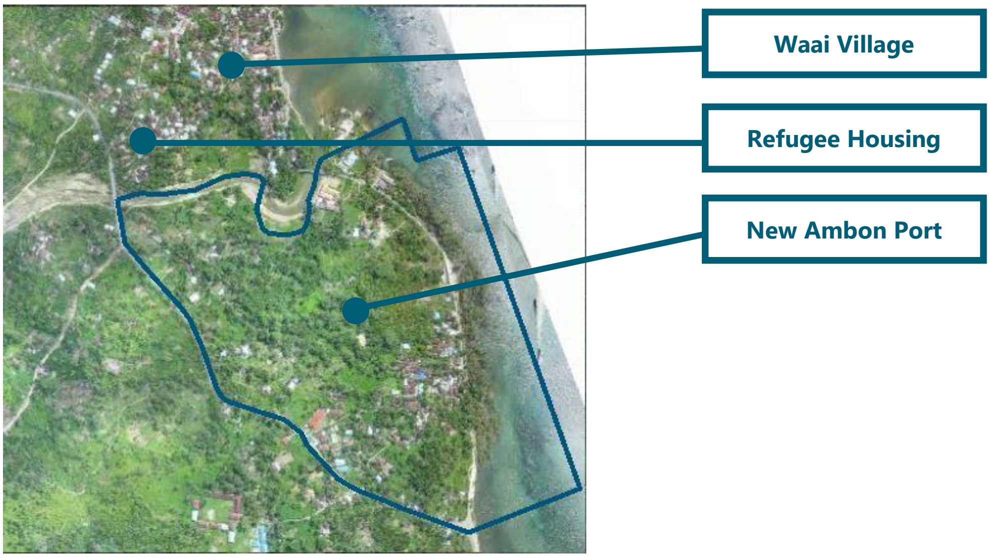
Land Usage

The land usage varies mainly between overgrowing nature and urban areas. The area is poorly accessible due to the density of the woodlands and constructions. Most of the smaller roads in the area exist out of private roads which were not accessible for the survey. There were few constructions higher than 2 stories in the area, even in the Waai village the housing existed primarily out of the traditional one floor housing. Between the overgrown areas and urban areas, sporadic farm lands were found. These were usually not bigger than $10\ m$ by $10\ m$.

Refugee Camp

One of the main conclusions drawn from the conversations with the people was the presence of a residential area on the south side of Waai which was constructed as a refugee site for Christians after the Ambon war in 2003[1], see figure 4-3. While unclear how big this zone is exactly and how many inhabitants it has, the local inhabitants made clear that this area was of great importance to the community, which might cause severe protest among the local community.

Figure 4-3 location of the refugee housing



Residential area

The area surrounding the new Ambon port contains spread out residential areas. In the north of the new Ambon port lays the village of Waai and in the South; the village of Tulehu. In between these villages there are sporadic clusters of houses and farms, see figure 4-6. The housing within the current new Ambon port is left out of this thesis since it falls out of the scope of this thesis. While forced relocation is possible and the government is willing to assist in this matter, during the stakeholder meeting held at the city hall in Ambon city on the 18th of October, 2016, a colonel of the Indonesian navy insisted that a minimum amount of forced relocation for the current inhabitants would be taken into account [Lit. 24].

Roads

The area contains two main roads; the national road and the local road, see figure 4-7. The national road (yellow) stretches all over the island and functions as the equivalent of a highway and is 8 to 10 m wide. The local road (orange) will already be partially demolished due to the development of the new Ambon port. The remaining road is 4 to 5 m wide. In figures 4-6 and 4-7 the outline of the current outline for the new Ambon port is shown in blue.

[1] The Ambon war was a religion based civil war between Christians and Muslims on the island of Ambon that lasted from 1999 to 2003.

Figure 4-4 housing in the surrounding of the new Ambon port

Figure 4-5 roads in the surrounding of the new Ambon port

Woodlands

The vast majority of Ambon consists of overgrown jungle; this applies to parts of the surroundings of the project location as well. Directly behind both Waai and Tulehu a dense jungle flourishes. The hinterland behind the current new Ambon part is less densely overgrown and contains sporadic farming, grass lands and forest/jungle; see figures 4-6, 4-7 and 4-8.

Figure 4-6 jungle west of Waai (A)

Figure 4-7 jungle west of Waai (B)

Figure 4-8 woodlands surround the project location

Mangrove Forests

Indonesia contains numerous mangrove forests. These forests often function as coastal defences and are an important part of the natural eco system and socioeconomic environment [Lit. 8]. The coast near the project location contains two separated mangrove forests, see figures 4-9 and 4-11.

Rivers

The area surrounding the project location contains two rivers. Both mostly dry but can contain a rapid flow of water during the rainy season or after heavy rain in the dry season. The volumetric flow rate of these rivers is unknown. Also the width of the river varies each year due to natural morphology. But can be up to seventy meters wide at the river mouth and as narrow as two meters in the hinterland, see figures 4-10 and 4-11.

Figure 4-9 mangrove forest south of the new Ambon port (A)

Figure 4-10 river south of the new Ambon port (B)

Figure 4-11 location of rivers and mangrove forests

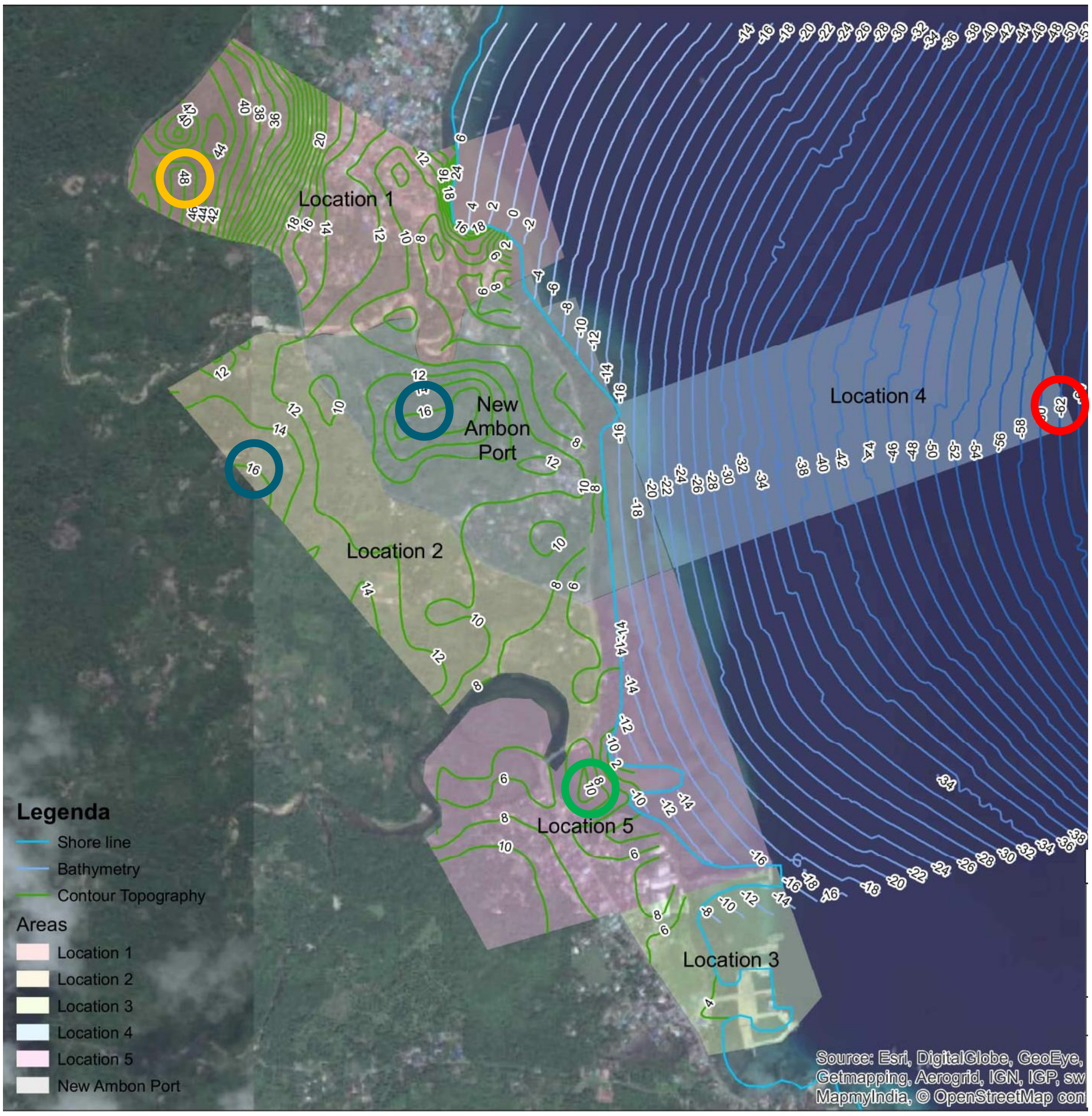
Topography and Bathymetry

Figure 4-12 shows that the topography of the project area contains adequate differences in elevation between the locations. For example; location one has a peak height of $48\ m$ above sea level (orange circle), a severe difference with locations three and five, which have a peak of $10\ m$ above sea level (green circle). The highest point in location two; peaks at $16\ m$, equivalent to the current port (blue circles).

The off-shore bathymetry shown in figure 4-12 is slightly off in comparison to the on-shore topography due to a lack of 'zero-point'. These 'zero-points' are used to ensure the overlap between two data sets is accurate. Since there were no 'zero-points' available, the overlap was done by hand. The image shown in figure 4-12 is the most accurate result feasible, the data is verified by comparing it with the results of the on-site bathymetry measurements conduct near the new Ambon port shore, which shows similar results, see appendix IV. At this point during the feasibility study this scale of accuracy is considered sufficient. At the following stages such as detail engineering, more accurate on-site measurements will be required.

The off-shore bathymetry exists of a rapidly deepening sea bottom as can be seen in figure 4-12. This results in a suitable environment for the docking of larger vessels; especially since the quay wall of the new Ambon port and expansions are located on a couple meters off-shore instead of directly along the shoreline. The downside of the deepening water is the investment required for location four, which contains water depths up to $60\ m$, see red circle in figure 4-12.

Figure 4-12 topography and bathymetry on the project location (peak levels are circled), appendix IV



4.4 Conclusions

Based on this chapter, the following conclusions are drawn:

- *There are various a-biotic and biotic obstacles located within the proposed port expansions.*
- *Locations one, two, three and five contain a similar off-shore elevation. Location four reaches greater water depths due to its expansion into the sea.*
- *The area between the two rivers contains relatively little urban area in comparison with the area north (Waai) and south (Tulehu) of the rivers.*
- *Location one contains the highest difference in on-shore elevation (48 m) and location three and five contain the smallest differences (10 m). Location four contains the overall highest elevation difference with a maximum water depth of minus 68 m below mean sea level.*
- *Locations one, two, three and five require the relocation of inhabitants; the quantity however varies per location. Location four is the only location that does not require the relocation of any inhabitants*
- *Even though location three and five fulfil the cliental preference of a port expansion in the direction of Tulehu, these locations have to overcome severe obstacles which might not be suitable for the expansion of a port.*
- *There are several woodlands present, which contain a variety in natural wildlife, both in fauna and flora. These areas will make an environmental impact when demolished as well as an increased financial costs due to the amount of effort required to prepare this land compared to relatively open grounds*

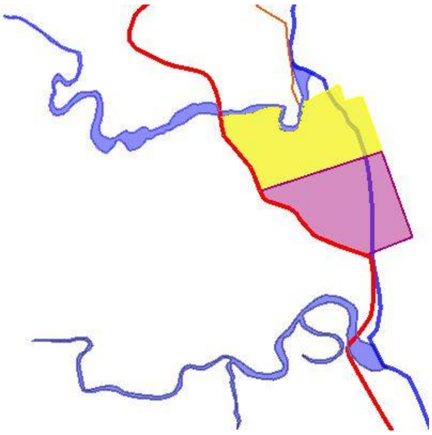
5

LAYOUT VARIANTS

This chapter will explore the characteristics of the different layouts, and will clarify the present obstacles

5.1 Variation Validation

Figure 5-1 current new Ambon port layout



Based on the five locations presented in paragraph 4.2; seven different layout versions were created, two variants for both locations one and two, and one variant for locations three to five. Location one and two have multipliable variants because the differences in layout resulted in a significant difference, while for the other locations; a change in layout was either unpractical, or caused no significant difference in functionality. See appendix V for the full layout study. Figure 5-1 shows the layout of the current new Ambon port. Yellow indicates the fishery terminal and purple indicates the container terminal. The roads (red/orange) and rivers (blue) and the coastline (blue) are presented as an indicator of the ports' location compared to the island and sea. All of the seven layouts contain the same assumed quay lengths for each type of terminal and contain the same surface area per terminal. In the following paragraphs the seven layout variants will be presented and examined.

5.2 Seven Variations

Layout 1A

Figures 5-2 and 5-3 show layout 1A. This layout is located on the north side of the current new Ambon port. The river is converted into a canal to straighten the river and maximize the possible land usage[1]. Straightening the river into a canal frees up a 2 ha land area on the south side of the canal which will be added to the current new Ambon port. Directly north of the canal is the container terminal with the liquid bulk terminal on the north of the container terminal.

Figure 5-2 port expansion layout 1A

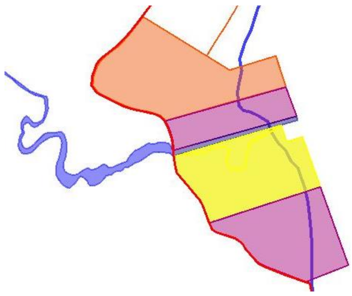


Figure 5-3 obstacles within layout 1A

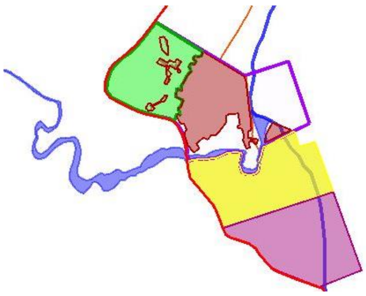


Figure 5-4 legend for layout 1A

[1] Dimensions for the canal are unknown since there is no information regarding the flow and water levels

Layout 1B

Figures 5-5 and 5-6 show layout 1B, this layout has a lot in common with layout 1A, except for the layout of the container terminal and liquid bulk terminal. The aspects regarding the fishery port and canal remain the same. In layout 1B the liquid bulk terminal borders the canal with directly north the container terminal. The big difference between the two locations is the distance between the local community in Waai and the liquid bulk terminal

Figure 5-5 port expansion layout 1B

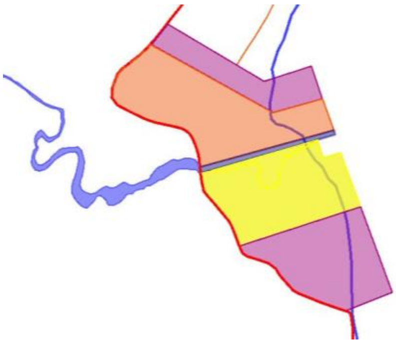


Figure 5-6 obstacles within layout 1B

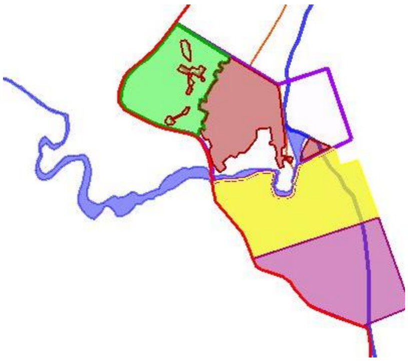


Figure 5-7 legend for layout 1B

Layout 2A

Figures 5-8 and 5-9 show layout 2A, this layout is located south, south west and west of the current new Ambon port. The national road will be rerouted in order to create an area for the container terminal. The container terminal borders the current container terminal on the south side. The liquid bulk terminal is located south of the container terminal extension and runs into the hinterland where the storage of the liquid bulk cargo will take place.

Figure 5-8 port expansion layout 2A

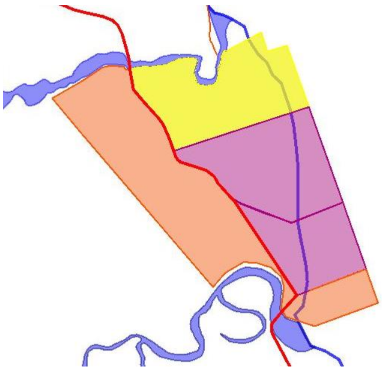


Figure 5-9 obstacles within layout 2A

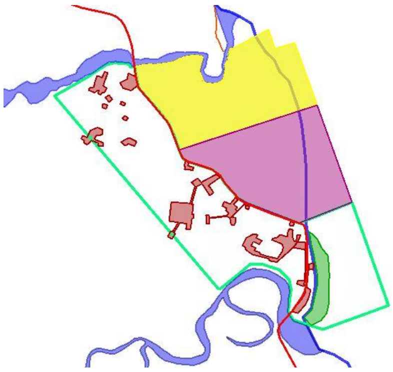


Figure 5-10 legend for layout 2A

Layout 2B

Figures 5-11 and 5-12 show layout 2B, in general the locations of the container terminal and liquid bulk terminal are the same compared to layout 2A. However, layout 2B does not reroute the national road but instead relocates the offices and parking spaces to the other side of the national road, minimizing the influences on the national road.

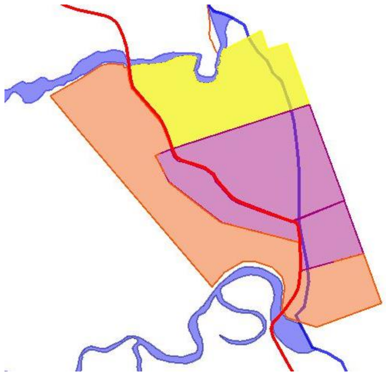


Figure 5-11 port expansion layout 2B

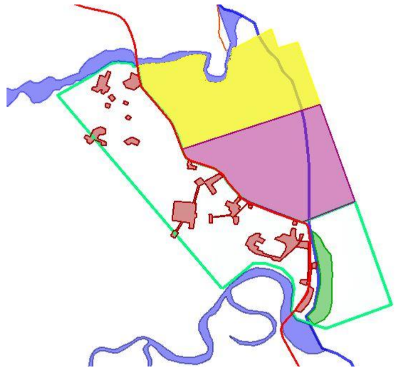


Figure 5-12 obstacles within layout 2B

Figure 5-13 legend for layout 2B

Layout 3

Figures 5-14 and 5-15 show layout 3, this layout is located on the south of the current new Ambon port. It stretches across the current ferry and fishery port of the Tulehu village and by doing so crosses a river. Just as done in layout 1A and 1B, this river will be converted into a canal to minimize the water surface area and maximizing the available on-shore area. The canal is located on the border between the container terminal and the liquid bulk terminal.

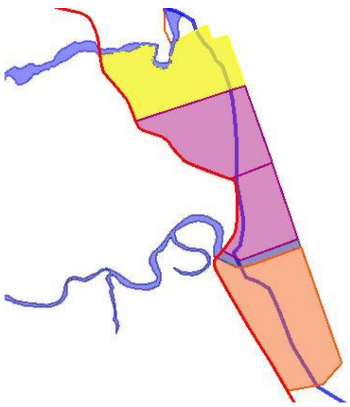


Figure 5-14 port expansion layout 3

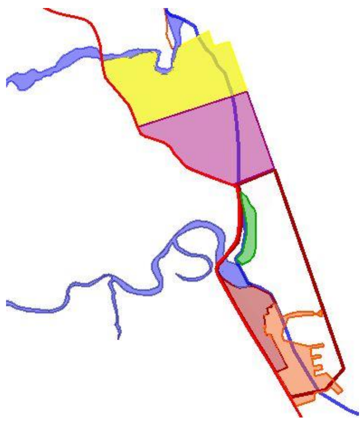


Figure 5-15 obstacles within layout 3

Figure 5-16 legend for layout 3

Layout 4

Figures 5-17 and 5-18 show layout 4, this layout is located on the east of the current new Ambon port. This requires the expansion to be built on either land reclamation or on a pile sheet deck. This layout requires both the storage as the handling of container cargo and liquid bulk cargo above the sea.

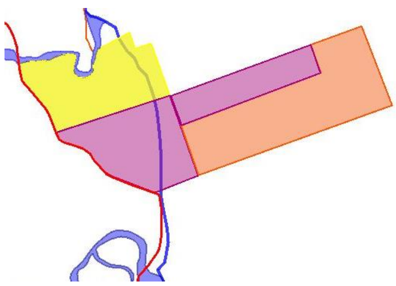


Figure 5-17 port expansion layout 4

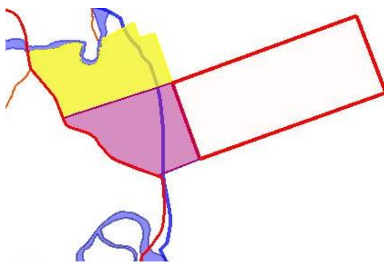


Figure 5-18 obstacles within layout 4

Figure 5-19 legend for layout 4

Layout 5

Figures 5-20 and 5-21 show layout 5, this layout is located on the south of the current Ambon port. To minimize the usage of urban area; this location stretches into the hinterland along the river. Just as in layout 1A, 1B and 3, a part of the river is required to be converted into a canal in order to maximize the land usage. The container terminal borders the container terminal of the new Ambon port and the Liquid bulk terminal is located on the south.

Figure 5-20 port expansion layout 5

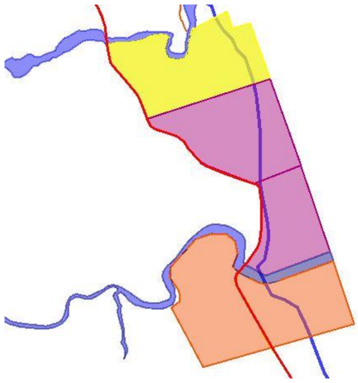


Figure 5-21 obstacles within layout 5

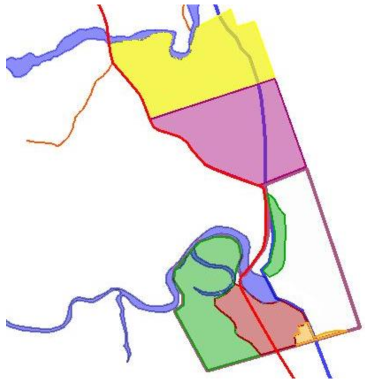


Figure 5-22 legend for layout 5

5.3 Conclusions

Based on this chapter, the following conclusions are drawn:

- *Layouts 2A, 2B and 4 contain the least amount of obstacles based on surface area.*
- *Layout 3 contains most obstacles based on surface area, with the whole on-shore area blocked with urban area and a port.*
- *Layout 1A, 1B, 3 and 5 require the construction of a canal in order to control the river within the expansion.*
- *Layout 2A, 2B, 3 and 5 contain mangrove forest, these are protected by national law and therefore might cause legal problems when planning to remove them.*
- *Layout 1A and 1B contain a container terminal which is separated from the container terminal of the current new Ambon port. This allows the exploitation by a second terminal operator but eliminates the possibility to re-use already present equipment in the current new Ambon port.*
- *Layout 2A is the only layout that directly alters the national road. However, this is only a rerouting that shortens the overall length of the road without influencing the connectivity or traffic flow in the area. (Not more than other layouts)*

6

MULTI CRITERIA ANALYSES

This chapter contains the results of the MCA used to select the most feasible expansion location, including an explanation of the MCA itself. The full Multi-Criteria Analyses is presented in appendix VI.

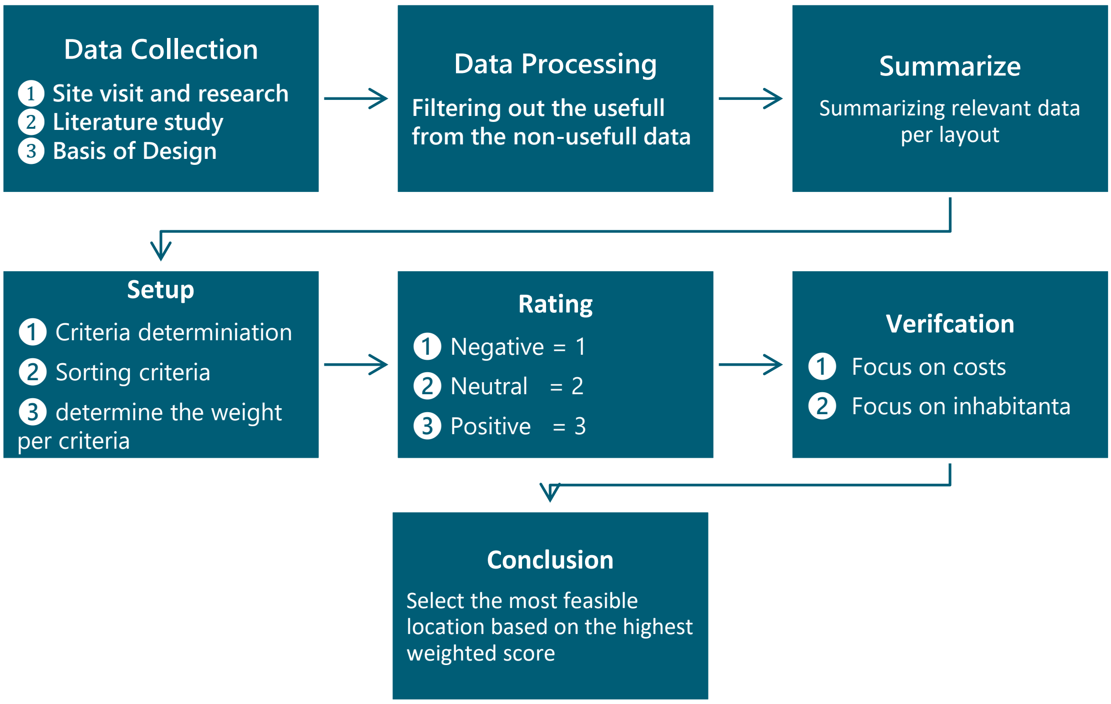
6.1 Introduction to the MCA

The purpose of the location evaluation study is to evaluate seven layout variants of the new Ambon port expansion. The Multi-Criteria Analysis (MCA) is used to form an objective selection of the most feasible location according to the required criteria. Once a location/layout is selected by the MCA it will be discussed with the stakeholders to ensure that the location is endorsed.

During the stakeholder meetings held in Ambon between the 17th and 21st of October, on-site data was collected in the area surrounding the new Ambon port. The data consists of physical conditions, interviews with locals and imagery of the areas. A bathymetry survey was held during a previous mission on the location when drone images of the location were made as well.

The data used in the MCA is based on the collected on-site data, a literature study and the criteria from the basis of design. This data will be bundled together to form the MCA. The MCA will then, by presenting a score for each variant, present the most feasible layout and location for the expansion of the port. A flowchart on the methodology is presented in figure 6-1. The full multi-criteria analysis is presented in appendix VI.

Figure 6-1 methodology for the MCA setup



6.2 Method

6.2.1 Scoring method

To allow a proper scoring of the selected criteria, the 'functional requirements' of the port were formulated and used as benchmark for scoring. Each criterion has a weighing appointed to it which will be multiplied by the scoring factor. The scoring factor is related to the characteristics of each location and layout. The guidelines in table 6-1 are used to score the criteria; an example is shown in figure 6-2.

Table 6-1 numerical guidelines for the MCA

Scoring	Numeric Score	Weighing	Numeric Score
Negative	1	Least Influential	1
Neutral	2		2
Positive	3	Neutral	3
			4
		Most Influential	5

Figure 6-2 example scoring of a MCA criterion

Example:
The safety for the surrounding inhabitants and environment is very important since the port is built to improve the economy of Ambon in order to create a better life standard on the island. Risking this, would undo most benefits created by the port therefore; the aspect 'safety' has been given a factor of 5.
Layout 1B scores 'positive' on the criterion; 'safety', which has a weighing factor of 5. This means the weighted score will result in: '$3 * 5 = 15$'. Giving Layout 1B a total score of 15 on the criterion 'Safety'.

In order to verify the accuracy of the MCA, two more analyses with a different weighing are applied to the locations and layouts; of which one is focused on the costs of the development and the other one is focused on the local inhabitants. To do so, the weighing of each criterion is adjusted based on the focus of the table. The scoring method will remain the same as shown in table 6-1, only the weightings will change.

6.2.2 Criteria clarification

Table 6-2 shows the ten criteria, their weight and functional requirements as used in the MCA. The criteria are split up in three different categories: physical aspects, socio economic aspects and development aspects.

Table 6-2 clarification of the criteria used on the location and layout selection

Category	Criteria	Functional requirement	Weight
Physical Aspects	Biotic obstacles	Effort required to overcome natural obstacles such as water masses (rivers) and flora (woodlands and mangrove forest)	3
	A-biotic obstacles	Effort required to overcome man made obstacles such as infrastructural, residential and corporate constructions	5
	Topography	Height differentiation on the location	4
	Bathymetry	Dredging aspects regarding the required and available water depths	4
Socio Economic Aspects	Relocation	Forced relocation of inhabitants	5
	Regional Employment	Creation/loss of employment in the surroundings of the port	4
	Safety	Risks for the surrounding environment and inhabitants	5
Development Aspects	Road Interference	Influences on the regions road accessibility	2
	Phasing Options	Flexibility to develop the port in different phases depending on the actual growth and needs of the port	5
	Identified Risks	Present known risks on the location of the port expansion	5

6.3 Numerical MCA Results

Table 6-3 shows the summarized version of the filled in MCA tables, all values in the table are already weighted and summed up. Table 6-4 shows the results of the two verification analyses that have been conducted. Since all three MCA variants give the same outcome, it can be concluded that "layout 2A" is the most feasible option.

Table 6-3 MCA results

	Criterion	Weight	Layout 1A	Layout 1B	Layout 2A	Layout 2B	Layout 3	Layout 4	Layout 5
Physical Aspects	Biotic Obstacles	3	3	3	6	6	3	9	3
	A-biotic Obstacles	5	5	5	10	10	5	15	5
	Topography	3	3	3	6	6	9	3	9
	Bathymetry	3	6	6	6	6	3	9	3
Socio-Economic Aspects	Relocation	5	5	5	15	15	10	15	10
	Regional Employment	5	10	10	15	15	5	15	10
	Safety	5	5	15	15	15	5	5	5
Development Aspects	Road Interference	5	15	15	15	5	15	15	10
	Phasing Options	3	3	3	9	9	3	3	6
	Identified Risks	3	6	6	6	6	9	3	6
	Total Score:		59	69	**105**	101	69	88	71

Table 6-4 results of the verification MCA tables

	Layout 1A	Layout 1B	Layout 2A	Layout 2B	Layout 3	Layout 4	Layout 5
Total score (focus on costs)	47	53	**85**	83	57	76	59
Total score (focus on community)	61	71	**103**	93	67	92	67

6.4 Selected Expansion

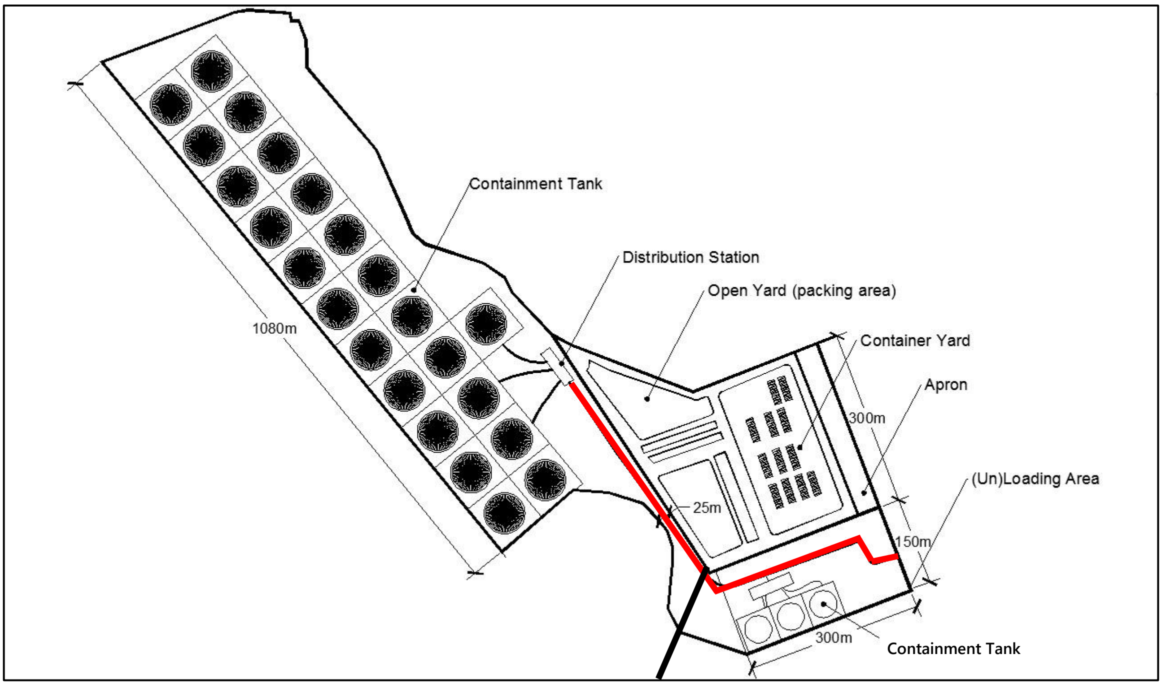
6.4.1 Road Diversion

As part of layout 2A, the national road will be rerouted; shortening the overall length of the road, since the development of the port overlaps all current structures within the location, this does not influence the connectivity of the area, see figures 5-8 and 5-9.

6.4.2 General Layout

Figure 6-3 on the next page shows a preliminary layout of the port expansion. This image provides a concept of the possible filling of the terminals. (note: this image is used for perspective purposes only)

Figure 6-3 preliminary port expansion layout



The preliminary layout in figure 6-3 shows the storage of liquid bulk in the hinterland to the west. The liquid is transported there via pipelines (red) from the (un)loading area to the distribution station and underpass the national road. The layout does not show a mooring method for liquid bulk.

6.5 Conclusions

Based on this chapter, the following conclusions are drawn:

- *Layout 2A is selected as the most feasible option based on the main weighing and both the verification weighing's, see tables 6-3 and 6-4. Layout variant 2B is the second most feasible option.*
- *Location two contains the most feasible conditions for the development of a port expansion, which is the main reason for the high scores of both variant 2A and 2B.*
- *Layout variant 4 is the third most feasible option, however is slightly less feasible than option 2A and 2B due to the environmental risks and the financial aspects required to build off shore.*
- *The ranking between layout variants varies little between the main weighing and the verification weightings. This is caused due to the significant differences per location of the variants such as the elevation, presence of rivers and housing etc.*
- *The expansion of the port on location two corresponds with the original plan of Witteveen+Bos regarding the location of the expansion [Lit. 17].*

7

CONTAINER TERMINAL DIMENSIONS

This chapter will explore the dimensions and layout of the quay length and storage area of the general and container cargo. The full analyses can be found in appendix VII.

7.1 Introduction

The dimensions of the port can be split up in three main components: 'the storage area', 'the quay' and 'other' (offices, infrastructure, safety space etc.). The dimensions of these components are related to the cargo quantities, cargo typology and the size of the vessels docking in the port. This chapter will determine both the quay length and the storage area required, based on the cargo capacities predicted in the market analysis. The component 'other' will be estimated, since this area requirement can be altered based on the available area and cliental preferences. Neither of these are available at this stage of the development but will be an important part of the detailed design in a later stage.

As is done in the current new Ambon port, the container terminal will handle both general- and container cargo. The quay requirement and required storage area for both cargo types are determined in the following paragraphs. For further exploration of the calculations see appendix VII.

7.2 Quay Requirements

7.2.1 Method

Container cargo requires a solid quay with a direct physical connection to the container yard to move the cargo from the vessels to the storage by crane, forklift or equipment alike. The lengths of the general- and container cargo quays are based on guidelines from '*Ports and Terminals (2012)'* by ir. H. Ligteringen and ir. H. Velsink [Lit. 9].

First the amount of required berths is determined by estimating the annual throughput per berth using formulas (1.1), (1.2) and (1.3). Formula (1.1) determines the throughput per berth based on general cargo and formulas (1.2) and (1.3) determine the throughput per berth based on container cargo. Once the annual throughput per berth is known; the 'total amount of berths required' is determined by using formula (1.4). Formula (1.4) is used for both general cargo and container cargo.

$$\boldsymbol{c_b} = \boldsymbol{P * N_{gs} * n_{hy} * m_b} \qquad \textbf{(1.1)}$$

c_b	=	$annual\ throughput\ per\ berth\ in\ tonnage\ general$	[t/yr]
P	=	$average\ gang\ productivity$	[t/hr]
N_{gs}	=	$number\ of\ gangs\ per\ ship$	[-]
n_{hy}	=	$number\ of\ operational\ hours\ per\ year$	[hrs/yr]
m_b	=	$berth\ occupancy\ rate$	[-]

$$\overline{c_b} = P * f_{TEU} * N_{cb} * n_{hy} * m_b \quad (1.2)$$

$\bar{c_b}$	=	*annual productivity per berth in TEU*	[TEU/yr]
P	=	*net production per crane*	[moves/hr]
f_{TEU}	=	*TEU factor*	[-]
N_{cb}	=	*number of cranes per berth*	[-]
n_{hy}	=	*number of operational hours per year*	[hrs/yr]
m_b	=	*berth occupancy factor*	[-]

The TEU-factor in formula (1.2) is determined by using formula (1.3).

$$f_{TEU} = \frac{N_{20'}+2*N_{40'}}{N_{20'}+N_{40'}} \quad (1.3)$$

f_{TEU}	=	*TEU factor*	[-]
$N_{20'}$	=	*number of TEU's per time period*	[-]
$N_{40'}$	=	*number of FEU's per time period*	[-]

$$n = \frac{C}{c_b} \quad (1.4)$$

n	=	*number of berths*	[-]
C	=	*yearly general cargo throughput across the terminal*	[t/yr]
c_b	=	*throughput per berth*	[t/yr]

The length of each berth is determined by the size of the vessels docking. Using formula (1.5) the minimum length per berth will be determined. This is done based on the amount of berths and the vessel length. The free zone between vessels depends on the size of the vessel. The free zone functions as a safety margin during mooring operations. There is no exact guideline for the distance related to the vessel size since it's partially dependant on the type of mooring assistance, port layout and cargo type. The free zone for smaller vessels is approximately 15 m and can build up to 30 m for bigger vessels [Lit. 9].

$$L_q = \begin{cases} L_{s,max} + 2 * L_f & for\ n = 1 \\ 1.1 * n * (\overline{L_s} + L_f) + L_f & for\ n > 1 \end{cases} \quad (1.5)$$

L_q	=	*quay length*	[m]
$L_{s,max}$	=	*max length of the main vessel*	[m]
L_f	=	*free zone between for safety and mooring*	[m]
n	=	*number of berths*	[-]

7.2.2 Required General Cargo Quay Length

Number of Berths

In order to determine the number of berths required to handle the expected general cargo in 2040, several variables will have to be defined. According to the market study by the Port of Rotterdam, the port expects a total throughput of 242,000 tons of general cargo in 2040. Table 7-1 shows the average gang production per type of general cargo. According to the current cargo turnover (general- and container cargo) in the Pelindo IV ports in Ambon, the port main import product is cement (38.4%). Followed by food and lifestyle products such as sugar (9%), noodles and snacks (8%) and bottled water (8%). These types of product are mostly described as break-bulk. However, according to the Port of Rotterdam, most of the imported cargo is containerised. An estimate of 70% containerised and 30% break-bulk will be used as basis. In the calculation this will be written in the time of handling, 30% of the operational hours will be handling break-bulk (10 t/hr) and 70% of the operational hours will be handling containerized general cargo (50 t/hr). The bigger amounts of containerised general cargo are partially explained by the high amounts of food produces, which have to stay cooled, being exported from Ambon; for example, 21% of the total export consists out of cloves, 28% out of frozen fish and 30% out of copra (coconut flesh).

Table 7-1 average gang productivity per type of general cargo [Lit. 9]

Type of general cargo	t/hr
Conventional general cargo (break-bulk)	8.5 to 12.5
Timber and timber products	12.5 to 25
Steel products	20 to 40
Containerised cargo	30 to 55

The vessels docking the general cargo quay have an estimated length of 120 m. Vessels of this size has an average of 2 gangs. Assuming the port works two eight hour shifts per day, six days per week; the port berth will have 4,992 operational hours per year, of these hours, an estimated 1,997 hours are used for break-bulk and 2,995 hours are used for containerized general cargo. A low occupancy rate of 0.65 can be expected due to delays in shipping caused by (for example) extreme weather conditions. Table 7-2 shows the capacity per berth for both break bulk and containerized cargo within the container terminal.

Table 7-2 annual productivity per berth calculated

	Variable	Unit	Break-Bulk (30%)	Containerized General Cargo (70%)
Variables	P	t/hr	10	50
	N_{gs}	-	2	2
	n_{hy}	hrs/yr.	1747	3494
	m_b	0.65 to 0.90	0.65	0.65
Result	c_b	t/yr.	19,467	227,110

By combining the berth productivities of both; break-bulk and containerized general cargo, the average throughput per berth is determined. This results in the following calculation:

$$c_b = 19{,}467\ t/yr + 227{,}110\ t/yr$$
$$c_b = 246{,}579\ t/yr$$

The berth productivity is then used to determine the total amount of berths required to handle the total annual throughput of the terminal. The annual throughput of $242{,}000\ tons$ will be divided by the annual capacity per berth. This is done with formula (1.4):

$$n = \frac{C}{c_b} \qquad (1.4)$$
$$n = \frac{242{,}000}{246{,}579}$$
$$n = 0{,}98$$
$$n = 1 \text{ berth}$$

In order to handle the total expected quantity of general cargo in 2040 in the boldly optimistic scenario; a single berth is required for the (un-)loading of general cargo.

Berth Length

Formula (1.5) is used to determine the minimum berth length based the maximum length of docking vessels. In the previous paragraph the amount of berths required was estimated at a single berth. The $L_{s,max}$ for the general cargo vessels is assumed on 120 m and the free zone for safety and mooring is set at 15 m [Lit. 9]. Filling this data into formula (1.5) (one berth) results in:

$$L_q = L_{s,max} + 2 * L_f \quad (1.5)$$
$$L_q = 120 + 2 * 15$$
$$L_q = 150\ m$$

From this it is concluded that a minimum berth length of $150\ m$ is required.

7.2.3 Required Container Cargo Quay Length

Number of Berths

In order to determine the number of berths required to handle the expected container cargo in 2040, several variables will have to be defined. According to the market study by the port of Rotterdam; the port expects a total throughput of $3{,}799{,}000\ ton$ or $316{,}583\ TEU$. In order to reach this capacity, a certain amount of berths is required. The amount of berths depends on the capacity of the berth itself and the total required capacity of the port. Formula (1.2) is used to calculate the average annual production per berth.

In order to determine the required length, this paragraph will explore the variables used. The net productivity per crane 'P' is defined as; "*the average number of containers moved from ship to shore and vice versa during the period between berthing completed and deberthing started*". This period includes all sorts of unproductive intervals such as for crane repositioning from one bay to another, removal of hatches and replacing them, time loss between shifts and simple repairs of the cranes. Since the new Ambon port is expected to mainly handle feeder vessels with a TEU capacity of 1,200 TEU to 1,800 TEU and Panamax vessels with a TEU capacity of 2,800 TEU to 5,100 TEU the following assumptions will be used as a base for the new Ambon port:

"A modern terminal which receives 4,000 to 5,000 TEU vessels on a regular basis and working 24 hours per day, 360 days per year and receives average vessels of approximately 2,000 TEU and a length of 250 meter contains an average of three cranes per berth, a low berth occupancy factor of 35% and a net crane productivity of 25 moves per hour and a TEU-factor of 1.5." [Lit. 9]

This is further supported by the imagery in the feasibility report conducted by the consortium wherein three STS cranes are shown [Lit. 10]. In order to use formula (1.2), the TEU-factor will be determined first by using formula (1.3). The TEU-factor is based on the ratio between container types, shown in tables 7-3 and 7-4.

Table 7-3 assumed cargo ratio per type based on the new Ambon port ratio [Lit. 2]

Cargo Type	% of Total Throughput	Amount in TEU's
20-foot Standard Container	52.2%	174,753
40-foot Standard Container	2.2%	6,965
Total Standard Containers	54.4%	181,718
20 Foot Reefers	39.3%	124,417
40 Foot Reefers	2.6%	8,231
Total Reefers	41.9%	132,648
20 Foot Empties	0.7%	2,216
40 Foot Empties	3.1%	9,814
Total Empties	3.8%	12,030

Table 7-4 annual productivity per berth

Container type	Percentage (%)	TEU
20 ft. containers	92,1	291,573
40 ft. containers	7,9	25,010

Using the numbers from table 7-3 in formula (1.3) this results in:

$$f_{TEU} = \frac{N_{20'}+2*N_{40'}}{N_{20'}+N_{40'}} \quad (1.3)$$

$$f_{TEU} = \frac{291{,}573+2*25{,}010}{291{,}573+25{,}010}$$

$$f_{TEU} = 1.08$$

Table 7-5 shows the capacity per berth for container cargo within the container terminal.

Table 7-5 annual productivity per berth

	Variable	Unit	Value
Variables	P	moves/hr	25
	f_{TEU}	-	1.08
	N_{cb}	cranes/berth	3
	n_{hy}	hrs/yr.	8640
	m_b	-	0.35
Result	$\bar{c_b}$	TEU/yr.	244,944

Using the productivity per berth and the total capacity requirement; the required amount of berths can be determined. Using the expected throughput in TEU in the year 2040 and the calculated $\bar{c_b}$ value in formula (1.4); this results in:

$$n = \frac{316{,}583}{244{,}944} \quad (1.4)$$

$$n = 1{,}3$$

$$n = 2\ berth$$

In order to handle the amount of TEU's expected in 2040 in the boldly optimistic scenario two berths are required for the (un-)loading of container cargo.

Total Length Container Terminal Quay

Besides depending on the capacity per m[1]; the quay length depends on the length of the vessels which visit the port. According to the market study, the boldly optimistic scenario will handle bigger vessels then in the optimistic scenario, see table 3-2. This results in a bigger range in vessel sizes docking at the port. In paragraph 7.2.3 it is determined that 2 berths will be required in the port in order to reach the required capacity. The biggest size vessel will dock sporadically compared to the smaller sizes of vessels. The quay requires two berths; these berths have to fit two Feeder vessels at the same time and a single Panamax vessel. Therefore, the length of the quay should fit two $222\ m$ feeder vessels with $15\ m$ free zone, as well as a single $294\ m$ Panamax vessel with $25\ m$ free zone (not at the same time). Using this data in formula (1.5) results in the following calculations:

$$L_q = L_{s,max} + 2 * L_f \quad (1.5)$$

$$L_q = 294 + 2 * 20$$

$$L_q = 334\ m$$

And:

L_q	=	$1.1 * n * (\overline{L_s} + L_f) + L_f$	(1.5)
L_q	=	$1.1 * 2 * (222 + 15) + 15$	
L_q	=	$536\ m$	

The quay length needs to fit both scenarios of vessels and therefore the bigger quay requirement is selected.

$536\ m$ > $334\ m$

L_q = $536\ m$

The minimum required overall quay length for the container cargo is 536 m and contains two berths, with a minimum requirement of one berth of $334\ m$ length.

7.2.4 Total Required Quay Length

Based on the quay lengths determined in the previous paragraphs a total quay length of 686 m is required for the container terminal of the new Ambon port in the 'boldly optimistic' scenario in 2040, see table 7-6.

Table 7-6 required quay dimensions for the container terminal

	Number of Berths	Length per Berth (excl. free zones)	Total Quay Length (incl. free zones):
General Cargo	1	120 m	150 m
Container Cargo	2	222 m	536 m
Total	3	Varies	686 m

7.3 Storage Requirements

7.3.1 Method

Containerised cargo is stored on a concrete floor in the open. Reefers require the same type of surface with the addition of an electricity supply in order to cool the cargo. For general cargo there are several storages required, depending on the specific characteristics of the cargo these storages consist of: open yards and sheltered storage halls. Formulas used to determine the required surface area are based on [Lit. 9]. In order to determine the required surface area for general- and container cargo, two different formulas are.

For general cargo; formula (1.6) is used to determine the surface area required for the storage of general cargo. This type of cargo varies widely in shape, size, packaging and weight. As a result, this formula will be completed using several assumptions which will be handled in the following paragraphs.

$$A_{gr} = \frac{f_{area} * f_{bulk} * n_c * \overline{t_d}}{m_c * h_s * \rho_{cargo} * 365} \qquad \textbf{(1.6)}$$

A_{gr}	=	*required floor area*	[m^2]]
f_{area}	=	*ratio gross over net surface, accounting for traffic lanes etc.*	[-]
f_{bulk}	=	*bulking factor due to stripping and seperatly stacking etc.*	[-]
N_c	=	*total tonnage handeld annually*	[t/yr]
$\overline{t_d}$	=	*average dwell time*	[days]
m_c	=	*acceptable average occupancy rate*	[0.65 to 0.70]
h_s	=	*average storing height in the storage*	[m^2]
ρ_{cargo}	=	*average relative density of the cargo in the vessel*	[t/m^3]

For container cargo; formula (1.7) is used to determine the surface area required for the storage of container cargo. Container cargo is divided in stacks (import, export, standard containers, reefers and empties). Since these stacks have different values, the required area will have to be determined for each stack separately. The formula will be completed using several assumptions which will be handled in the following paragraphs.

$$\boldsymbol{A} = \frac{\boldsymbol{N_c * \overline{t_d} * A_{TEU}}}{\boldsymbol{r_{st} * 365 * m_c}} \qquad \textbf{(1.7)}$$

A	=	$area\ required$	[m^2]
N_c	=	$number\ of\ container\ movements\ per\ year\ per\ type\ of\ stack\ in\ TEU's$	[m]
$\overline{t_d}$	=	$average\ dwell\ time$	[days]
A_{TEU}	=	$required\ area\ pet\ TEU\ inclusive\ of\ equipment\ traveling\ lanes$	[m^2]
r_{st}	=	$average\ stacking\ height/nominal\ stacking\ height$	[0.6 to 0.9]
m_c	=	$acceptable\ average\ occupancy\ rate$	[0.65 to 0.70]

7.3.2 Required General Cargo Storage

The storage surface area for general cargo is calculated with formula (1.6). Most variables for formula (1.6) can be estimated based on [Lit. 2] and [Lit. 9] with the main exception of the cargo density. The cargo density 'ρ_{cargo}' in the feasibility study is unrealistically high and will therefore have to be redefined. The feasibility study assumes cargo vessels with an average of 1,200 GT and a load of 6,400 tons. This amounts to an average ρ_{cargo} of $5{,}400\ kg/m3$. This density is unrealistically high and will therefore be determined by analysing the weights and density of the current products being handled as cargo. Table 7-7 shows the import ratio of the products imported and exported by the Pelindo IV ports in Ambon [Lit. 2]. The commodity 'other' is assumed to be the same as the average density of the other commodities combined. For several commodities the density depends on more specific types of the product, for example sugar (brown, granulated, cane, etc.), for these situations the highest density is used.

Table 7-7 Ambon cargo capacities in 2015 [Lit. 2], [Lit. 11] and [Lit. 15]

Import			Export		
Commodity	Density in kg/m^3	Percentage of total Import	Commodity	Density in kg/m^3	Percentage of total Export
(Portland) Cement	1,506	38%	Copra	401	30%
Frozen Chicken	1,113	5%	Frozen Fish	881	28%
Wheat Flour	561	7%	Cloves	440	21%
Bottled Water	1,000	8%	Nutmeg	687	17%
Soap and Shampoo	240	8%	Scrap Metal	5,000	3%
Noodles and Snacks	737	9%			
Sugar	881	9%			
Other	N/A	16%			
Total Average kg/m^3	1,085	100%	Total Average kg/m^3	726	100%

Table 7-7 shows the values used in formula (1.6). Formula (1.6) is used in order to determine the surface area required for the storage of general cargo. The 'ratio gross over net surface' is set on 1.5 and the 'bulking factor' is set on 2, both values are common in developing ports with an average stacking height of $2\ m$ [Lit. 9]. The port will handle $242{,}000\ ton$ of general cargo in 2040 with an average occupancy rate of 0.65. From table 7-6 the lowest density is used, since this requires most storage volume, this is the export density with an average of $0.7\ t/m3$.

Table 7-8 variables and area requirements for the general cargo terminal

	Variable	Unit	Value
Variables	f_{area}	-	1.5
	f_{bulk}	-	2
	N_c	t/yr.	242,000
	$\bar{t_d}$	days	7
	m_c	0.65 to 0.70	0.65
	h_s	m	2
	ρ_{cargo}	t/m^3	0.7
Result	A_{gr}	m^2	15,300

Based on the results in table 7-8 a total storage area of $15{,}300\ m^2$ or $1.53\ ha$ is required for the general cargo in 2040.

7.3.3 Required Container Storage

The surface area for container storage is calculated by using formula (1.7). The required area depends foremost on the type of container, the dwell time and the cargo quantity. According to the 'boldly' optimistic scenario the port will handle a total of $316{,}583$ containers in the year 2040. These containers are split up into three different stacks: standard containers, reefers and empties, the ratio of which is shown in table 7-3.

At the current stage of the port development there is no available ratio between import and export of the container cargo. While a difference in dwell time between import and export can be expected, there is no standard indication to assume the ratio; since it varies in either direction per port [Lit. 12]. Therefore, its assumed that the import and export cargo contain the same dwell time; three days for full standard containers, two days for reefers and six days for empties [Lit. 2] and [Lit. 9]. The surface area required per TEU varies per type of handling equipment. According to the BoD, the containers will mainly be handled by forklifts, reach stackers and mobile harbour cranes. Each type of equipment has its own m^2/TEU margin, see table 7-9. The new Ambon port will stack containers to a nominal stacking height of 3. Therefore, a A_{TEU} value is assumed to be $30\ m2/TEU$.

Table 7-9 types of cargo handling equipment in the new Ambon port [Lit. 9]

Equipment Type:	Nominal Stacking Height	m^2/TEU
Forklifts	2	35-40
	3	25-30
Reach stacker	2	35-40
	3	25-30
Mobile Harbour Crane	N/A	N/A

All above discussed variables are used with formula (1.7) and are presented in table 7-9. The area requirement is split up in three different sections; based on the type of container.

Table 7-10 variables and area requirements for the different container cargo stacks

Cargo Type	Variable	Unit	Standard Containers	Reefers	Empties
Variables	N_c	TEU	181,718	132,648	5,699
	$\bar{t_d}$	Days	3	2	6
	A_{TEU}	m^2	30	30	30
	r_{st}	0.6 to 0.9	0.9	0.9	0.9
	m_c	0.65 to 0.70	0.65	0.65	0.65
Result	A	m^2	76,593	37,273	4,804

Based on the results in table 7-10 a total storage area of $118{,}670\ m^2$ or $11.87\ ha$ is required for the container cargo in 2040.

7.3.4 Total Area Requirement

Table 7-11 shows the total surface area required in the container terminal. The table contains the general- and container cargo storage area combined with the "other" area. The "other" area contains port related activities such as offices, parking spots, a power plant, etc.

Table 7-11 total surface area requirements for the container terminal

Area usage	Required Surface Area	Required Surface Area
Container Cargo	118,670 m^2	11.87 ha
General Cargo	15,300 m^2	1.53 ha
Other	70,000 m^2	7 ha
Total Terminal (current + expansion)	203,970 m^2	20,4 ha

7.4 Conclusions

Based on this chapter, the following conclusions are drawn.

Quay Wall

- *The total required length of the container terminal quay for both the current and expansion of the port is* $686\ m$ *(two* $222\ m$ *vessels and one* $120\ m$ *vessel), see table 7-7.*
- *The current new Ambon port has a quay length of* $400\ m$*, therefore, based on the requirements in the BoD, an expansion of approximately* $200\ m$ *is required.*

Surface Area

- *The total required surface area for the container port is 20.4 ha. This includes the storage area for both general- and container cargo, as well as the "other", see table 7-10.*
- *The current container terminal of the new Ambon port has a total surface area of 15 ha. Therefore, based on the values in the BoD, an expansion is required in order to handle the predicted cargo quantities in the 'boldly optimistic' scenario in 2040.*
- *The required surface area as stated by the Port of Rotterdam in [Lit. 2] is higher than calculated in this chapter, see table 7-12.*

Table 7-12 differences in surface area requirement

	Port of Rotterdam	Previous chapters	Difference
Required Surface Area:	27 ha	20.4 ha	6.6 ha

8

LIQUID BULK TERMINAL DIMENSIONS

This chapter will explore the dimensions and layout of the quay length and storage area of the liquid bulk terminal. The full analyses can be found in appendix VIII.

8.1 Introduction

As stated in the Basis of Design, the port will contain a liquid bulk terminal. This terminal specialises in the storage and handling of fuels [Lit. 2]. The dimensions of a liquid bulk terminal are mainly determined by the mooring method and the storage capacity requirements. In the following paragraphs, both the mooring method and storage requirements will be explored. The full exploration of the dimensions and background of the liquid bulk terminal is presented in appendix VIII. A minimum of two berths will be required as stated in the basis of design in appendix II.

8.2 Quay Requirements

8.2.1 Mooring Variants

Liquid bulk berths have an extremely high efficiency which can be as high as $70\ million\ t/yr/berth$ when using VLCC and ULCC tankers. But also for smaller vessels the tanker berths have a relatively high capacity and a low occupancy [Lit. 9]. Considering the total yearly amount of 625.000 tons in 2040, a single berth has enough capacity to fulfil the capacity requirements. However, on-shore mooring systems often contain more berths to fit difference vessel sizes for offshore berths this is no factor (with the exception of a fixed offshore terminal).

There are several different methods to (un-)load liquid bulk. In general, the mooring methods are split up in two main groups: 'on-shore mooring' and 'off-shore mooring', see table 8-1. For further information, see appendix VIII.

Table 8-1 on-shore and off-shore mooring methods [Lit. 9]

On-shore mooring	Off-shore mooring
L Jetty	Multi Buoy Mooring (MBM)
T Jetty	Single Buoy Mooring (SBM)
Finger Pier	Fixed offshore terminal

8.2.2 Port References

The selection of the mooring variant depends on the specific requirements stated by the exploiter of the liquid bulk terminal. At this stage of the design, there are no requirements or suggestions from the port exploiter.

To determine the mooring system for the liquid bulk terminal, there are several reference ports used. The first reference port is the Wayame port on Ambon island. The other reference ports are located in South Africa, all of the ports used as a reference are classified as liquid bulk terminals specialised in handling liquid fuels.

Wayame Port

The Wayame port is the current liquid bulk port of Ambon island and is exploited by Pertamina, see appendix III. The port uses T and L jetties in order to dock the vessels. The port contains a total of three berths varying in length in order to dock several vessels of different sizes.

Liquid Bulk Terminals in SA

These ports are recommended as a reference by [redacted] senior port engineer at Witteveen+Bos. Tables 8-2 and 8-3 show the operational numbers of liquid bulk ports in South-Africa and their capacity per ha.

Table 8-2 operational numbers of liquid bulk ports in South-Africa [Lit. 21]

Liquid Bulk Port	Terminal area (ha)	Total Berths	Usable berths	Berth length (m)	Installed Capacity (mtpa[1])	Design capacity (mtpa)	Installed capacity/design capacity	Mooring method
Saldahna	3,6[2]	1	1	360	6,946,229	25,000,000	28%	T Jetty
Cape Town	11	2	2	489	3,400,000	3,400,000	100%	T Jetty
Port Elizabeth	16	1	1	242	972,208	2,926,829	33%	L Jetty
Durban	157	9	8	1765	11,000,000	21,000,000	52%	T and L Jetty
Richards Bay	73	2	2	600	1,011,432	3,152,778	32%	T Jetty
East London	19	1	1	259	918,688	3,000,000	31%	L Jetty
Mossel Bay[3]	0	2	2	0	1,893,127	7,971,600	24%	SBM

Table 8-3 mtpa/ha capacity of liquid bulk ports in South-Africa

Liquid Bulk Port[4]	mtpa/ha (Installed Capacity)	mtpa/ha (Design Capacity)
Saldahna	1,929,508	6,944,444
Cape Town	309,091	309,091
Port Elizabeth	60,763	182,927
Durban	70,064	133,758
Richards Bay	13,855	43,189
East London	48,352	157,895

From these ports it is clear there is no direct correlation between the amount of berths, the capacity and the mooring method. Therefore, the mooring method for the new Ambon port liquid bulk terminal cannot be determined based on these reference ports.

8.2.3 Multi-Criteria Analyses

Since the mooring method is too complex to solely determine based on reference port, a multi-criteria analyses is created to compare different mooring systems in order to advice on the most feasible mooring method for this liquid bulk terminal. The MCA is setup on the same method as previously covered in chapter 6 regarding the layout selection. The full MCA is shown in appendix VIII.

As done in the previous MCA, there is one main weighing conducted and two verification weighing's. The results of these are presented in tables 8-3 to 8-5 on the next page.

[1] Metric Tons Per Annum

[2] As stated on page 41 of [Lit. 21] instead of the original table on page 29

[3] The Mossel Bay operates with a fully offshore operating SBM system and therefore uses no terminal and berth on shore

[4] Mossel bay is left out since there is no capacity per ha available

Table 8-3 original Weighing

Rank	Version	Points
1	SBM	83
2	L and T jetty	77
3	Fixed offshore terminal	74
4	Finger Pier	72
5	MBM	62

Table 8-4 focus on efficiency

Rank	Version	Points
1	SBM	87
2	L and T jetty	78
3	Fixed offshore terminal	75
4	Finger Pier	73
5	MBM	64

Table 8-5 focus on the costs

Rank	Version	Points
1	SBM	88
2	L and T jetty	84
3	Fixed offshore terminal	81
4	Finger Pier	79
5	MBM	65

Out of these tables, the mooring method "Single-Buoy Mooring" is presented as the most feasible method. Therefore, this thesis will recommend the development of a port using the SBM system. However, during the further development of the port, the preferences of the exploiter of the liquid bulk terminal should be taken into account.

8.3 Storage Requirements

8.3.1 Storage Capacity per Tank

According to the 'new Ambon feasibility study' and benchmark assumptions from similar operations in South East Asia each containment tank in the new Ambon port will have a storage capacity of $10{,}000\ kilolitres$ on a 0.8 ha surface area.

$$C \quad = \quad 10{,}000\ m^3/tank\ per\ 0.8\ ha$$

8.3.2 Number of Storage Tanks

The annual throughput of $625{,}000\ tons$ has a volume of $795{,}165\ m^3$. According to the 'new Ambon feasibility study' and benchmark assumptions from similar operations in South East Asia each containment tank in the new Ambon port will have an average dwell time of 60 days. This means in a full year each tank can storage 6 storage units of 10,000 m^3 ($60\ days\ x\ 6\ =\ 360\ days$) which results in an annual storage capacity of $60{,}000\ m^3$ per tank.

Based on an annual throughput of $795{,}165\ m^3$ and a storage capacity of $60{,}000\ m^3/yr/tank$, a minimum of 11 tanks is required to store the bulk. This however, does not account for peak storage and variety of bulk types. As a margin for the peak storage and a variety in bulk types and maintenance/cleaning of the tanks, the minimum amount of tanks is multiplied by a safety factor of '2'. Multiplying the eleven storage tanks by a factor of '2'; results in:

$$n \quad = \quad 22\ storage\ tanks$$

8.3.3 Storage Surface Requirement

Based on a total of 22 containment tanks with a surface area of 0.8 ha each requires the following surface area:

$$A \quad = \quad 22 * 0.8$$
$$A \quad = \quad 17.6\ \text{ha}$$

This area does not include any area reserved for the barriers surrounding the tanks, roads, offices etc.

8.3.4 Total Area Requirement

A total of 17.6 ha is required for the storage area of the liquid bulk. Besides storage area, the liquid bulk terminal requires an area for roads, offices, pipelines and other facilities. The area required for these components varies per port. In general, these components contain an area varying between 10 to 25% of the ports area [Lit. 21]. Since there are no references regarding the preferences for this terminal available, a high surface usage of 25% of the total terminal will be assumed.

Table 8-4 total surface area requirements for the container terminal

	Required Surface Area	Required Surface Area
Storage Area	176,000 m^2	17.6 ha
Other Facilities	68,000 m^2	5.9 ha
Total Terminal	244,000 m^2	23.5 ha

8.4 Conclusions

Based on this chapter, the following conclusions are drawn.

Mooring Method

- *A minimum of 2 berths is recommended for the liquid bulk terminal in order to handle varying vessel sizes and types of liquid bulk.*
- *Based on the Multi-Criteria Analyses; "Single Buoy Mooring" is recommended as the most feasible method for this port.*
- *A SBM system requires a limited amount of shoreline/quay since the mooring takes place in open sea. The only required point is the station where the off-shore pipelines connect to the on-shore pipelines.*
- *All conclusions regarding the liquid bulk terminal are recommendations only, since there is no available input from the future exploiter of the liquid bulk terminal.*

Surface Area

- *Based on this chapter, a total of 22 containment tanks with a capacity of 10,000 kilolitres each are required for the storage of liquid bulk in the liquid bulk terminal. Each tank has 0.8 ha of surface area results in a total storage area of 17.6 ha required. This does not include roads, pipelines, offices and other facilities.*
- *The height of the barriers surrounding the containment tanks, is relatively low. While a height of 1.35 m is commonly used in SEA, it is relatively low compared to containment tanks in other locations where heights up to 3 m are common. Increasing the barrier heights increases the capacity and lowers the required surface area.*
- *Table 8-5 shows a difference of 5.6 ha between the market study of the Port of Rotterdam and this thesis. Taking into account that this thesis used a factor 2 for peak storage and a maximum ratio for the area used by roads, offices and other constructions, and still results in a lower surface area usage. It is highly likely that the 30 ha requirement is an unrealistic situation.*

Table 8-5 differences in surface area requirement

	Port of Rotterdam	Previous Paragraphs	Difference
Required Surface Area:	30 ha	23.5 ha	6.5 ha

9

OPTIMIZATION DESIGN

This chapter will attempt to minimize the area usage of the port by altering several values that are stated in the BoD. By doing so, this chapter aims to provide recommendations regarding the minimisation of land usage.

9.1 Introduction

Based on the conclusions in paragraphs 7.4 and 8.4, several components of the new Ambon port seem suitable for optimisation. This chapter will provide an alternative method to determine the storage requirements of both the container terminal and the liquid bulk terminal, reducing the surface area required for the expansion of the new Ambon port.

9.2 Container Terminal

Storage Area

The surface area for container storage is determined in the same method as done in chapter 7. The variables used are therefore mainly the same, with the exception of " A_{TEU}". In chapter 7 this variable is based on the usage of port equipment such as reach stackers and forklifts. In order to minimize the required surface area, this equipment will be upgraded to so called "gantry cranes", see table 7-9.

Table 9-1 cargo handling equipment [Lit. 9]

Equipment Type:	Nominal Stacking Height	m²/TEU
Gantry Crane (RMG/RTG)	5	6-8

Upgrading the equipment to gantry cranes results in the variables as stated in table 9-2.

Table 9-2 variables and area requirements for the different container cargo stacks

Cargo Type	Variable	Unit	Standard Containers	Reefers	Empties
Variables	N_c	TEU	181,718	132,648	5,699
	$\bar{t_d}$	Days	3	2	6
	A_{TEU}	m²	8	8	8
	r_{st}	0.6 to 0.9	0.9	0.9	0.9
	m_c	0.65 to 0.70	0.65	0.65	0.65
Result	A	m²	20,425	9,940	1,281

Table 9-3 shows the differences between the required surface area when the handling equipment is upgraded. It shows a significant decrease of $87{,}024\ m^2$ required storage area.

Table 9-3 comparison between the original requirements and the upgraded variant

	Variable	Unit	Standard Containers	Reefers	Empties	Total:
Based on the BoD	A	m^2	76,593	37,273	4,804	118,670
Upgraded	A	m^2	20,425	9,940	1,281	31,646
Difference	A	m^2	56,168	27,333	3,523	**87,024**

Total Area Requirement

Table 7-10 shows the total surface area required in the container terminal with the general- and container cargo storage area combined with the "other" area. The "other" area contains port related activities such as offices, parking spots, a power plant, etc.

Table 9-4 total surface area requirements for the container terminal

Area usage	Required Surface Area	Required Surface Area
Container Cargo	31,646 m^2	3.16 ha
General Cargo	15,300 m^2	1.53 ha
Other	70,000 m^2	7 ha
Total Terminal (current + expansion)	116,946 m^2	**11.7 ha**

Table 9-5 shows the difference between the new area requirement and the current surface area of the new Ambon port.

Table 9-5 differences in surface area requirement

	Current Container Terminal	Total Required area (based on upgraded equipment)	Difference
Required Surface Area:	20 ha	11.7 ha	8.3 ha

9.3 Liquid Bulk Terminal

Capacity per containment tank

In chapter 8, the capacity and land usage per containment tank is based on the feasibility study by the consortium and recommendations from the port of Rotterdam. The tanks have a periphery of $90\ m\ x\ 90\ m$ with an effective barrier height of $1.25\ m$. This provides a storage capacity of $10{,}000\ kilolitres$ per containment tank per $0.8\ ha$.

In order to minimize the surface area, a containment tank with a periphery of $130\ m\ x\ 130\ m$ with an effective barrier height of $3\ m$ [Lit. 9]. This provides a storage capacity of $50{,}000\ kilolitres$ per containment tank per $1.7\ ha$.

Table 9-6 differences between the containment tanks

	Storage Capacity (kilolitre)	Periphery (m)	Effective Barrier height (m)	Surface Area (ha)
Original Containment Tank	10,000	90 x 90	1.25	0.8
Upgraded Containment Tank	50,000	130 x 130	3	1.7

Number of Storage Tanks

According to the 'new Ambon feasibility study' and benchmark assumptions from similar operations in South East Asia each containment tank in the new Ambon port will have an average dwell time of 60 days. This means in a full year each tank can storage 6 storage units of 50,000 m^3 ($60\ days\ x\ 6\ =\ 360\ days$) which results in an annual storage capacity of 300,000 m^3 per tank.

The annual throughput of 625,000 $tons$ has a volume of 795,165 m^3. Based on the annual throughput of 795,165 m^3 and a storage capacity of 300,000 $m^3/yr/tank$, a minimum of 3 tanks is required to store the bulk. This however, does not account for peak storage and variety of bulk types. As a margin for the peak storage and a variety in bulk types and maintenance/cleaning of the tanks, the minimum amount of tanks is multiplied by a safety factor of '2'. Multiplying the 3 storage tanks by a factor of 2 results in:

n = $6\ storage\ tanks$

Storage Surface Requirement

Based on a total of 6 containment tanks with a surface area of 1.7 ha each requires the following surface area:

A = $6 * 1.7$
A = $10.2\ ha$

This area does not include any area reserved for the barriers surrounding the tanks, roads, offices etc.

Total Area Requirement

A total of 10.2 ha is required for the storage area of the liquid bulk. Besides storage area, the liquid bulk terminal requires an area for roads, offices, pipelines and other facilities. The area required for these components varies per port. In general, these components contain an area varying between 10 to 25% of the ports area [Lit. 21]. Since there are no references regarding the preferences for this terminal available, a high surface usage of 25% of the total terminal will be assumed.

Table 9-7 total surface area requirements for the container terminal

	Required Surface Area	Required Surface Area
Storage Area	102,000 m^2	10.2 ha
Other Facilities	34,000 m^2	3.4 ha
Total Terminal	136,000 m^2	13.6 ha

9.4 Conclusions

Based on this chapter, the following conclusions are drawn.

Container Terminal Surface Area

By upgrading the cargo handling equipment, an expansion of the port is no longer required. This is caused due to the possibility to stack higher and more efficient equipment. This upgrade downsizes the required surface area to a total of 11.7 ha. Since the current container terminal contains 20 ha or surface area, this upgrade would make the expansion of surface area obsolete.

Liquid Bulk Terminal Surface Area

By upgrading the containment tanks to a higher capacity the required surface area can be downsized to 13.6 ha. Which is significantly less than the 30 ha requirement as stated in the market study by the port of Rotterdam.

10

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on this thesis, the following conclusions are drawn:

- *In order for the new Ambon port to be developed based on the 'boldly optimistic' scenario instead of the optimistic scenario, a physical expansion is required to the addition of the liquid bulk terminal.*
- *Based on the physical conditions, an off-shore expansion is deemed unpractical since the rapidly deepening sea bottom increases the costs of either land reclamation or sheet piling enormously.*
- *The best location for an expansion of the new Ambon port is to the south, southwest and west direction without crossing any of the nearby rivers. In this document location is called location two.*
- *As concluded in paragraph 3.3, the cargo quantity predictions of the port of Rotterdam contained unlikely numbers which might indicate inaccurate values. Based on the conclusions in paragraphs 7.4 and 8.4 these assumptions are further confirmed, since the area requirements as stated by the Port of Rotterdam are unlikely to be met based on the cargo quantities predicted.*
- *The surface area requirements as predicted by the Port of Rotterdam are higher than required, based on the cargo quantities predicted by the Port of Rotterdam. Both the container terminal and the liquid bulk terminal, require severely less surface area as predicted as is concluded in chapters 7 and 8.*
- *The storage area required for the container cargo can be severely reduced by upgrading the cargo handling equipment from forklifts etc. to gantry cranes. This reduction in required storage area reduces the required surface to a point where an expansion is no longer needed since the current new Ambon port is able to fulfil the area requirements.*
- *The storage area required for the liquid bulk can be severely reduced by increasing the storage capacity per containment tank. This can be done by heightening the surrounding barriers and increasing the size of the containment tanks. This increases the storage capacity per hectare. This can at least halve the required storage area, compared to the area requirements as stated by the Port of Rotterdam.*
- *Expansion of the container terminal quay might be unavoidable, based on the required berths and vessel dimensions.*
- *The liquid bulk terminal is recommended to use a single-buoy mooring system for the (un)loading of the tankers visiting the new Ambon port. This system is primarily recommended based on the lower investment costs.*

Recommendations

Based on this thesis, the following recommendations are made:

- *It is recommended to conduct a cost-benefit analyses to compare the costs of land acquisition versus the costs of upgrading the port equipment and cargo storage. If the upgrade has severely higher costs than the acquisitioning of the land, an upgrade might be less favourable.*
- *It is recommended to conduct a study on the rivers bordering the new Ambon port in order to prevent flooding of the port when the river shores overflow and to prevent collapse of the river shores in general.*
- *It is recommended to conduct a more precise bathymetry and topography survey of the locations, including a soil analysis.*
- *It is recommended to gather more information relevant to the liquid bulk terminal, by involving the future operator of the port. By including the preferences and objectives of the operator, the port can be developed more accurately.*
- *It is recommended to conduct a new market study or to verify the market study currently used since it presumably contains inaccurate values regarding cargo quantities and required surface areas.*

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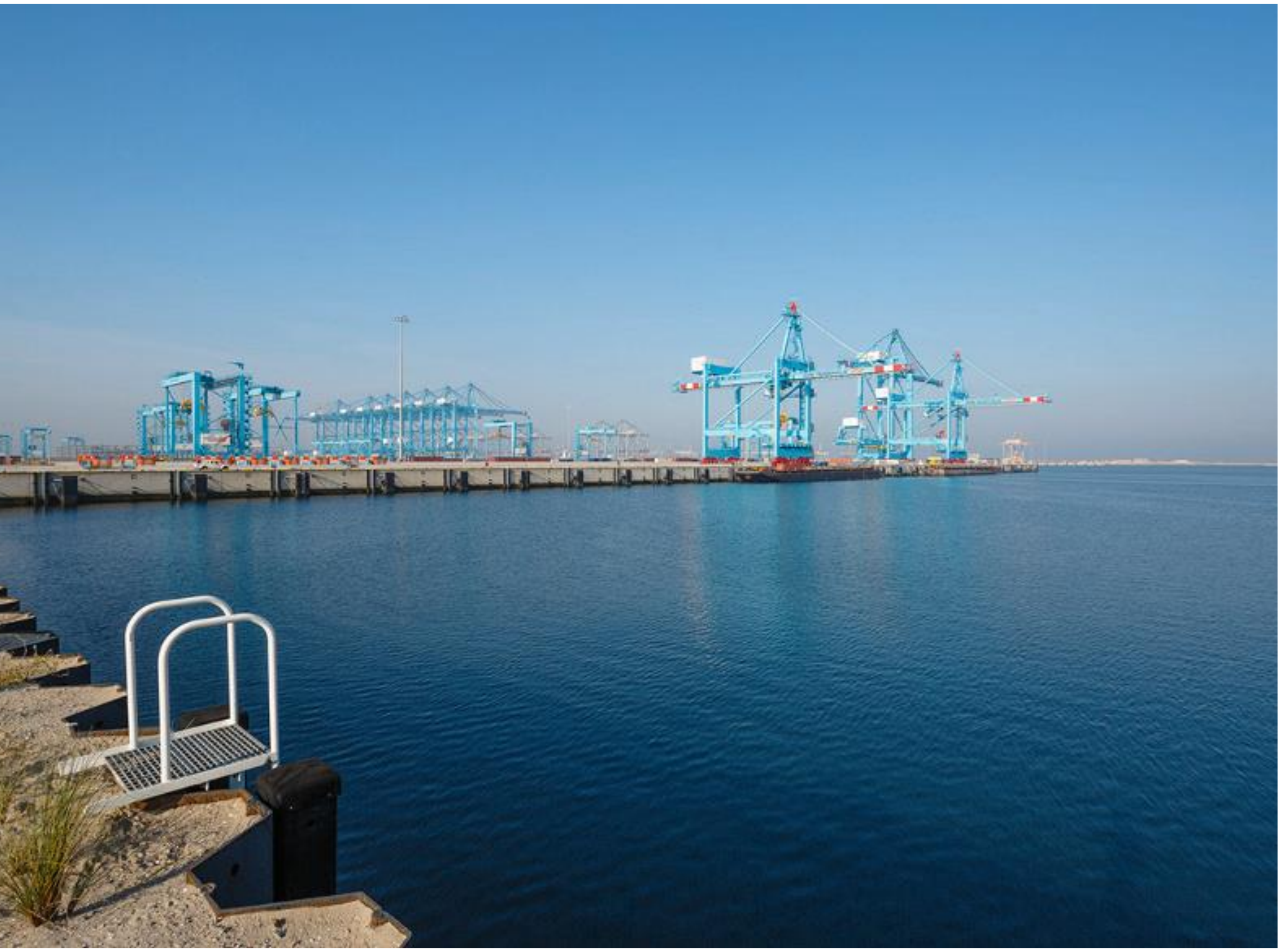

Appendices

Expanding the new Ambon port

Rotterdam University of Applied Sciences
Department of Civil Engineering

12th of January, 2017

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APPENDICES

APPENDIX: STAKEHOLDERS

STAKEHOLDERS

Table I shows the main stakeholders of the new Ambon port project, including a summary of their role.

Table I: stakeholders of the new Ambon port project

Stakeholder	Description
The embassy of the Kingdom of the Netherlands	The embassy is the main client of the project. The embassy is the party who wrote the initial tender for the feasibility study of the new Ambon port and assists in the connection between the engineering consortium and the government of Maluku.
Ministry of Maritime Affairs and Fishery Indonesia	This ministry is responsible for the overall port development of Indonesia and licensing of the international trade between ports.
Government of Maluku Province	The government of Maluku is one of the main stakeholders, overseeing the regulations and overall development of the Maluku province including ports.
Government of Ambon	The government of Ambon owns most of the land on the island and is responsible for the spatial planning regulations (RTWT).
PT Witteveen+Bos Indonesia	Witteveen+Bos is the main consultant of the new Ambon port project, conducting parts of the feasibility and location study.
PT Royal HaskoningDHV Indonesia	Sub consultant to WiBo, conducting parts of the feasibility and location study.
PT Bita Enarcon Engineering	Sub consultant to WiBo, conducting parts of the feasibility and location study.
PriceWaterhouseCoopers	Sub consultant during the initial phase on the operational & financial aspect
Port of Rotterdam	Sub consultant during the initial phase, Responsible for the market analysis study and the future business model for the new Ambon port.
Pelindo 4	Pelindo IV is a state owned port exploiter specialized in container ports. Pelindo will be the exploiter of the container terminal in of the new Ambon port.
PERTAMINA	Pertamina is a state owned oil and gas company. Which whom currently handles the Wayame oil terminal in the Ambon bay. Pertamina will also exploit the liquid bulk terminal in the new Ambon port.
Local inhabitants and workers	Inhabitants of the Waai and Tulehu village and other inhabitants living close to the new Ambon port.

APPENDIX: BASIS OF DESIGN

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1

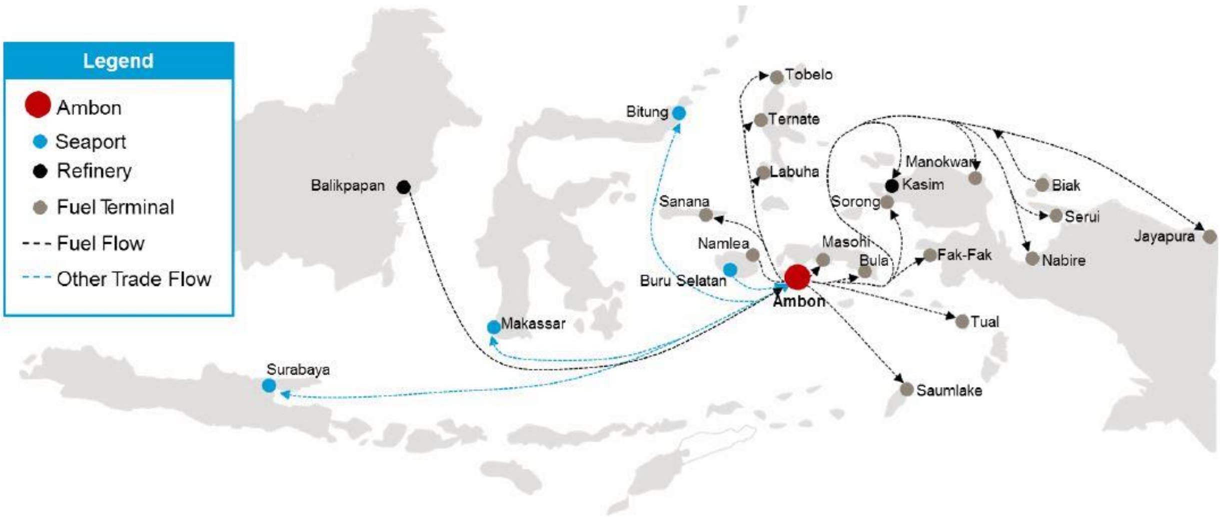
INTRODUCTION

1.1 Project description

Ambon

Ambon is one of the islands located in the Indonesian province of Maluku. The island has a strategic position and is being used as a regional transport hub for centuries. Cargo from and to Jakarta, Surabaya and Makassar is transhipped in Ambon. From Ambon cargo is shipped to ports throughout Eastern Indonesia, see figure 1-1.

Figure 1-1 Ambon as a regional transport hub [Lit. 16]



New port

The current container port in Ambon City will reach the maximum handling capacity in 10 to 15 years [Lit. 1]. The port has severe congestion problems. Moreover, a growing number of passenger vessels visit the same location, which results in an unsafe working environment.

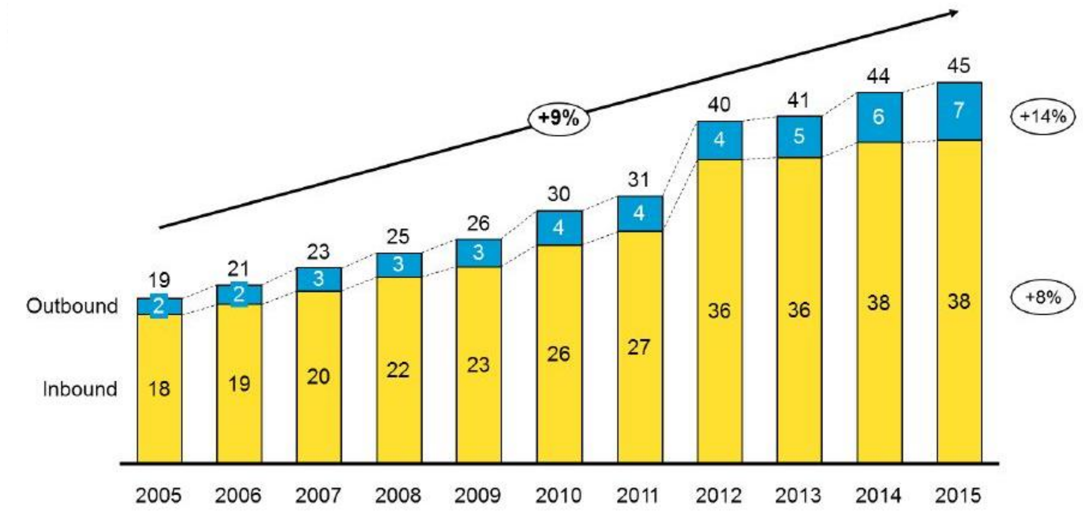
A 'Pressure-cooker' Stakeholders Session on January 19th and 20th, 2016 was organized by a senior policy advisor from The Embassy of the Kingdom of the Netherlands. The members consisted of consultants from PT Witteveen+Bos Indonesia, PT Royal HaskoningDHV Indonesia and PriceWaterhouseCoopers Consulting. During this event all participants agreed that a new central fishing cargo port will have a positive socioeconomic impact on the fishing industry and inhabitants of Ambon and Maluku [Lit. 1]. For a full overview of the involved stakeholders, see Appendix II.

Current trading market Ambon

Based on the 2014 measurements, Maluku is Indonesia's second largest fish producer with a total annual production of 500.000 tons, of which 100.000 ton origins from the island of Ambon. It is estimated that the province of Maluku has the potential to produce 1.7 million tons annually, see Appendix III. To reach this capacity the province will need to invest in an expansion of the fishing fleet, software and hardware [Lit. 2]

The current container port is located in the city centre of Ambon City and is mainly focused on the import and transhipment of container goods. Export from Ambon is currently a limited part of the overall trade. The port has experienced an average annual growth of 9% between 2005 and 2015, see figure 1-2. This includes the model shift from not containerized cargo to container cargo. Containers are not allowed to leave the port area and are therefore handled inside the port itself, limiting the flow of cargo.

Figure 1-2 Container throughput Ambon (Unit: '000 TEU) [Lit. 1]



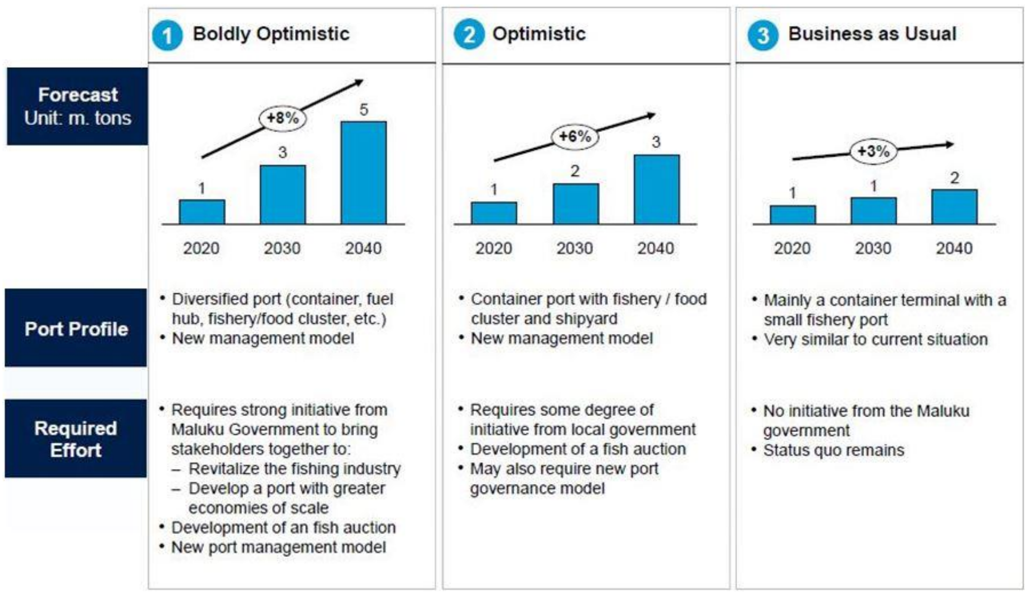
Future port development

A Market Positioning study was carried out by the Port of Rotterdam, [Lit. 2] and [Lit. 16]. This market study presents the expected future volume of cargo in the new port of Ambon for various commodities. Figure 1-3 shows three development scenarios for the Port of Waai:

1. Boldly Optimistic
2. Optimistic
3. Business as Usual

The 'business as usual' and the 'optimistic' scenario include the fishery port and the container terminal. The 'boldly optimistic' scenario adds a liquid bulk terminal. To realise the optimistic and boldly optimistic scenario a significant increase of throughput is required which is based on external factors that cannot be fully guaranteed by the development of a new port alone.

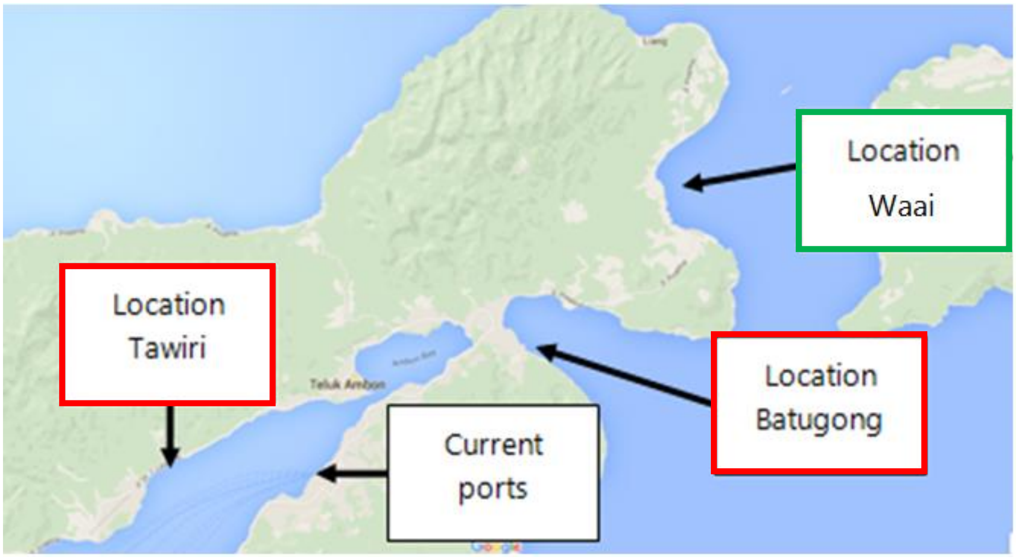
Figure 1-3 Development scenarios fort Ambon by the Port of Rotterdam [Lit. 16]



Location for the new port

At the start of the project two locations, shown in figure 1-4, were considered for the new integrated fishery and container cargo port: Waai[1] and Batugong[2]. During the Kick-off meeting on June 14th 2016, one additional location at Tawari[3] was added by the Navy (*LANTAMAL*) [Lit. 17].

Figure 1-4 Current and proposed port locations on Ambon



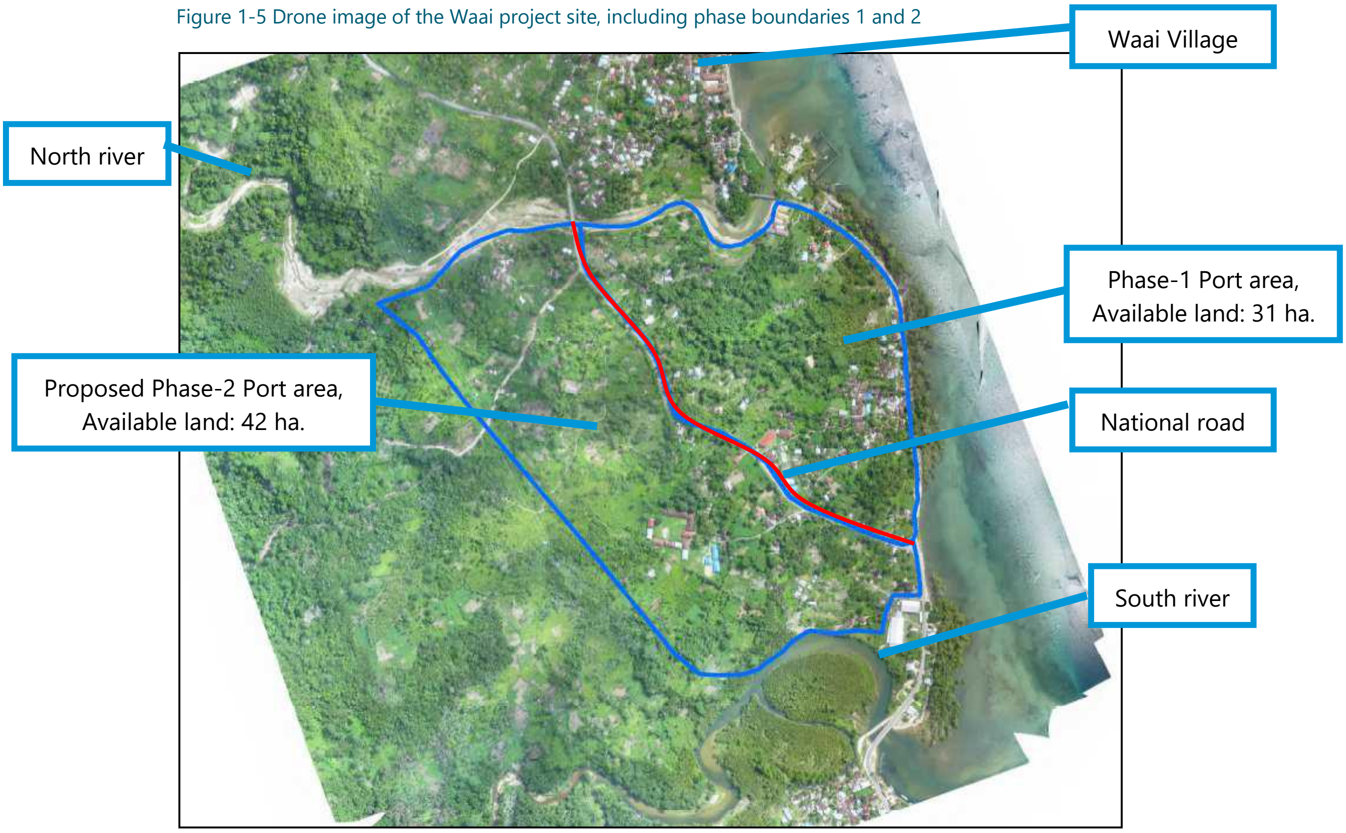
After a site survey was conducted, the collected data was used for in a Multi Criteria Analysis (*MCA*). This MCA concludes that the Waai location is the best tested location for the development of a new port. During the Counterpart-meetings in Ambon on August 25th and 26th, 2016 the Waai location was confirmed as the location for the new port, see figure 1-5.

[1] A small port community on East Ambon

[2] An abandoned wood processing plant in Central Ambon

[3] An old factory and port location on the west side of the Ambon bay, currently abandoned

Figure 1-5 Drone image of the Waai project site, including phase boundaries 1 and 2



Current optimistic port development

During the Counterpart-meetings in Ambon on August 25th and 26th, 2016, it was decided that the boldly optimistic scenario would be the preferred scenario for the port development, see figure 1-3. However, the surface area on the Waai location is limited, so the current feasibility study performed by a consortium consisting of: PT Witteveen+Bos Indonesia, PT HaskoningDHV Indonesia and PT Bita Enarcon Engineering, is based on the optimistic scenario in order to fit the available 33 ha, see figure 1-5. A 47 ha expansion is proposed on the southwest side of the initial phase but has not been used in the current design made by the consortium, see figure 1-5.

The current design made by the consortium will develop in two phases: the first phase and the second phase, see chapter 3.1. Both phases will be situated within the 33 ha "Phase-1" area, pictured in figure 1-5. To increase the capacity in the second phase; the handling equipment will be upgraded and the available space will be used to further construct port related facilities [Lit. 10].

Future boldly optimistic port development

If the trade in the Port of Waai takes off, a further expansion as planned according to the boldly optimistic scenario is possible. In order to realise this, the currently planned 33 ha will need to expand to a total of approximately 90 ha total. In order to prepare for this possibility, this bachelor thesis will create a concept design for the expansion of the Waai port.

In order to develop the port with the boldly optimistic scenario; some assumptions have to be made. These assumptions form the basis of the possible expansion; however, it is possible that they might change in the future. These assumptions are:

- *Ambon experiences a 6% GDP growth*
- *Ambon experiences a 8% CARG (Compounded Annual Rate of Growth)*
- *PERTAMINA (a state owned oil and gas company) moves to the Ambon New Port in 2030*
- *Fishery auction and 'food cluster' develop in the Port of Waai*
- *Ambon New Port hosts a shipyard and a small power plant*

1.2 Scope of thesis

In scope

This thesis will create a conceptual design for the expansion of the Port of Waai according to the boldly optimistic scenario. This thesis will focus on the following parts of the future capacity expansion of the Port of Waai on Ambon:

- *Location analysis for the port expansion:*
  - *Characteristics of the possible locations*
  - *Physical obstacle analysis*
- *Location recommendation for the port expansion:*
  - *Most favourable location based on an MCA*
  - *Recommendations to overcome physical obstacles*
- *Lay-out recommendation for the expansion:*
  - *General lay-out information*
  - *General lay-out design*

Not in scope

This thesis will disregard the following parts of the future capacity expansion of the Port of Waai on Ambon:

- *Financial cost of the overall project*
- *Technical details:*
  - *Construction details*
  - *Lay-out details, such as drainage systems and building sizes*
- *Detailed calculations*

1.3 Scope of this document

This report describes the Basis of Design (BoD) for the conceptual design and planning of the capacity expansion of the Port of Waai in Ambon. The BoD determines the requirements, standards, scenarios and assumptions to be used as foundation for the design process. It is used as a follow up on the conceptual design for the optimistic phase design of the Port of Waai.

This BoD is based on the documentation provided by; PT Witteveen+Bos Indonesia, PT Royal HaskoningDHV, The Port of Rotterdam, the Embassy of the Kingdom of the Netherlands and will be completed by literature from the Delft University of Technology and the Rotterdam University of Applied Sciences. The Basis of Design elaborates on:

- *Functional requirements*
  - *Development phases*
  - *Terminals*
  - *Trade quantities and capacities*
- *Requirements for handling cargo*
  - *Cargo types*
  - *Required area*
  - *Equipment*
  - *Quays*
- *Boundary conditions*
  - *Natural conditions, such as rivers and land heights*
  - *Infrastructure*
  - *Hydrological and hydraulic conditions*
  - *Geotechnical conditions*

2

GENERAL GUIDELINES

2.1 General information

The Port of Waai is located near the village of Waai, which is in the Salahutu Sub District in the Central Maluku Regency.

When developing the layout, the following will be considered:
- *The container terminal, fishery terminal and fuel terminal will be handled in separated parts of the port*
- *The quay for the fishing boats cannot be expanded, however it is possible to expend the finger piers*

2.2 Land ownership

The area of the Port of Waai itself and the surrounding areas are owned by various individuals, companies and government. These areas will have to be cleared before the physical development can start. To do so, possible inhabitants will have to be relocated and a change in the zoning plan might be required. The (possible) zoning plan needs to be changed with the permission of the responsible government.

2.3 Fishing regulations

In an attempt to stimulate the local fishery; Joko Widodo[1] and Susi Pudjiastuti[2] have increasingly dealt with the ban on illegal fishery for example by blowing up caught illegal vessels. This regulation resulted in an 80% drop of illegal fishery in Indonesia and an increase of fish caught by Indonesian fishermen; however, the drop in illegally caught fish resulted in a smaller amount of fish being sold at the island of Ambon. Since not enough time has passed to see the full effect of these actions, it’s hard to predict the future amount of fish being caught. For the expansion of the port it will be assumed that fishery will restore to previous levels, this can be reached by, for example:

1. *Foreign ships are legally entering the waters*
2. *Local ships fill the gap left behind*

[1] The current president of the Republic of Indonesia, November 2016

[2] The current minister of Maritime Affairs and Fishery, November 2016

3

FUNCTIONAL REQUIREMENTS

3.1 Terminal requirements

The current port, designed by the consortium, is being developed according to the optimistic scenario, without a liquid bulk terminal. Table 3-1 and 3-2 show the difference in surface area requirement between the optimistic and the boldly optimistic scenario.

Table 3-1 required area per cargo type and scenario in 2040 [Lit. 2]

Cargo type	Optimistic Scenario	Boldly Optimistic Scenario	Additional Required Area for the Port Expansion
Container (Stacked 6 high)	15 ha	20 ha	**5 ha**
General Cargo (Integrated on CT)	8 ha	15 ha	**7 ha**
Fish and Food	20 ha	20 ha	0 ha
Liquid bulk	-	30 ha	**30 ha**
Shipyard	5 ha	5 ha	0 ha
Total ha	48 ha	90 ha	**42 ha**

In the first phase of the port development, the general- and container cargo are integrated into the same area of the port. In the boldly optimistic scenario, this will happen as well. Therefore, the general- and container cargo port will be combined into one terminal of 12 ha. The liquid bulk terminal will require 30 ha, resulting in a total of 42 ha of required port expansion, see table 3-2.

Table 3-2 boldly optimistic expansion area in regard to the optimistic scenario

Terminal type	Required area
General- and container cargo	12 ha
Liquid bulk	30 ha
Total expansion area	**42 ha**

3.1.1 Cargo Quantities

Table 3-3 on the next page; shows the expected turnover the port is required to handle in the optimistic and the boldly optimistic scenario.

Table 3-3 Predicted turnover in commodities with the optimistic scenario [Lit. 2]

Scenario	Cargo	Unit	2020	2025	2030	2035	2040
Optimistic	Containers	'000 Tons	863	1190	1614	2163	2870
	General Cargo	'000 Tons	153	172	193	216	242
	Fish	'000 Tons	0	60	85	100	100
	Liquid Bulk	'000 Tons	-	-	-	-	-
Scenario	**Cargo**	**Unit**	**2020**	**2025**	**2030**	**2035**	**2040**
Boldly Optimistic	Containers	'000 Tons	929	1360	1945	2736	3799
	General Cargo	'000 Tons	153	172	193	216	242
	Fish	'000 Tons	10	60	90	100	100
	Liquid Bulk	'000 Tons	0	0	540	581	625

3.1.2 Port exploiters

Table 3-4 shows the expected exploiters of the Ambon port terminals.

Table 3-4 Port operators

Cargo type	Operator
General- and container cargo	Pelindo IV
Liquid Bulk	PERTAMINA

3.1.3 Vessel Dimensions

The minimum berth length depends on maximum length of vessels docking. Table 3-5 shows the governing ships that influence the minimum berth length. The berth dimensions will be determined on a later time.

Table 3-5 Normative ships per cargo type and the fitting berth length [Lit 5]

Cargo	Ship Type	Vessel Sizes
General- and container cargo	Feeders and Panamax	Capacity = 4,800 *to 5,100 TEU* LOA = *211 to 294 m* Draft: = *10 to 12 m*
Liquid bulk	Handysize	Capacity = *10,000 to 25,000 ton* LOA = 176 to 183 m Draft = *9 to 11 m*

3.2 Quay and equipment requirements

The general- and container cargo port will use the same handling equipment in both the 2040 optimistic and boldly optimistic scenario. The fishery port will not expand in the boldly optimistic scenario and will therefore not change its handling material between the two scenarios. Liquid bulk can be handled on several different methods, which method will be chosen depends on the location specifications and turnover requirements. Therefore, the exact method will be determined on a later time. Options are shown in table 3-6.

Table 3-6 Handling material general- and container cargo

Cargo	Possible quay configuration(s)	Quay components
General cargo and containers	Quay	Fork Lifts Reach stackers (mobile) Harbour Crane Quay wall
Liquid bulk	*T-Jetty* *L-Jetty* *Finger pier* *SBM*	*Platform* – *Loading arms* – *Control room* – *Fire-fighting equipment* *Bridge and pipe trestle* *Breasting dolphins* *Mooring dolphins*

3.3 Storage methods (to functional)

General- and container cargo

Containers will be stored on a container storage yard in the open air; this consists out of a flat concrete floor accessible by the container moving equipment such as the RTG's.
General cargo will be stored in two different methods depending on the type of goods, either indoor in a shed or outdoor on the storage yard.

Liquid bulk

Liquid bulk will be stored in onshore containment tanks with either a floating roof or a fixed dome. The spatial planning requires extra space for pipelines, pumping stations and service roads. Spacing will depend on bund heights and safety requirements which will be determined in a later stage

3.4 Nautical requirements

In the development of a port nautical aspects play an important role, like the movement of vessels in the approach and access areas, manoeuvring within the port area as well as mooring operations at the terminals.

Table 3-7 Nautical criteria

Subject	Explanation
Manoeuvrability in the port	The port needs to be developed in a way the biggest ships can reach the quay without obstacles. This can be done either on their own power or under the guidance of tugboats.
Waves [Lit. 16]	The maximum allowed wave height is set on 0,5m, very sheltered. This limit is set for the fishing ships in the fishery terminal but will be applicable throughout the whole port.
Water depth[1] [Lit. 2]	– Container terminal: *13m CD* – Liquid bulk terminal: *12m CD*
Quay freeboard[2] [Lit. 18]	– Container terminal: *+4,5m CD*[3] – Liquid bulk terminal: *T.b.d.*

[1] The distance between the CD and the bottom of the water

[2] The distance between the CD and the surface level of the quay

[3] LAT and CD are on equal levels and is therefore changed from LAT in [Lit. 18] to CD in this document.

3.5 Modalities

Table 3-8 shows the different modalities available on the island of Ambon. The port needs to be able to connect to the available modalities. The island does not contain a functioning railroad system and will therefore not need a connection to rail transport.

Table 3-8 Available modalities on Ambon

Modality	Explanation
Air transport	Pattimura airport is the main airport on the island Ambon and is located on approximately 37.0 km from the Port of Waai and handles both passenger and cargo.
Road transport	The port is located near two roads: the national road and the local road, allowing the port to use road transport. Further details of these roads can be found chapter 4.1.3.
Ship transport	The rivers near the port of Waai are unsuitable for freight shipping due to the dependence on rainfall. Ship transport will be conducted via seafaring only.

4

BOUNDARY CONDITIONS

4.1 General conditions

4.1.1 Site overview

An overview of the Waai location can be seen in figure 4-1 on the next page.

Current land usage
The general land usage in this area is mixed crop agriculture and sporadic clusters of housing. There is a customary village[1] with a population of more than 1,500 households located in this area. The land itself exists of a mixture of customary and privately owned land.

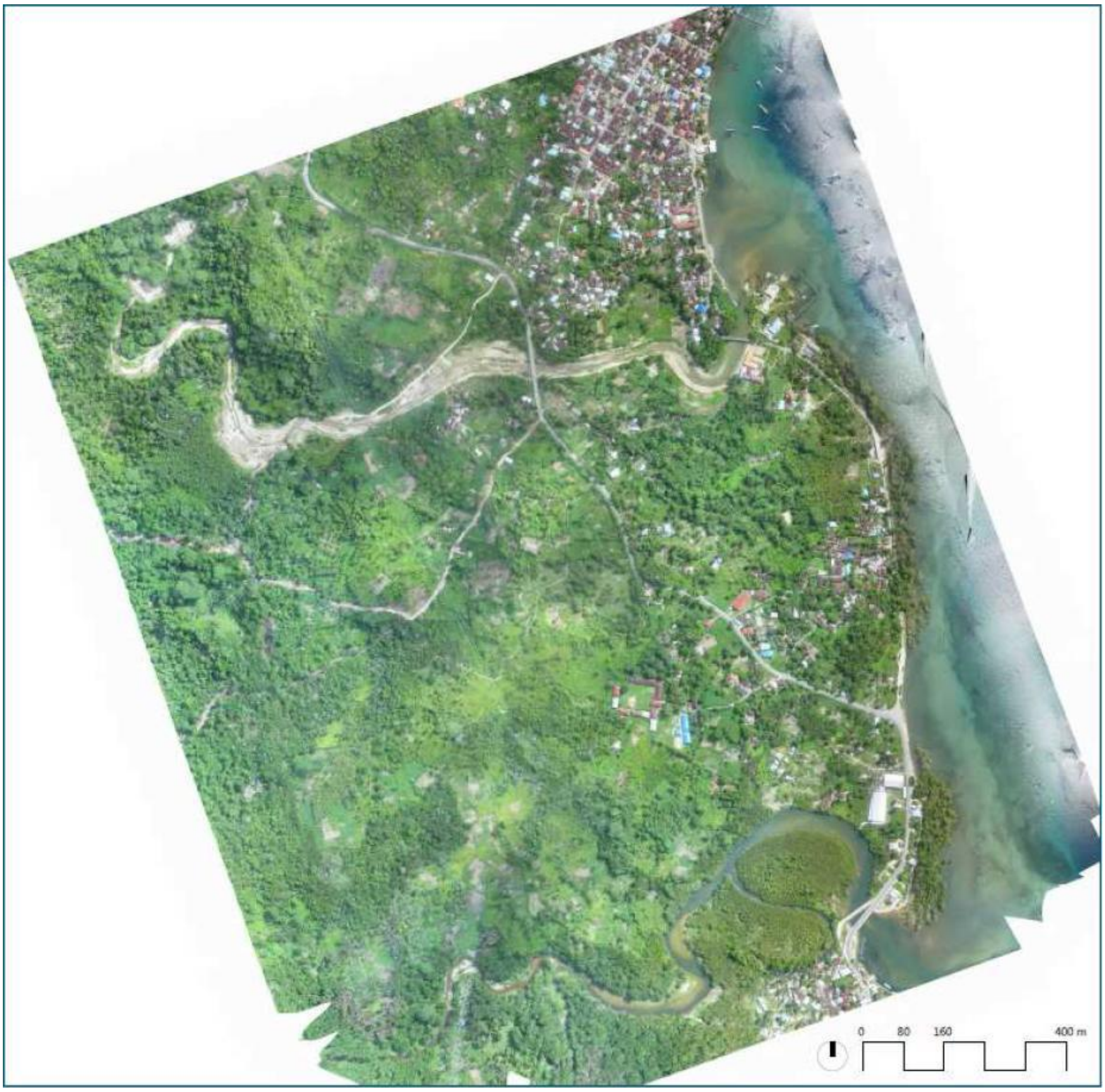
Intended land usage
According to the regional spatial plan (*RTRW*) the land use is intended for plantation and dry land agriculture. In order to develop a port on this location the land will need to be bought and the spatial plan will need to be adjusted, see table 4-1.

Table 4-1 Land prices per m^2 in Waai

Platform	Price
Market price (m^2)	IDR 50-60 thousand
NJOP (m^2)	IDR 20 – 48 thousand

[1] This is a sacred village in the eyes of the local inhabitants

Figure 4-1 Drone image of the Waai site



4.1.2 Bathymetry and topography

As a part of the location study a bathymetry- and topographical survey have been conducted. These surveys clarify the existing conditions of both the water depths as well as the land heights. Further information regarding the bathymetry and topography can be found in Appendix IV.

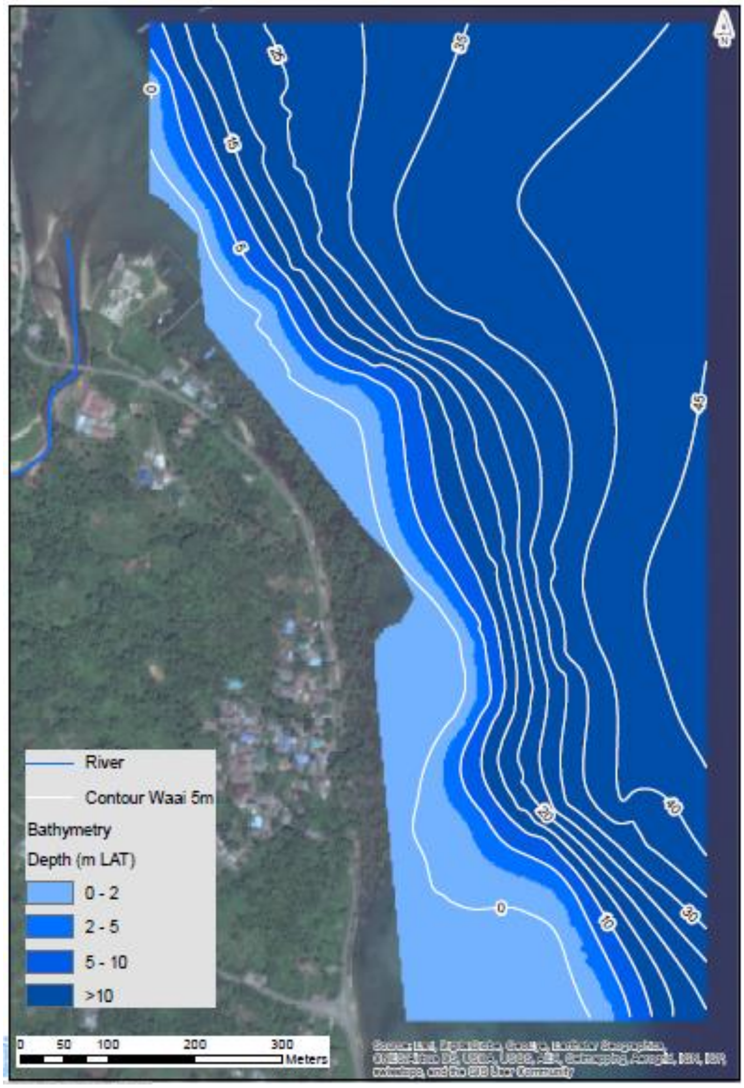
Bathymetry

The natural water depth has to be followed as much as possible to minimize the required dredging as well as the use of extensive civil works for deep waters. The exact location of the berthing front may require more attention. The minimum water depth should be consistent with the requirements as stated in chapter 3.8.1.

A 15m LAT water depth at Waai is reached within 50m to 100 m from the shoreline and the depth of 30 m LAT is reached within approximately 175 m from the shore.

Figure 4-2 shows the result of the first bathymetry survey near Waai. Already close to the shoreline, within 50 to 150 m from the LAT-line, it becomes deeper rapidly.

Figure 4-2 Bathymetry in Waai



Note 1: the survey results are adjusted for tidal conditions

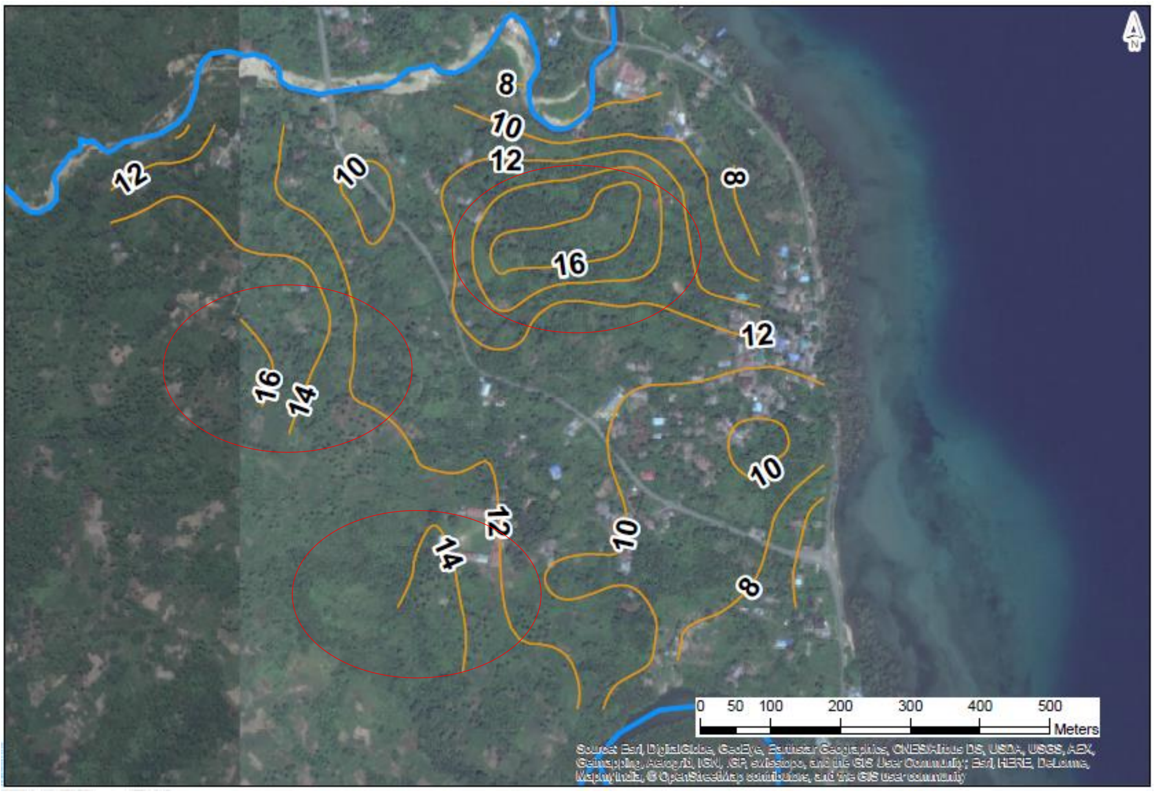
Note 2: survey is done on Thursday, 16 June 2016 from 11.48 WIT to 13.00 WIT

Topography

The Port of Rotterdam predicts a total surface area of 90 ha is required to fulfil the boldly optimistic scenario in 2040. To reach this amount it is required that the Port of Waai expands by approximately 58 ha. The geographical conditions of the Waai location are relatively flat and become increasingly hilly in the west with slopes ranging from 10 to 20%.

Figure 4-3 shows the topography around the proposed port location in Waai. The surface level rises from 0 to 10 m in the first 100 m from the coast. From port area 200 m behind there are hills up to 16 m to the north. Further landward and to the northeast the maximum height is 16 m. 100 m further from the coast, more the topography is becoming flat. Excavation and levelling works might be needed on the higher grounds to the east of the port area as shown in the red circled areas in figure 4-3.

Figure 4-3 Topography in Waai



4.1.3 Infrastructure

Roads

The Waai location contains two major roads; the national road and the local road, see table 4-2 and figure 4-4. The national road is the main connection with the other locations on the island, see table 4-3. The local road will be partially removed in order to establish the Port of Waai in its first phase.

Table 4-2 Conditions of the national and local road near Waai

	Road detail	Description
National Road	Type of surface coarse	AC (Asphalt Concrete)
	Road width (hardened)	Approx. 9-10m
	Road line	2 ways, 4 lanes
	Road segment	Tulehu-Humimua
	Road condition	Good
	Drainage	Sporadic
Local Road	Type of surface coarse	AC (Asphalt Concrete)
	Road width (hardened)	Approx. 4-5m
	Road line	2 way, 2 lanes
	Road segment	Waai
	Road condition	Good
	Drainage	None

Figure 4-4 Location of the local and national road

Table 4-3 Connectivity with road infrastructure on Ambon

Destination from the port	Distance	Average travel time[1]
Airport	37.0 km	55,5 minutes
Existing Yos Sudarso Port	27,3 km	40,95 minutes
Ambon City	25,7 km	38,55 minutes

Water

Water can be gained from the Waai Waterfall in the hinterland of the Waai Village, according to a study performed by the Pattimura University, the waterfall has a potential discharge of $0.92m^3$/sec.

Electricity

In order to function properly the port will need a substantial supply of electricity. According to Mr. Yulisar, from the department of Electricity Distribution, the island of Ambon has a total of 62 MW available. On peak load the island uses 53 MW. This results in 9 MW of electricity which is 15% of the total supply being available during peak load.

The current electricity supply in Waai comes from 'PLTD Poka', a power plant with a 30 MW capacity. The power plant is located on the west side of the Ambon Bay.

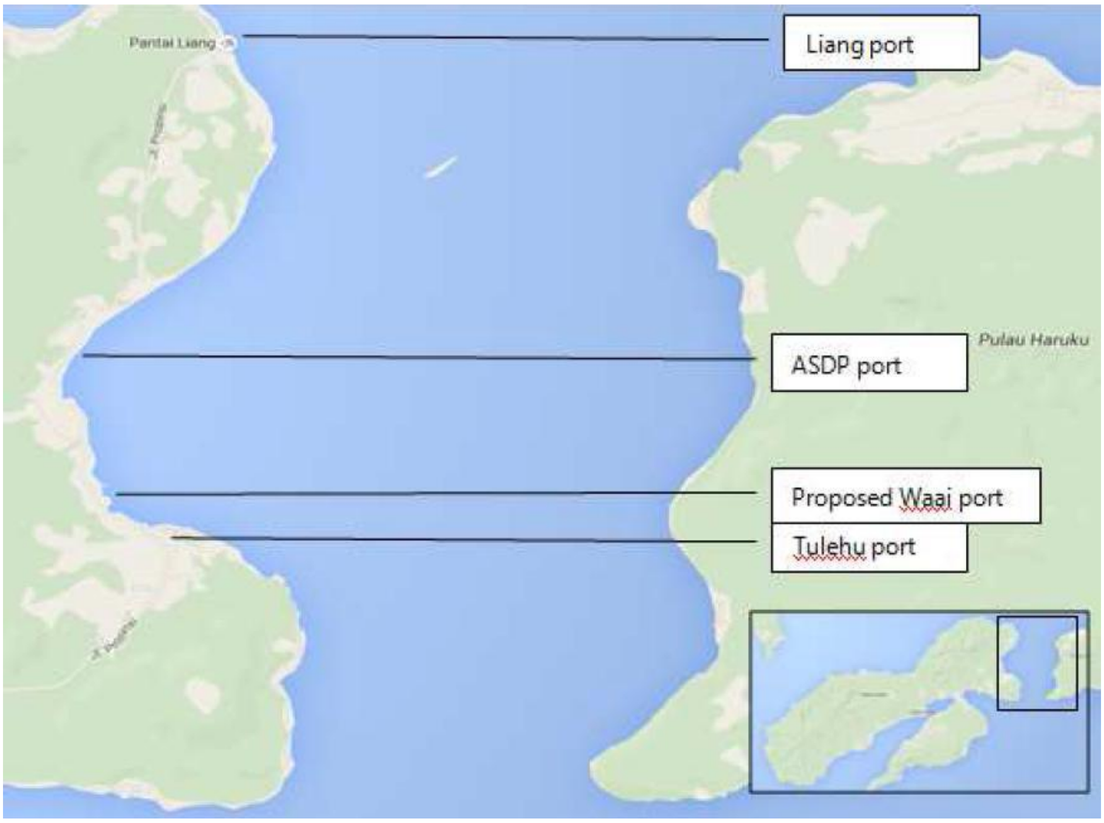
In 2017 'PLTU Waai', a state owned power plant north of Waai, will commence operations as well, resulting in an extra power supply to the Waai region. The power plant is located approximately 4km north of Waai.

[1] The average realistic driving speed is 40km/hr. Based on interviews and the previously conducted site visit.

Ports

There is no cargo port present in Waai, but there are several other ports present in the direct surroundings of Waai, see figure 4-5. On the north-side of the village is a Ro-Ro[1] terminal and on the south-side in the village of Tulehu there is a ferry terminal present. These ports are also used for fishery and small amounts of cargo.

Figure 4-5 Ports near the Waai location



4.1.4 Expansion locations

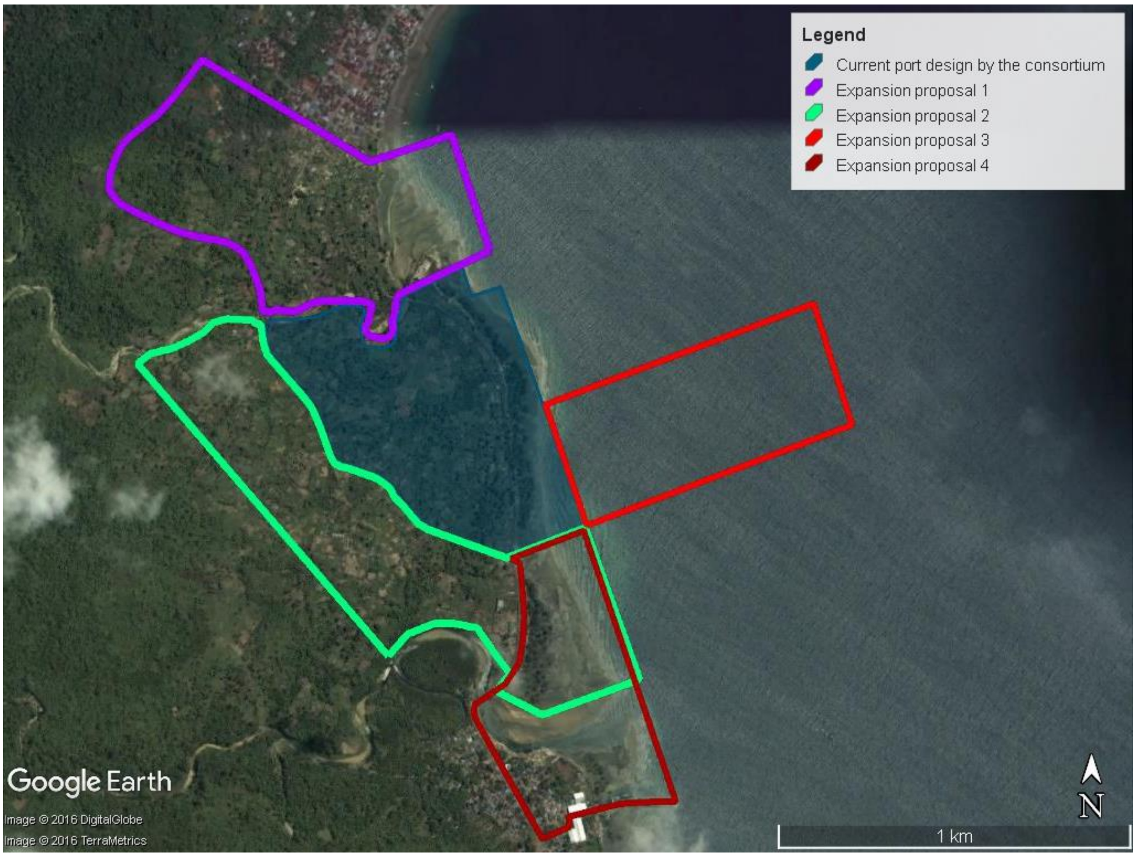
The current port is located on the south side of the city of Waai, in the north eastern regions of the island Ambon in Indonesia. The expansion consists of four possible locations which are described in table 4-4 and shown in figure 4-6. The expansion location will be chosen based on the location study combined with an MCA.

Table 4-4 Location options for the port expansions

Area	Details
Expansion proposal one (North side)	This expansion will cross the river on the north side of the Port of Waai and will stretch across the village of Waai itself. The port will expand in the direction of the Waai village
Expansion proposal two (South and southwest side)	The port will expand in the south and south west direction, this direction contains the national road, housing and mangrove forestation.
Expansion proposal three (East side/land reclamation)	The port will expand into the sea, in order to make this port suitable, land reclamation is required
Expansion proposal four (South side to Tulehu)	The port will expand in the southward along the shoreline in order to connect to the Port of Tulehu. This direction contains the village of Tulehu

[1] Roll-on, Roll-off cargo

Figure 4-6 Location options for the port expansion (aerial view)



4.2 Hydrological conditions

4.2.1 Wind

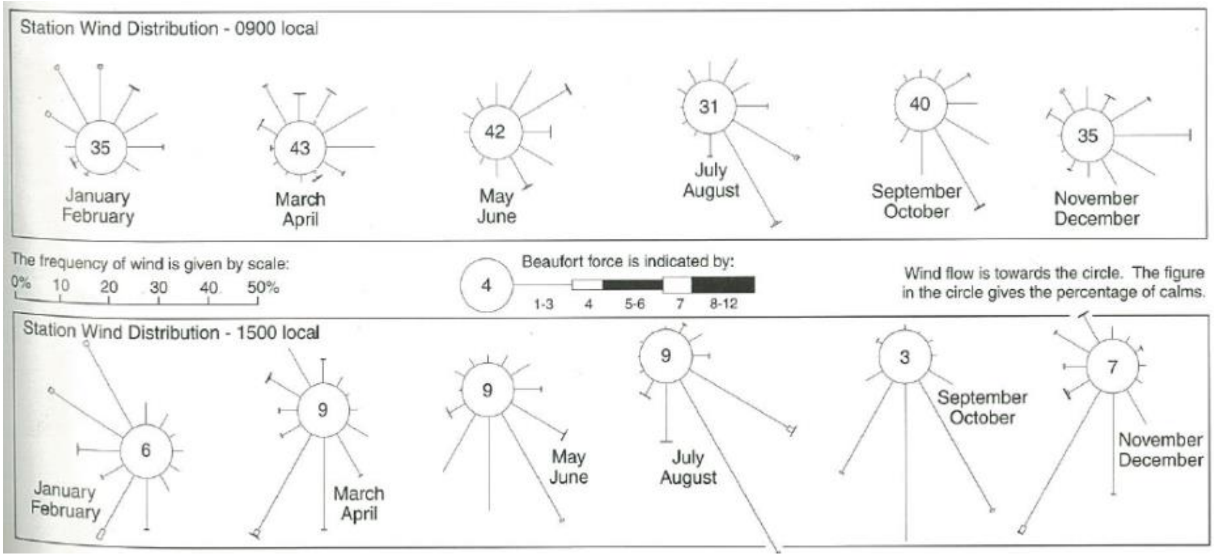
According to interviews the maximum wind conditions in Waai occur during the east monsoon and wind comes from east and north direction. In such a maximum condition there is no significant effect or damage. It was mentioned that the current conditions are milder than the in the period.

According to the Maluku statistics bureau[1] in 2015, the wind velocity has an average of 5 knot, mostly from west. Figure 4-7 shows the wind distribution according to the Admiralty Sailing Direction Indonesia Pilot Book volume III. This figure shows the following:

- *In the morning, the wind is year round weak, 1 to 3 Bft. From July until December the wind blows slightly more from the easy.*
- *In the afternoon, from January until April, winds blow mostly from the west.*
- *In the afternoon from May until December winds tend to blow from the south and south-east.*

[1] Locally named: Maluku dalam Angka

Figure 4-7 Wind distribution in Ambon [Appendix IV]



4.2.2 Rivers

The Waai location contains two rivers; one on the north side and one on the south side. These rivers contain more water during the rainy season, in the dry season the rivers run dry except for the river mouth. There is currently no data available regarding the discharge of these rivers.

4.2.3 Rainfall and evaporation

For the conceptual design of the port, the rainfall will not be taken into account since it has no influence on the design. The capacity of the drainage systems and similar constructions will be handled in the Detail Engineering Design (DED), which is not a part or direct result of this thesis.

4.3 Hydraulic conditions

4.3.1 Tide

Tidal constants for Ambon[1] are derived from the 'tide tables' book of 2006' by Jawatan Hidro-Oseanografi TNI AL. Table 4-5 shows the 9 tidal constants for Ambon.

Table 4-5 Tidal constant at Ambon [Appendix IV]

Tidal constant	M2	S2	N2	K2	K1	O1	P1	M4	MS4	Z0
Amplitude (cm)	47	17	10	5	29	21	9	-	-	130
Degree (360-g)	318	250	355	266	36	47	41	-	-	

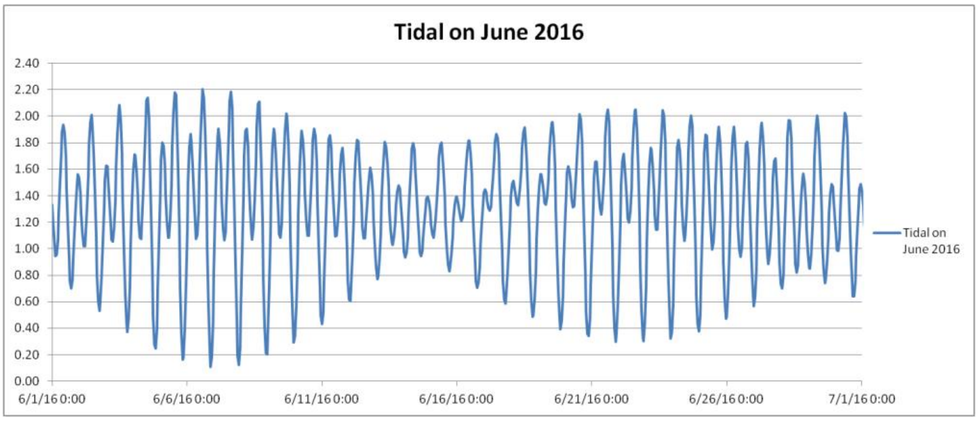
Table 4-6 shows the tidal characteristics. These are used to generate the tidal level in June shown in figure 4-8. The maximum tidal difference is approximately 2.6 metres.

[1] At: Latitude 03^0.07 S Longitude 128^0 2 E

Table 4-6 Tidal characteristics for Ambon [Appendix IV]

abbreviation	description	level [LAT+m]
HAT	highest astronomical tide	2.6
HHWS	highest high water spring	2.4
MHWS	mean high water spring	1.9
MSL	mean sea level	1.3
MLWS	mean low water spring	0.7
LLWS	lowest low water spring	0.2
LAT	lowest astronomical tide	0.0

Figure 4-8 Tidal forecast on June 2016 in Ambon [Appendix IV]



4.3.2 Waves

The local fisherman that joined the survey on the June 16th, 2016, told that the maximum wave height is around 1.0 m during the east monsoon. The east monsoon period is unpredictable, but it is mainly from July to January. According to the fisherman, due to climate change, the weather has changed in the past decades. In 1970-1980 the wave height in Waai could reach 3.0 m during east monsoon.

The wave height is also calculated based on the fetch and the wind velocities in chapter 2. The fetch in Waai is shown below and varies from 3 to 19 km. For 98% of the year the wind velocity is 3 Bft or less, so this results in a wave height of 0.15 m. With a wind velocity of 7 Bft, which statistically occurs less than 1 day per year, the wave height can be between 0.65 m to 1.39 m.

Table 4-7 Fetch length in Waai [Appendix IV]

Direction (^{0} from North)	0	30	60	90	120
Fetch length (km)	3	19	11	10	10

Figure 4-9 Fetch in Waai [Appendix IV]

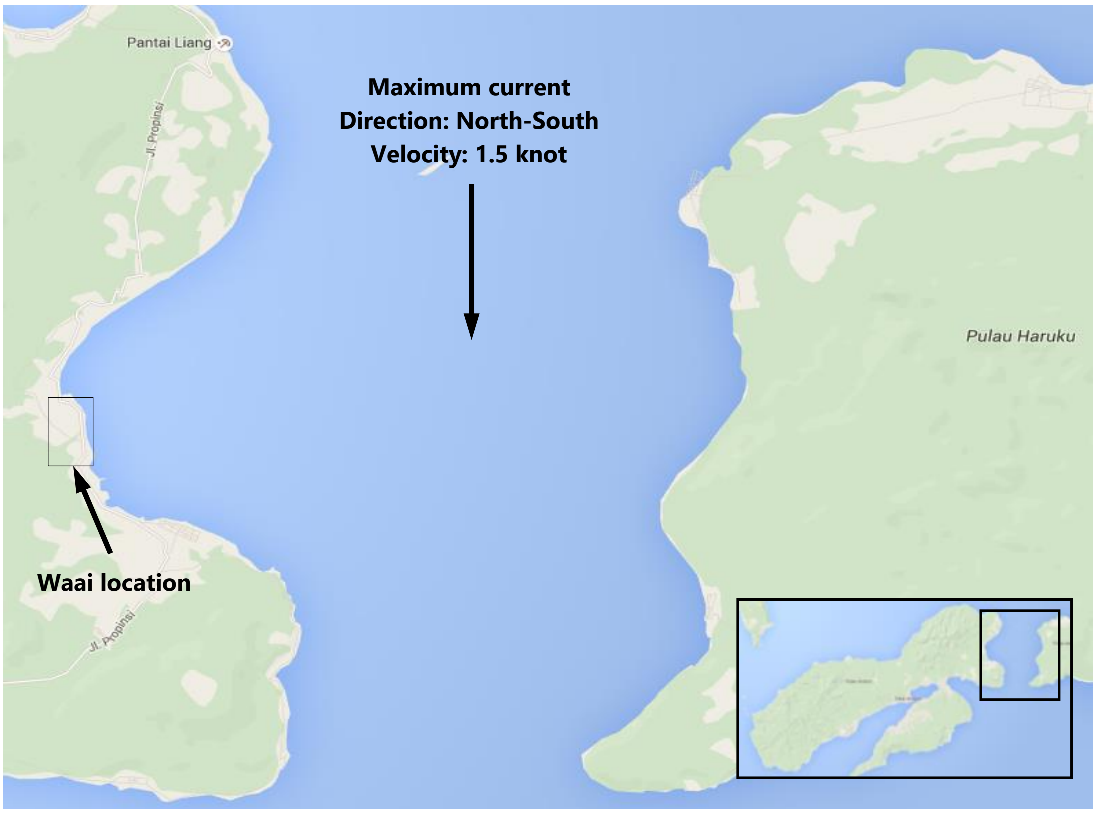
Table 4-8 Wave height in meters for the relevant directions and various wind velocities at Waai [Appendix IV]

Wind velocity (Bft)	0^0	30^0	60^0	90^0	120^0
1	0.02	0.02	0.02	0.02	0.02
3	0.15	0.29	0.24	0.23	0.23
4	0.24	0.50	0.41	0.39	0.39
5	0.36	0.76	0.61	0.58	0.59
6	0.50	1.06	0.84	0.80	0.81
7	0.65	1.39	1.11	1.05	1.07

4.3.3 Currents

Waai is located in a bay and on quite a distance from the Haruku strait. The current at Waai will be less than the maximum current rate of 1.5 knot, approximately 0.75 m/s, which is stated in the Indonesia Pilot Book in chapter 4.107 section two. Its direction is from North to South and is strongest around the South West extremity of Pulau Haruku, see figure 4-10. In interviews it was mentioned that the currents at Waai and Tulehu Port are calm. In average the velocity in the basin is only a few centimetres per second. Vessels never had interference of the current.

Figure 4-10 Maximum current velocity at Waai [Appendix IV]



4.3.4 Tsunamis

Southeast Asia is regularly struck by tsunamis; however, the design of this port will not take these into account. The port needs an open connection with the sea in order to be able to unload and load the ships.

4.4 Geotechnical conditions

The soil condition on the three locations is in general sandy, mixed with some gravel. It is expected only light groundwork is needed before construction can start. In Waai there is a mangrove forest, some clay can be expected. At Waai there are existing jetties. In Waai the jetty for the power plant has tubular piles with a thickness of 4.0 inch, see figure 4-11.

Figure 4-11 Jetty at Waai for the power plant with the pile size

III

APPENDIX: MAIN PORTS ON AMBON ISLAND

TABLE OF CONTENTS

1

INTRODUCTION

The island of Ambon contains several different ports which have their own speciality. This document will explore these ports based on their location, speciality and characteristics. Some of these ports will be relocated and together form the new Ambon port. Others contain information which is used as a reference in the design of the new Ambon port.

Since the new Ambon is directly related with these ports, this document will summarize the key characteristics of these ports in Ambon. This is done combining the information that is either gathered during the field survey on the location, a literature study related to ports in general and information provided by Pelindo IV.

Chapter two describes the location and main functions of the ports on the island. Chapter three explores the Yos Sudarso Port located in the centre of Ambon city. In chapter four the Tulehu port is explored which is located to the south of the new Ambon port. In the last chapter, chapter five, the Wayame port in the bay of Ambon is analysed.

2

PORTS OF AMBON

The main port of Ambon is the Yos Sudarso Port. The port handles is specialised in the handling of container cargo but also handles general cargo and contains a passenger terminal. At the moment there is no main fishery port on the island. Fishery ports are spread throughout the islands coastline across the coastal villages. The Wayame Port is the main Liquid Bulk terminal on the island and is managed by Pertamina a stated owned fuel company. Ferry's ship from mainly from two ports: The Yos Sudarso Port and the Tulehu ferry port. All these ports are spread out over the islands as is shown in figure 2-1.

In the next chapters the three main ports will be analysed:

- Yos Sudarso Port
- Tulehu Port
- Wayame Port

Figure 2-1 Location of the Yos Sudarso Port

3

YOS SUDARSO PORT

Table I contains the operating details of the Yos Sudarso Port; these numbers are provided by the operator of the port 'Pelindo IV'. The port is specialized in the handling of container cargo but also has a section devoted to passengers and a section for the handling of general cargo.

One of the problems within this port is the traffic congestion in the surrounding area. Do to the increasing amount of people, traffic and trade in Ambon, the traffic flow is limited. It is not allowed for the containers of the Yos Sudarso Port to leave the port and will therefore have to be handled on location [Lit. 11].

Table 3-1 Function details of the Yos Sudarso Port in Ambon

Port Overview	Unit	Amount
Total area usage	Ha	5.203
Quay length	m	685
Ships docking per year	-	1644
Berthing Occupancy Ration in 2015	%	60,57
Total yard	**Unit**	**Amount**
Container yard	m^2	44.121
Capacity	TEU/year	+/-300.000
Multipurpose yard	m^2	10.000
Reefer plugs	-	32 (plug shocked)
Yard Occupancy Ration in 2015	%	70
Dwelling Time	Days	2-3 (domestic handling)
(Un)Loading Equipment	**Unit**	**Amount**
Level-luffing crane (LLC)	-	1 (25 ton)
Container Crane (CC)	-	1 (40 ton)
Supporting Equipment	**Unit**	**Amount**
Head Truck 20"	-	11 (25 ton)
Head Truck 40"	-	2 (40 ton)
Rubber tired gantry (RTG)	-	2 (40 ton)
Reach Stacker (RS)	-	3 (40 ton)
Fork Lift	-	1 (7 ton)
Other Supporting Equipment	**Unit**	**Amount**
Mooring Pilot	-	1 (370 HP)
Tug Boat	-	2 (2000 HP)
Passenger Terminal	Persons	+/- 800

4

TULEHU PORT

The Tulehu port is located on the north east region of the island roughly one kilometre south of the new Ambon port. Figure 4-1 shows the two main ports of Tulehu. The north port is a relatively big fishery port. The difference between the Tulehu fishery port and other fishery ports surrounding the island is the presence of the cooling facilities, see figures 4-1 to 4-3. There are no known numbers regarding the amount of fish being handled in this specific port. The ferry port sails between the islands on the east of Ambon and back.

Figure 4-1 Tulehu fishery and ferry port

Figure 4-2 Cooling facilities Tulehu

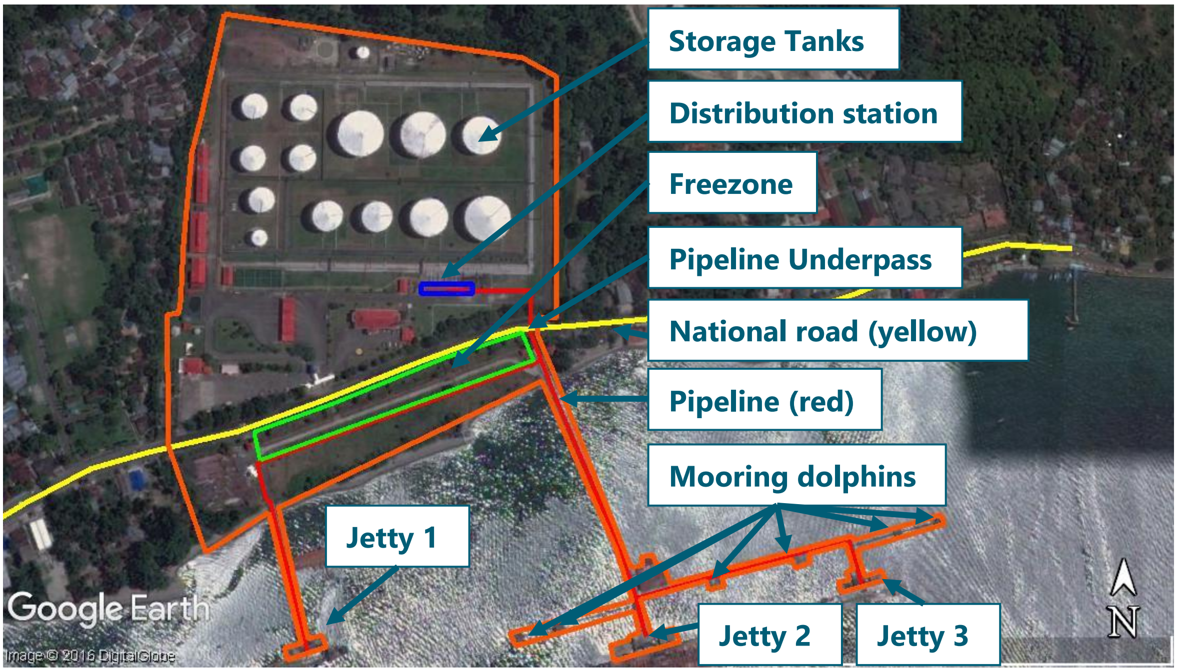
Figure 4-3 Cooling facilities Tulehu

5

WAYAME PORT

The Wayame port is located on the east side of the Ambon bay and solely handles fuel cargo. The port is owned and managed by Pertamina. Although the port was a part of the site survey on the 21st of October, 2016, the present security did not allow pictures to be made. Figure 5-1 shows the layout of the port from above.

Figure 5-1 Wayame port and the national road of Ambon



The port has three berthing locations made out of one T-jetty and one L jetty with two smaller T-jetties attached to it. Out of the three jetties, the second Jetty has the highest capacity, see table 5-1.

Table 5-1 biggest vessel allowed in the Wayame port [Lit. 19]

Terminal BBM	Jetty	Draft	DWT (Max)	LOA
Wayame	Jetty 2	16 m	35000 MT	200 m

The loading and unloading of the fuel is done at the jetties and the storage takes place in the hinterland. In order to transport the bulk from the jetty to the storage tank, the bulk is transported via pipelines, see figure 5-1. In order to connect the pipeline between the jetty and the storage tank, the pipeline has to pass the national road. The pipeline underpasses the road; that way the road and the pipeline do not interfere with each other.

As a safety precaution, the pipeline on the sea side of the port is located on a 30m distance from the national road. In figure 5-1 this is shown by the green block which highlights the free zone between the ports pipeline and the national road.

IV

APPENDIX: METOCEAN AND TOPOGRAPHICAL SURVEY NEAR WAAI

TABLE OF CONTENTS

1

INTRODUCTION

In order to gather information regarding the physical conditions around the project location, a metocean survey and a topographical survey have been conducted. The data in this document is gathered by combining both field research conducted by Witteveen+Bos and a desk study.

Chapter two contains the data collected during the metocean survey. Chapter three contains the data collected during the topographical survey.

2

METOCEAN SURVEY

2.1 Method of data collection

To get a first estimate regarding the water depths on the project location, a bathymetry survey is carried out in the waters near the coastline between Waai and Tulehu. The measuring is carried out by the "Deeper Fish Finder". The Deeper Fish Finder is a measuring device used to map the depths of sea floors. It works with the assistance of a Smartphone. The GPS on the smart phone will indicate the location and show the depth of the location which is measured by the Deeper Fish Finder. The survey was carried out with the assistance of local fisherman and a boat. During the measuring, several interviews were carried out regarding the met-ocean conditions.

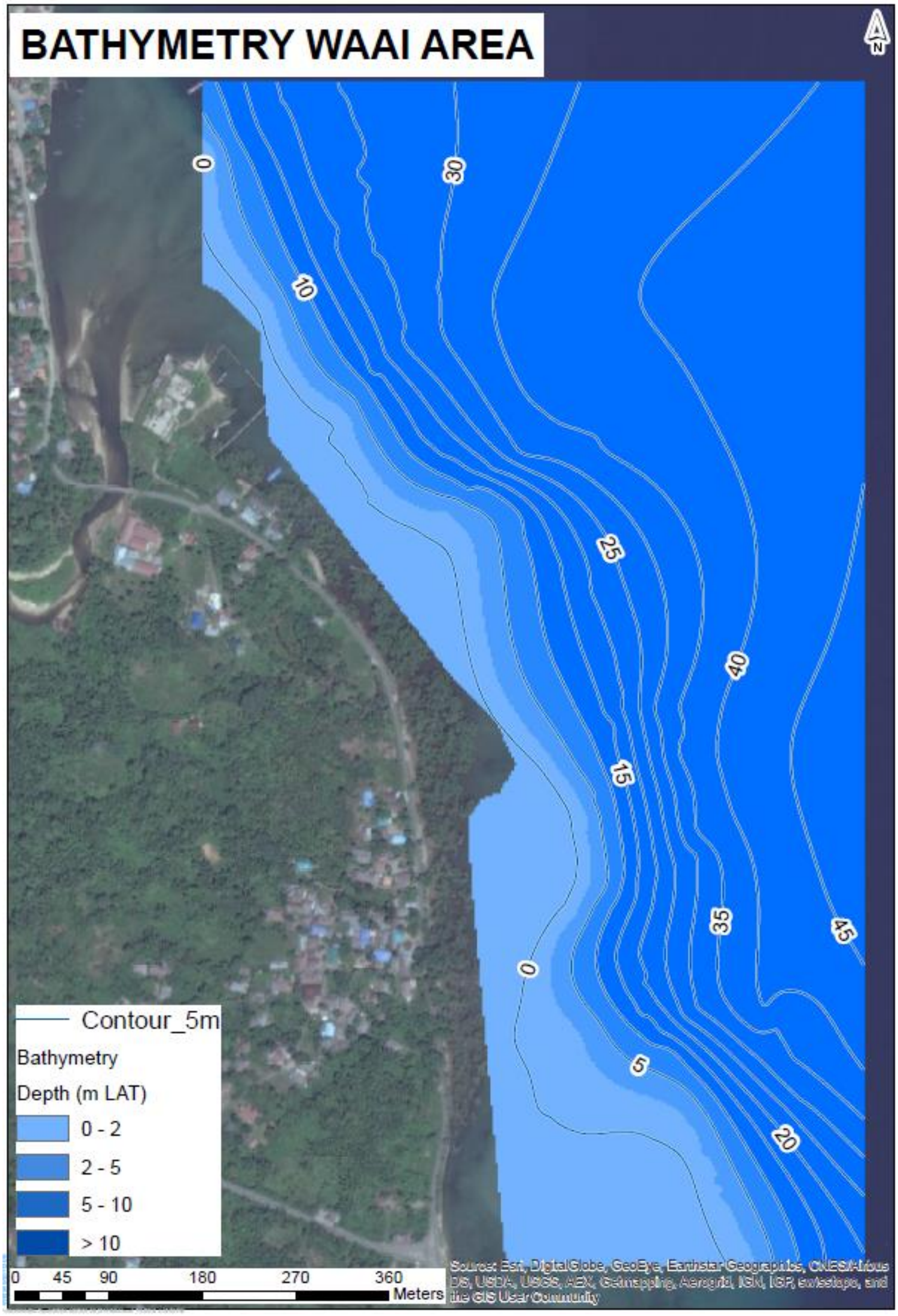
Figure 2-1 Deeper fish finder

2.2 Bathymetry

The Bathymetry in Waai was measured on Thursday, 16 June 2016 from 11.48 WIT to 13.00 WIT. The survey results are adjusted with the tidal conditions; therefore, the bathymetry results are in LAT conditions. This is the best for port design and navigation recommendations.

According to the map in figure 2-2 the bathymetry is subtler in the north area than it is in the south. A water depth of 5.0 m is reached between 40 .0 m and 150.0 m into the sea. A water depth of 15.0 m is reached between 50.0 m and 300.0 m into the sea. At a distance of 150.0 m from the coast, the water depth falls to 30 m. For a port with a wharf, dredging will be needed to fulfil water depth requirements.

Figure 2-2 Bathymetry in Waai



2.3 Wave

The calculation of wave height (Table 2-2) depends on the fetch length. The fetch in Waai is shown in Figure 2-2 and detailed in table 2-1. The fetch length in Waai varies between 3.0 and 18.9 km.

Figure 2-3 Fetch in Waai

Table 2-1 Fetch length in Waai

Degree (^{0}) from North	Fetch length (km)
0	3.00
30	18.90
60	10.80
90	9.59
120	9.89

Table 2-2 Wave height per wind speed and direction in Waai

Wind speed (Beaufort scale)	Wave height per wind direction (m)				
	0^0	30^0	60^0	90^0	120^0
1	0.02	0.02	0.02	0.02	0.02
3	0.15	0.15	0.15	0.15	0.15
4	0.24	0.24	0.24	0.24	0.24
5	0.36	0.36	0.36	0.36	0.36
6	0.50	0.50	0.50	0.50	0.50
7	0.65	0.65	0.65	0.65	0.65

During an interview with local fishermen, local wave data was collected. Due to climate change, the weather patterns have changed. In 1970-1980, a wave height in Waai reached 3.0 m during the east monsoon. In the recent years, the maximum wave height measured is 1.0 m during the east monsoon. The east monsoon is unpredictable but most of the time it occurs from July to January. During the maximum wave height, the maximum capacity of ships being handled is 15 GT. These vessels may be filled with a maximum of 20 people.

Most of the year, the wind speed is 3 Beaufort scale, see table 2-2. In this condition the wave height in Waai is below 0.3 m. More extreme conditions can be expected during the east monsoon from January to July. According to the wind distribution in table 2-2 the maximum wind frequency during the east monsoon occurs in the afternoon and contains 30% wind speeds with 3 Beauforts. Therefore, the wave height of 0.3 m occurs more often. The overall maximum wave height occurs during wind speeds of 7 Beauforts. The possibility of occurrence for these wind speeds is 0.2% in year. This is the threshold for wave design in ports, with a wave height of 0.65 m. According to OCDI 2002 a wave height of 0.7 m is suitable for ports which serve vessels of maximum 50.000 GT.

2.4 Tidal

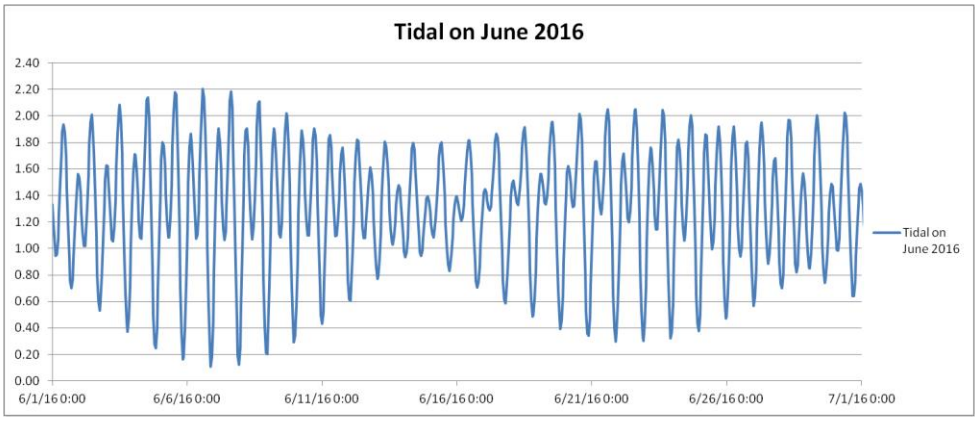
Tidal references at Ambon (Latitude $03^0.07$ S Longitude 128^0 2 E) are used in this study. This data is derived from the 'Tide Tables Book 2006', which is published by Jawatan Hidro-Oseanografi TNI AL. The amplitudes for nine tidal constants are presented in table 2-2.

Table 2-1 Tidal constant at Ambon

Tidal constant	M2	S2	N2	K2	K1	O1	P1	M4	MS4	Z0
Amplitude (cm)	47	17	10	5	29	21	9	-	-	130
(360-g) degree	318	250	355	266	36	47	41	-	-	

The tidal levels in June 2016 are based on the tidal constant shown in Figure 2-3.

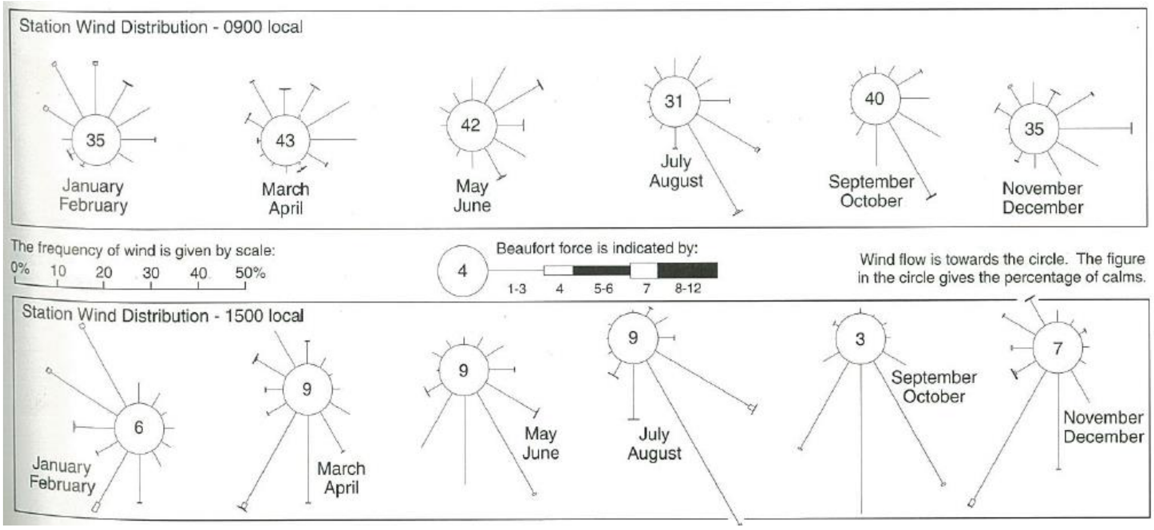
Figure 2-3 Tidal forecast on June 2016 in Ambon



2.5 Wind

According to "Maluku Dalam Angka"; the average wind in 2015 had a speed of five knot and mainly came from the west. Data regarding currents is taken from; 'Admiralty Sailing Direction Indonesia Pilot Book volume III'. The wind distribution in Ambon is taken from: 'The Indonesian Pilot Book' as shown in Figure 2-4.

Figure 2-4 Wind distribution in Ambon



The data from the wind rose is used to create a clear overview of the frequency of wind speeds and their directions as is shown in Table 2-3

Table 2-3 distribution wind and speed in Ambon

Direction [° from N]	Calm (no wind)	Wind speed (Beaufort Scale)				Total
		1-3	4	5-6	>7	
	22.42%					22.42%
0		4.36%	0.02%	0.02%	0.00%	4.41%
30		4.49%	0.01%	0.01%	0.02%	4.53%
60		5.46%	0.03%	0.01%	0.01%	5.51%
90		6.11%	0.03%	0.00%	0.02%	6.16%
120		8.42%	0.05%	0.01%	0.01%	8.49%
150		11.65%	0.07%	0.01%	0.04%	11.76%
180		10.57%	0.03%	0.00%	0.00%	10.59%
210		8.71%	0.37%	0.00%	0.02%	9.10%
240		3.19%	0.03%	0.00%	0.02%	3.25%
270		2.20%	0.05%	0.01%	0.01%	2.27%
300		5.37%	0.08%	0.03%	0.02%	5.49%
330		5.84%	0.10%	0.00%	0.00%	5.93%
Total	22.42%	76.36%	0.87%	0.09%	0.17%	100.00%

The wind speed of 3 Beauforts occurs more than 75% per year. Wind from direction South East to South West is over 30% of the time. For the purpose of this reconnaissance study, the wave heights in the project area were estimated using the Bretschneider formula for shallow water conditions. The dominant wave in the project area can be generated from a wind direction of 0º to 180º from North (depending on the location). The effective fetch length (defined on the length of water over which a given wind has blown and generates waves) is presented for each location, see figure 2-1. Wave heights are determined according to the Bretschneider formula for several wind speeds and effective fetch lengths.

According to the interview results, the wind conditions in Waai reach a maximum during east monsoon. These winds mainly come from North and East. In maximum conditions, no significant effect or damage has occurred in the past.

2.6 Current

According to the data from the Indonesia Pilot Book (Chapter 4.107 section 2), in the Haruku Strait the maximum current speed is 1.5 knot (0.75 m/s) from North to South. It is strongest around the South West area of Pulau Haruku. As Waai is located in a bay far from the strait, the current in Waai does not reach 1.5 knot. According to the interviews, the current on Waai location and Tulehu Port is calm. The vessels never interfere because of the currents velocity.

Figure 2-5 speed and direction of the current in the Haruku straight

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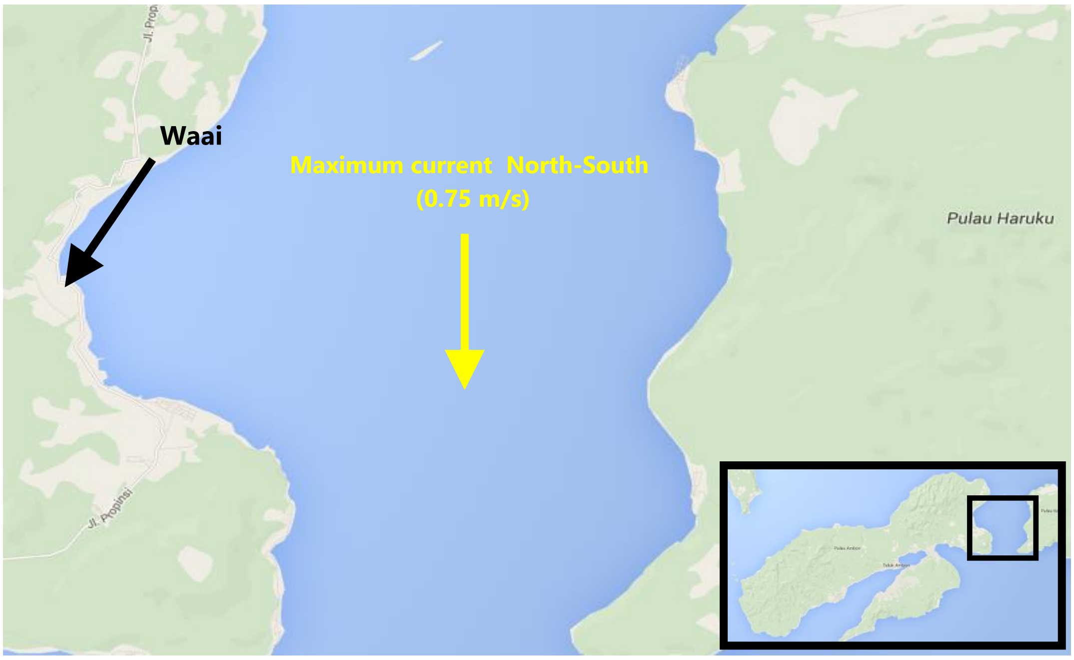


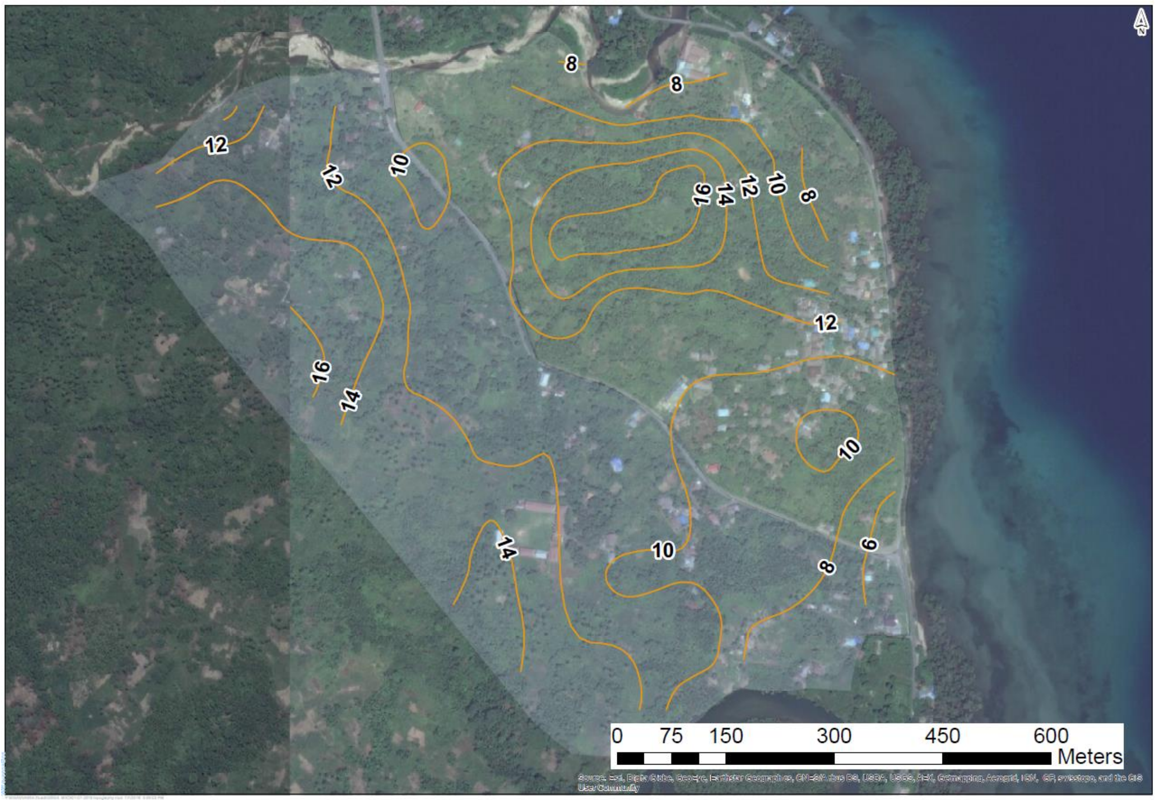
3

TOPOGRAPHY IN WAAI

3.1 Topography

Figure 3-1 shows the topography on the location of the current new Ambon port. The general topography of Waai is relatively flat compared to the other considered locations. The maximum height in the area is 16 m. On the north east there are some small hills. In order to prepare the area for the development of a port, elevation works have to be conducted.

Figure 3-1 Topography in Waai



Figures 3-2 and 3-3 on the following pages, show the topographical data for the expansion locations as described in paragraph 4.2 of the main bachelor thesis.

Figure 3-2 topography on the project location

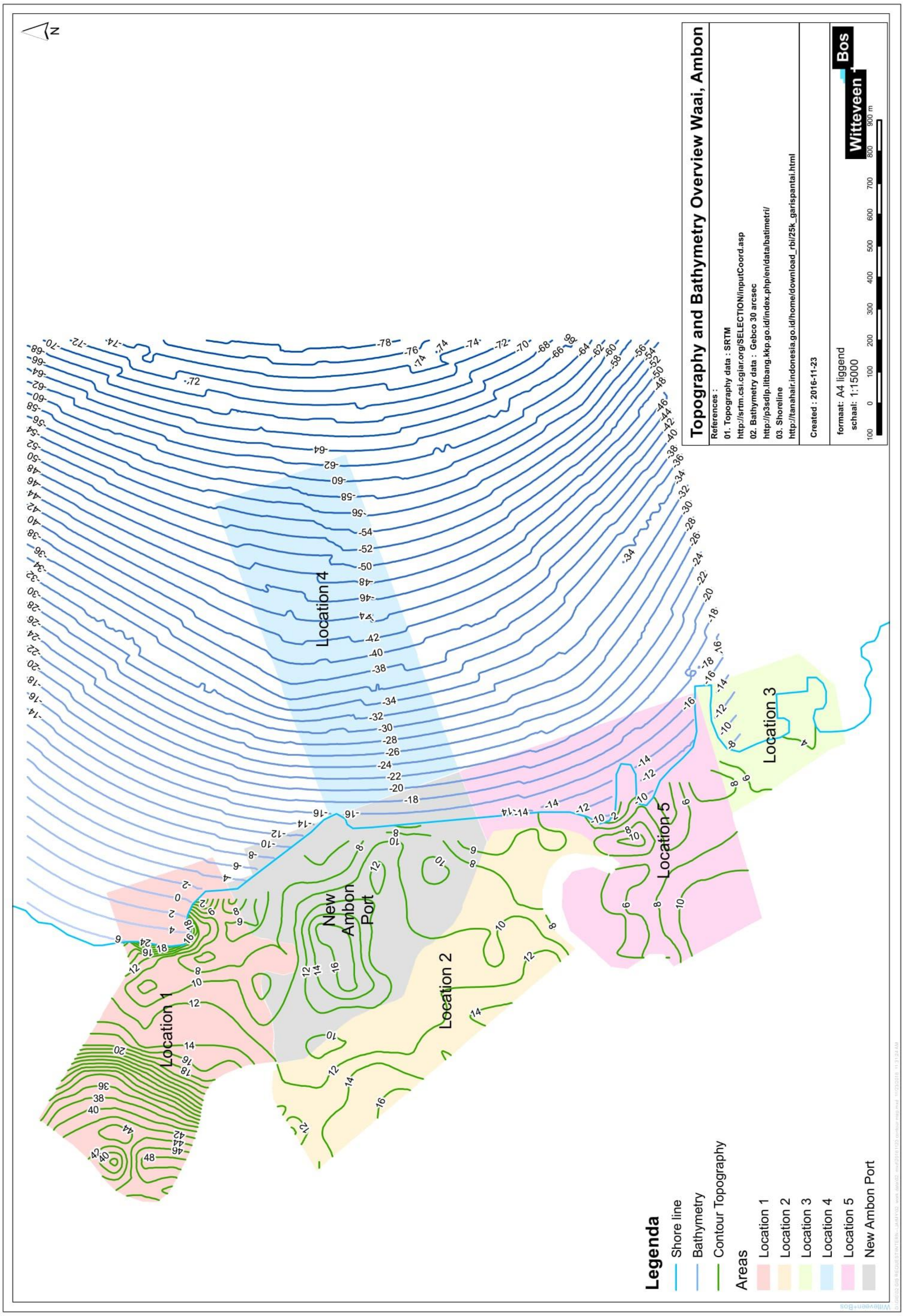
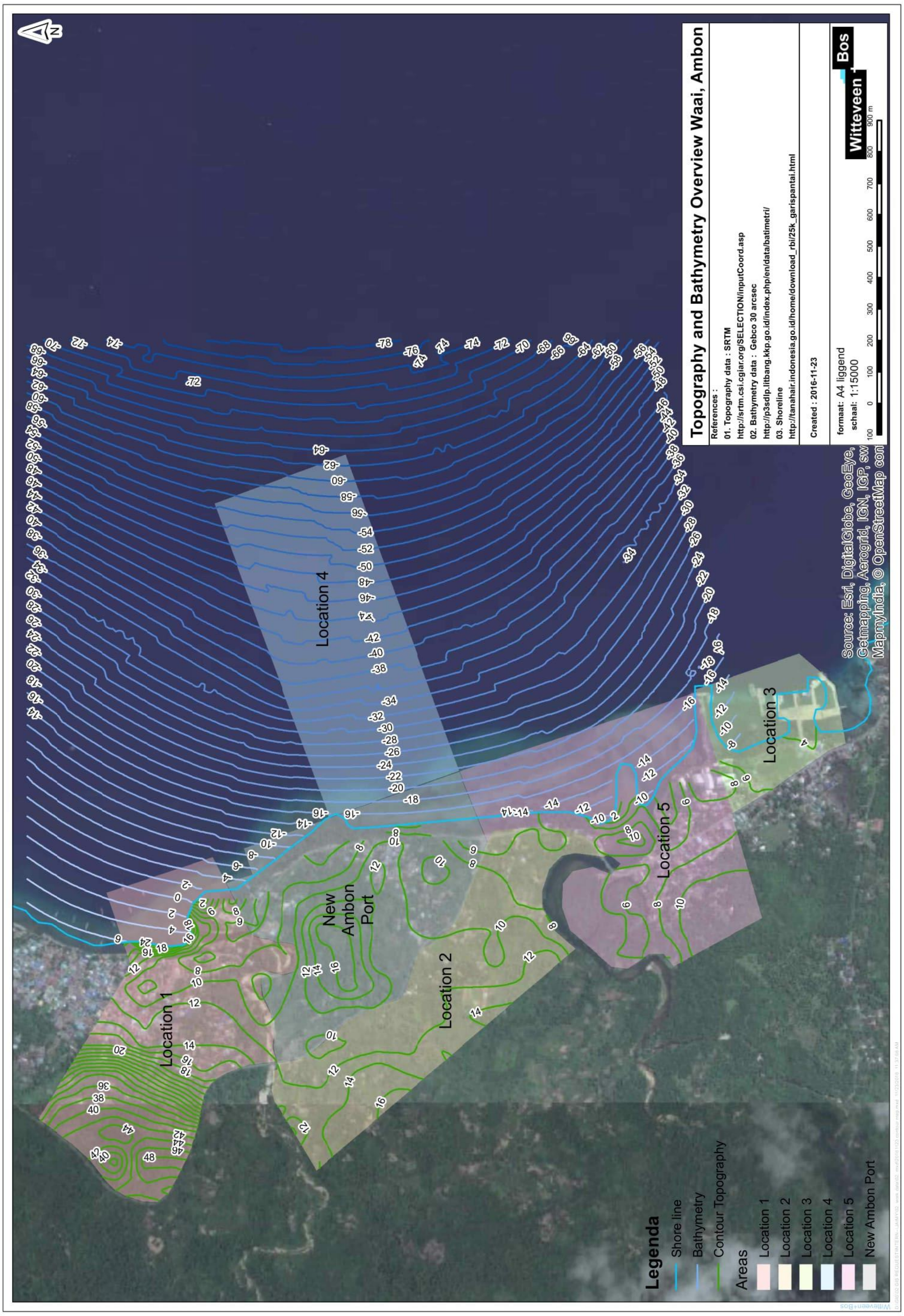


Figure 3-3 topography on the project location including aerial view



3.2 General condition

In the front of Waai, there is Haruku Strait, separating Ambon and Haruku Island. Pambo Island located in the middle of the strait with distance from Ambon Island is 2.4 km. The Haruku Strait is easy to navigate even at night in good visibility as there are good navigational aids available.

There are 2 ports near the Waai location. The first port is the Tulehu Port which contains a ferry port and a fishery port. The ferry sails from Ambon to Seram and Haruku Island. This port is operated by 'Directorate Sea Transportation'. The second port is operated by ASDP (Directorate Land Transportation) used for people transportation as well and is located to the north of Waai village.

In Tulehu Port maximum operated vessel is 14.000 DWT, but it is very rare used by this vessel. The common ferry vessel size in Tulehu is 200-300 GT. The vessel length is 30 m and it is able to be filled by 300 people.

In this area there are a lot of mangrove trees. The mangroves have been growing on this location for a hundred years. There are two types of mangroves growing in Waai. The first mangrove has root type cane and is able to grow for hundred years. Another mangrove which has a common type of root grows has a shorter life span.

3.3 Soil Conditions

The Waai location contains a lot of Mangrove growth. It indicates that there is clay in the bottom which might lie under the sand layer. The existing jetty in Waai is constructed using tubular piles. The power plant jetty in Waai the wall contains tubular piles with a thickness 4.0 inch.

Figure 3-4 pile size at the power plants' jetty at the north of Waai

V

APPENDIX: LOCATION AND LAYOUT STUDY

TABLE OF CONTENTS

1

INTRODUCTION

1.1 Overview proposed locations

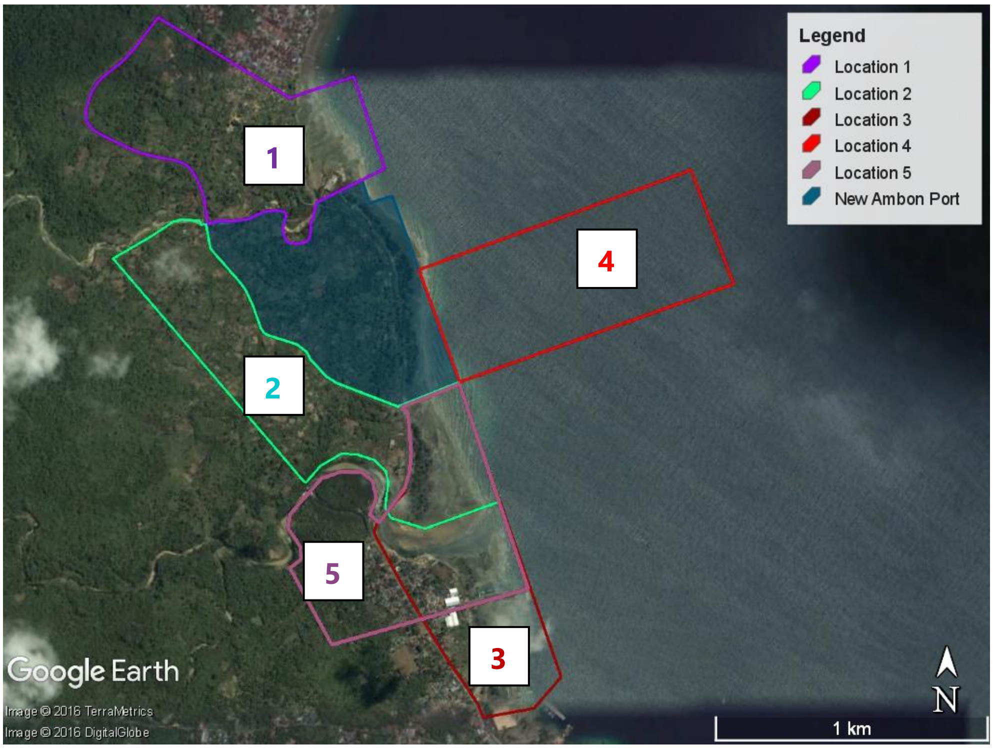
1.1.1 Proposed locations

In order to reach the requirements for the boldly optimistic scenario the new Ambon port will have to expand both the container terminal by 12 ha and create a liquid bulk terminal of 30 ha. There are five selected locations where this expansion can be developed, see table 1-1 and figure 1-1. These five locations are then used to create seven concept layouts which are further explained in the next chapters.

Table 1-1 Five proposed locations for the expansion around the new Ambon port

Area	Details
Location One	This location expands north towards Waai and northwest into the hinterland. It will also cross a river.
Location Two	This location expands south and west surrounding the new Ambon port. It will also cross the national road.
Location Three	This location expands south towards Tulehu and will cross a river and the fishery port of Tulehu.
Location Four	The port will expand into the sea, in order to make this port suitable, land reclamation is required.
Location Five	This location expands south towards Tulehu and southwest into the hinterland.

Figure 1-1 Five proposed locations for the expansion around the new Ambon port



1.1.2 Basic layout versions

In consultation with Mr. Octareza Shiaraan[1], seven conceptual layouts were created based on the five locations. These layouts were considered the most reasonable options for the presented situations, taking the available space and the requirements into account. However, the actual measurements of these layouts are might be subject to change during a more detailed design of the port expansion. The following conceptual layouts have been made:

- Layout 1A and 1B
- Layout 2A and 2B
- Layout 3
- Layout 4
- Layout 5

1.1.3 General area characteristics

Since the proposed locations are located relatively close to each other and to the new Ambon port, some of the Physical Obstacles is the same on all locations. Because these characteristics are the same they do will not be used in the description and analysis of these different locations and layouts. Characteristics that are commonly shared among the locations include:

- Physical conditions such as; wind, waves, tidal and soil conditions
- Travel distances from the port to other locations

The height maps used for the topography and the bathymetry contain a small error in the layover. The heights are correct, only may be several meters of horizontally. The measurements come from two different sources that have been put together into one map. Due to a lack of checkpoints, the X- and Y-axel of this map could not be matched to ensure a 100% correct layover. The heights are correct, only may be several meters of horizontally.

1.2 Purpose of the location evaluation study

The purpose of the location evaluation study is to evaluate the seven layouts on five locations where the expansion of the Waai port can be developed. The most feasible location is selected based on collected on-site data and a Multi-Criteria Analysis (MCA). The selected location will be discussed with the stakeholders to ensure that the location endorsed.

1.3 Methodology

On-site data was collected in the area surrounding the new Ambon port. This was done during the stakeholder meetings held in Ambon between the 17th and 21st of October 2016. The data consists of the physical conditions surrounding the rivers, interviews with locals and imagery of the area. A bathymetry survey was previously executed on the 16th of June, 2016. Drone images of the Waai region have been made on the 1st of July, 2016. All collected data will be bundled together with the analysis of conceptual layouts to form the base of the MCA. The MCA will then be used to determine the most desirable location for the port location.

1.4 Set-up of this document

Chapter one contains the introduction to this report. The second till the sixth chapter contain the locations and layouts and the related details. The seventh chapter contains a summary of the seven locations. The last chapter contains the literature list on which this document is based.

[1] Coastal Engineer at PT Witteveen+Bos Indonesia

2

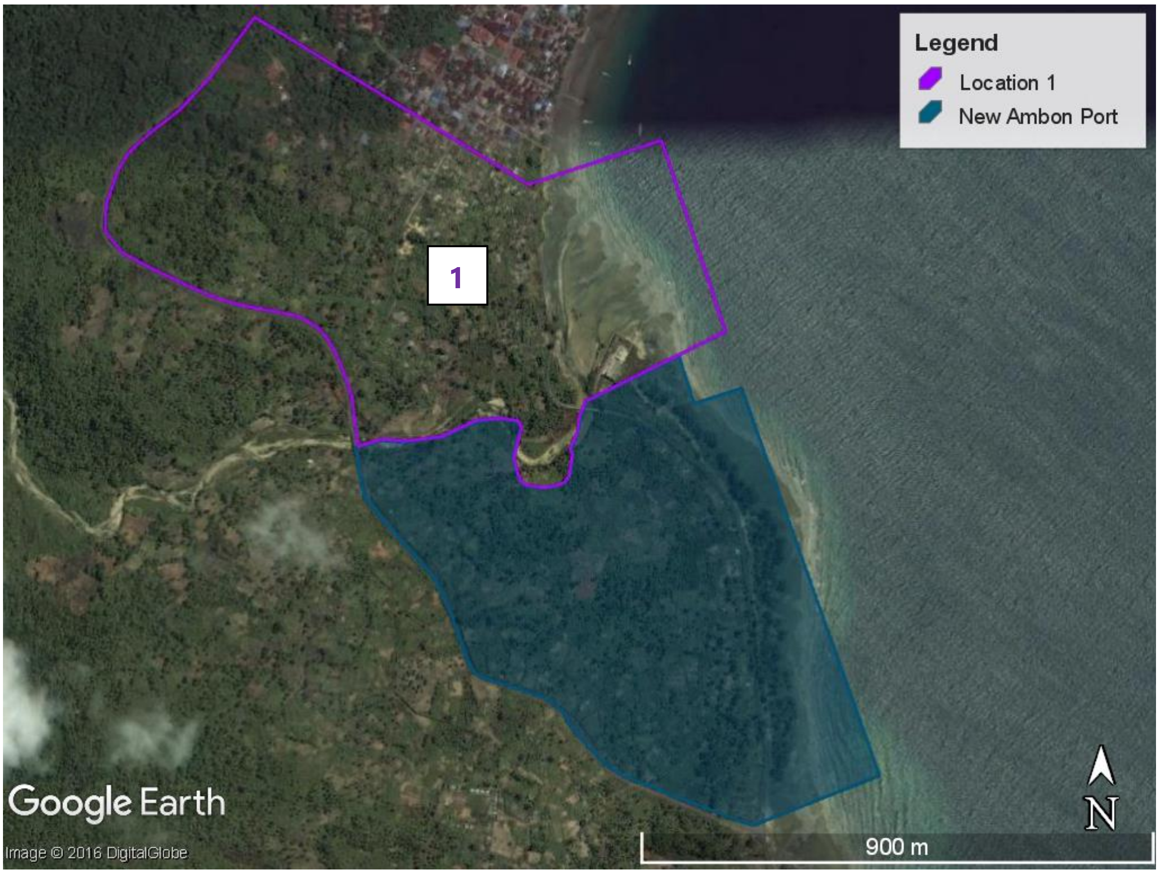
LOCATION ONE

2.1 General Characteristics

Figure 2-1 shows the outline of location one. The expansion is located on the north side of the new Ambon port near the village of Waai. The expansion borders the fishery terminal of the new Ambon port and contains 46 ha of available land[1].

The boundaries of this port are determined by both the national road, on the west side, and the local road, on the north side. The east side of the location follows the quay of the new Ambon port and on the south side borders with the new Ambon port.

Figure 2-1 Location one project boundaries (purple), new Ambon port (blue)



[1] This available land area includes the surface area of the river

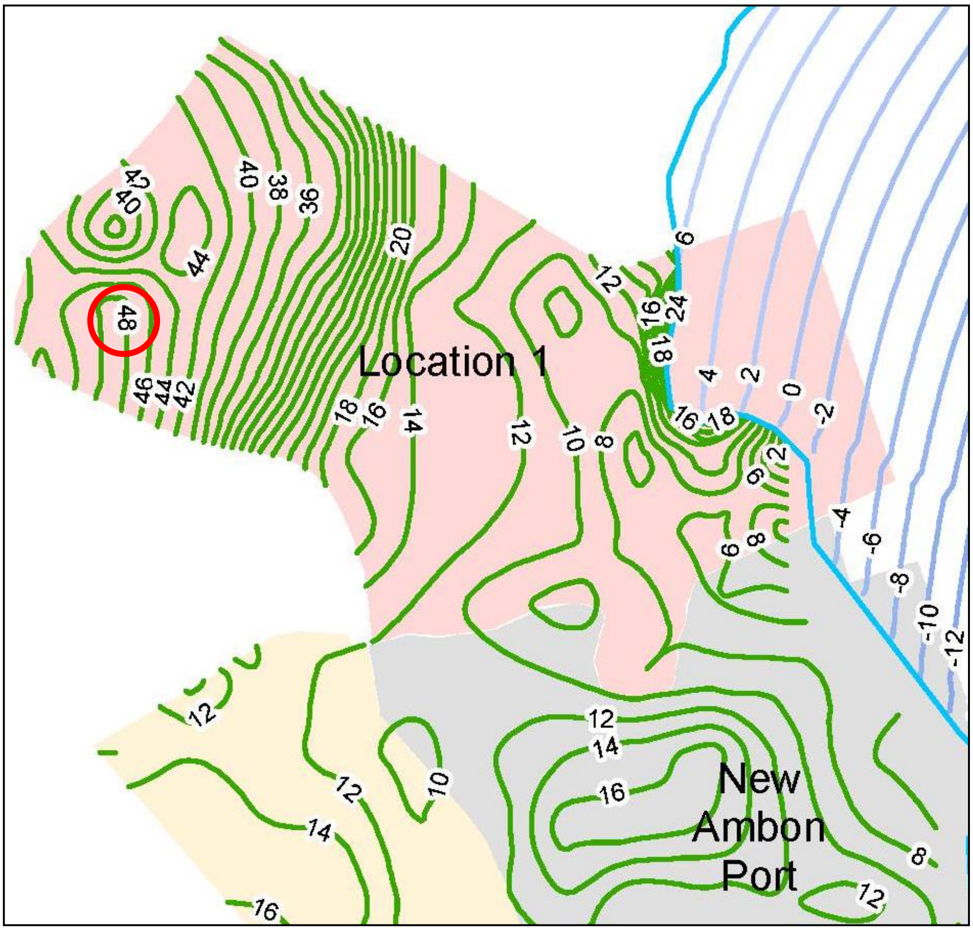
2.1.1 Topography and Bathymetry

Topography

Location one has the greatest difference in elevation out of all selected locations. Along the shoreline the elevation is relatively flat, the higher peaks can be found on the North West side of the location. The highest point is the 48 m high peak in the North West area, see figure 2-2.

Height measurements might contain a margin of error in general the heights measure the heights as seen on the locations. Water depths however are taken from the more accurate bathymetry survey held on location.

Figure 2-2 topography of location one, full image in appendix I



Bathymetry

According to the bathymetry survey held on location, the following water depths are measured:

Table 2-1 Water depths at the coast of location one

Distance from coast	Water depth
0 to 10 m	0 to 20 m
10 to 40 m	20 to 35 m
40 m +	35 m +

2.1.2 Physical Obstacles

Biotic obstacles

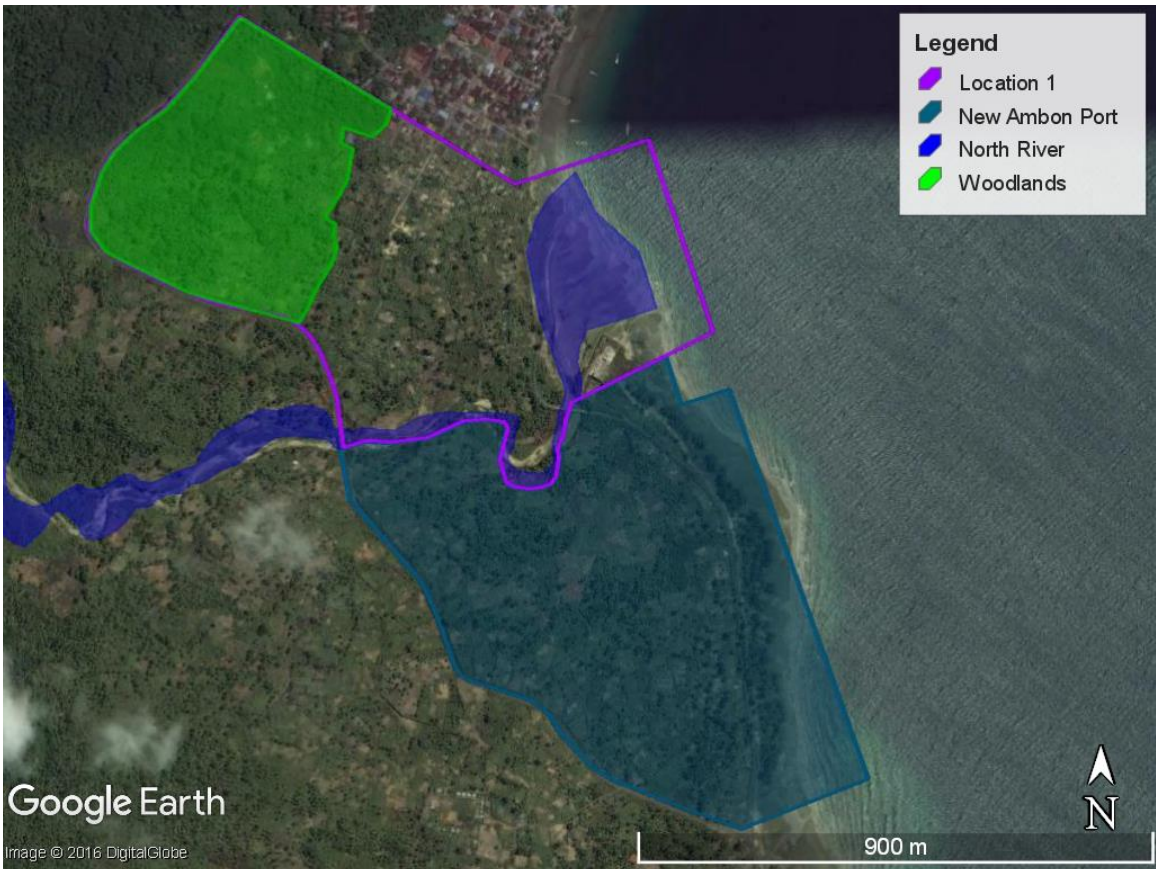
Table 2-2 describes the biotic obstacles present within the boundaries of location one.

Table 2-2 Biotic obstacles of location one

Biotic Obstacle	Present on location	Details
Mangrove Forests	No	The shoreline of location one is free of mangrove trees, the coastline itself exists out of sand beaches and woodlands.
Woodlands	Yes	The location contains an area of approximately 16 ha of woodland on the North West side. This area is untouched and consists of the local fauna.
Rivers	Yes	The "North River" with a width between 5 and 30 m, crosses through this area. The river functions as a border between the new Ambon port and location one. The river is usually dry and only contains water during the rainy season.

Figure 2-3 shows the location and relative size of the biotic obstacles described in table 2-2.

Figure 2-3 Biotic obstacles of location one



A-biotic obstacles

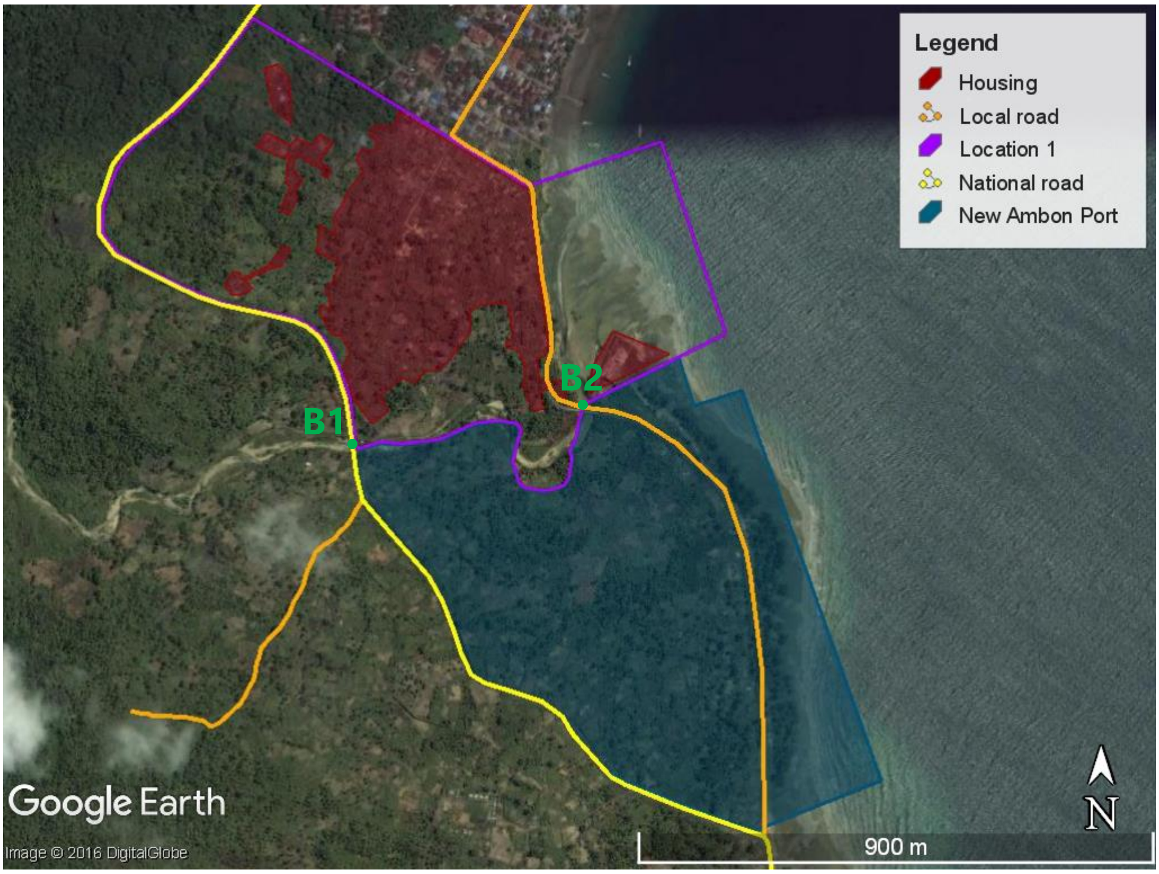
Table 2-3 describes the a-biotic obstacles present within the boundaries of location one.

Table 2-3 A-biotic obstacles of location one

A-Biotic Obstacle	Present on location	Details
Roads	Yes	The local road is 4 to 5 m wide. The road runs a length of 450 m inside the project boundaries. The national road is 8 to 10 m wide. The road functions as a boundary on the west side of the location and will not be directly crossed.
Urban areas	Yes	The location contains approximately 15 ha of urban area which half the village of Waai. This urban area is densely populated and covered in residential housing and small businesses. In accordance to Mr. Fahmi Ollong[1], some of the residential houses were constructed for refugees of the Ambon War[2].
Bridges	Yes	The area contains two bridges, one for the national road and one for the local road. In figure 2-4 they are shown as B1 and B2.

Figure 2-4 shows the location and relative size of the a-biotic obstacles described in table 2-3.

Figure 2-4 A-biotic obstacles of location one



[1] Director of the Ambon based clove company PT Ollop

[2] A religion based civil war between Christians and Muslims on the island Ambon which lasted from 1999 till 2003.

2.2 Concept 1A

2.2.1 Layout

Figure 2-5 shows layout 1A. The north river is converted into a canal. This minimizes the space required for the river and a maximization of land usage for the port. On the south side of the canal, a piece of land will be used for the expansion of the fishery terminal of the new Ambon port. The container terminal is located on the south side of the expansion with a direct connection to the open water. The liquid bulk terminal is located on the north side of the expansion.

Figure 2-5 Layout 1A and new Ambon Port

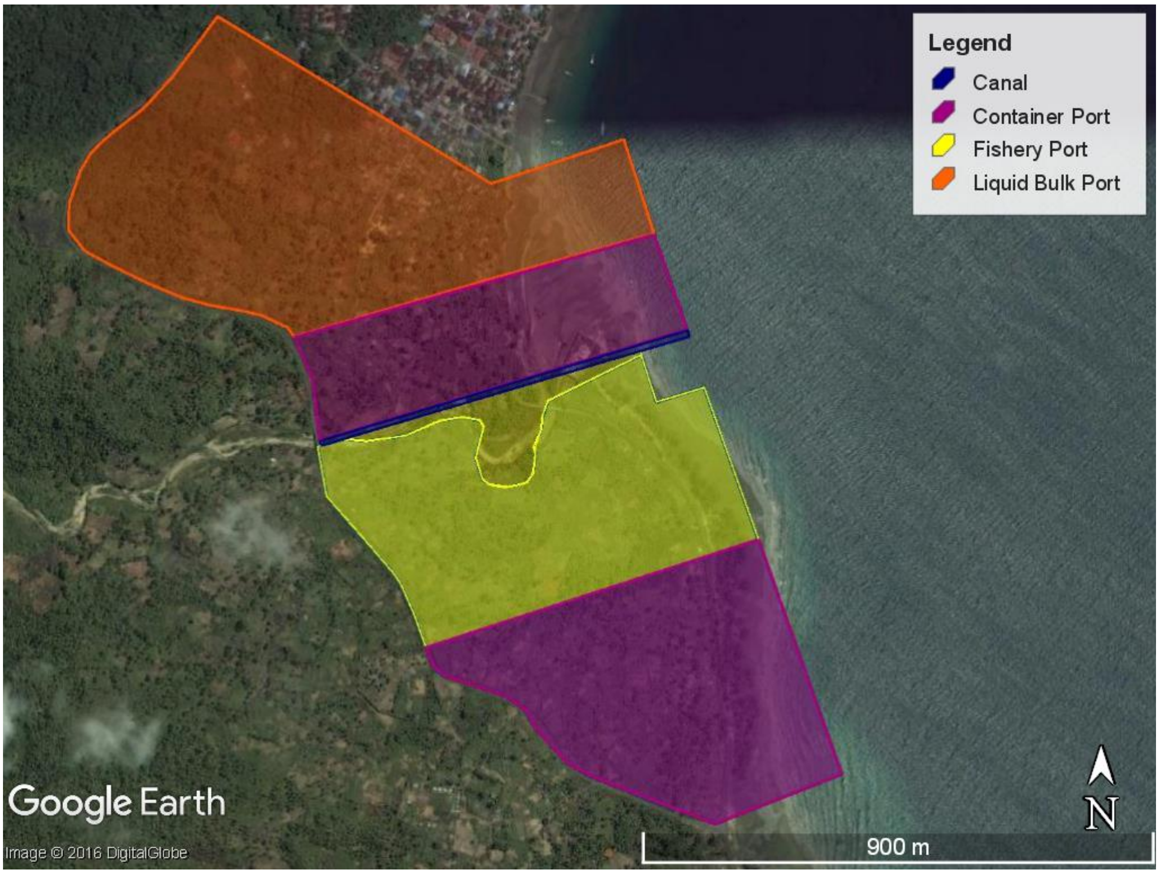


Table 2-4 shows the land usage in the situation of layout 1A as presented in figure 2-5.

Table 2-4 Land usage in layout 1A

A-Biotic Obstacle	Detail	Value
Container Port	Available surface area: Quay length:	12 ha 200 m
Liquid Bulk Port	Available surface area: Quay length:	30.5 ha 200 m
Fishery Port	Available surface area: Quay Length:	2.5 ha 0 m
Canal	Available surface area:	0.7 ha

2.2.2 Opportunities and Constraints

Opportunities

+Does not cross the national road
+Provides the opportunity to service a second container terminal operator
+Fulfils the area size requirements

Constraints

- Requires the relocation of a lot of inhabitants
- The area has huge differences in elevation which need to be levelled out
- The local road will be further demolished
- Increased costs for the conversion of the river into a canal
- Risks regarding the river output on the docking ships in the port
- Possible increased sedimentation in the port due to the river
- Risks for civilians due to the liquid bulk storage directly next to the village
- Current container handling equipment can’t be used in this port and will have to be purchased as new

2.3 Concept 1B

2.3.1 Layout

Figure 2-5 shows layout 1B. The north river is converted into a canal. This minimizes the space required for the river and a maximization of land usage for the port. On the south side of the canal, a piece of land will be used for the expansion of the fishery terminal of the new Ambon port.

The container terminal is located on the north side of the expansion along the village of Waai and has a direct connection to the open water. The liquid bulk terminal is located on the south side of the expansion and borders both the canal and fishery terminal.

Figure 2-5 Layout 1B and new Ambon Port

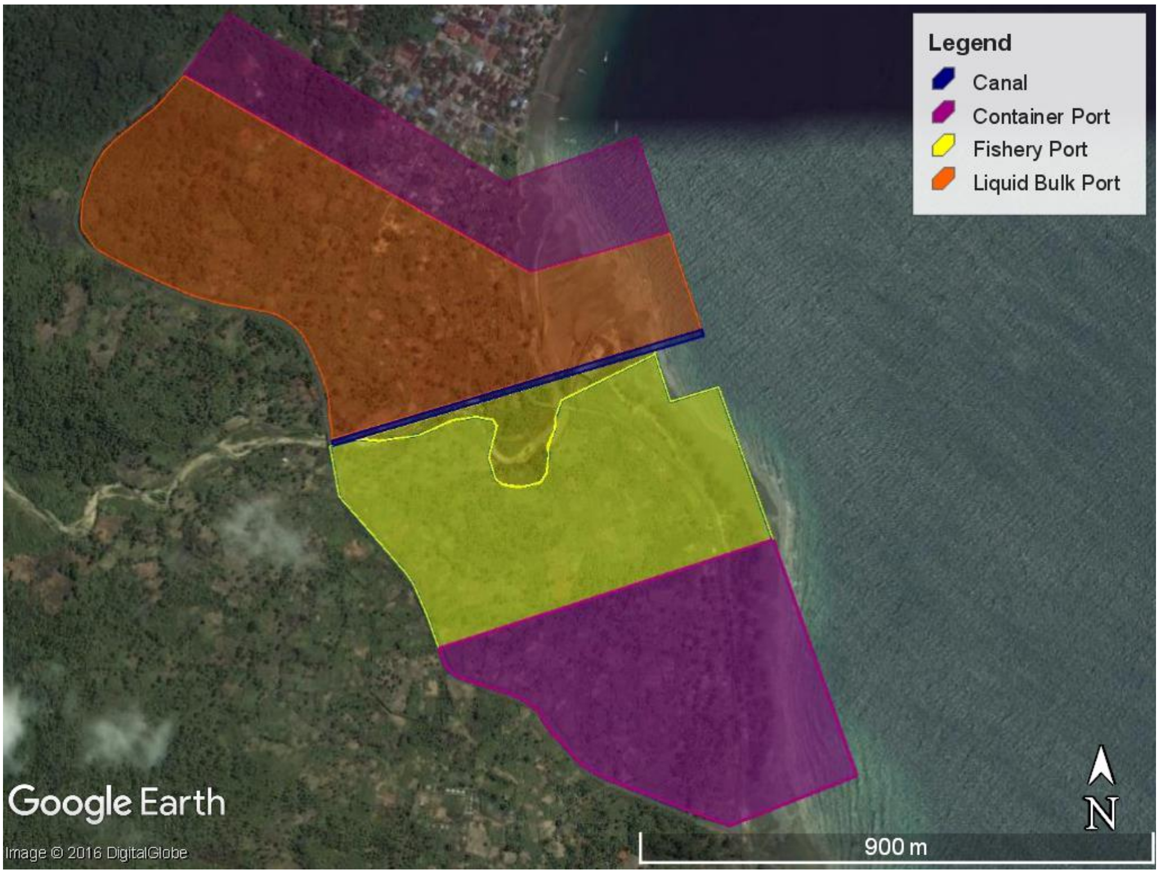


Table 2-6 shows the land usage in the situation of layout 1B as presented in figure 2-5.

Table 2-6 Land usage in layout 1B

A-Biotic Obstacle	Detail	Value
Container Port	Available surface area: Quay length:	12 ha 200 m
Liquid Bulk Port	Available surface area: Quay length:	30.5 ha 200 m
Fishery Port	Available surface area: Quay Length:	2.5 ha 0 m
Canal	Available surface area:	0.7 ha

2.3.2 Opportunities and Constraints

Opportunities
+Does not cross the national road
+Provides the opportunity to service a second container terminal operator
+Fulfils the area size requirements
+Liquid bulk storage is not located directly next to the village

Constraints
- Requires the relocation of a lot of inhabitants
- The area has huge differences in elevation which need to be levelled out
- The local road will be further demolished
- Increased costs for the conversion of the river into a canal
- Risks regarding the river output on the docking ships in the port
- Possible increased sedimentation in the port due to the river
- Current container handling equipment can’t be used in this port and will have to be purchased as new

3

LOCATION TWO

3.1 General Characteristics

Figure 3-1 shows the outline of location two. The expansion is located on the south and west side of the new Ambon port. The expansion borders both; the container terminal and the fishery terminal of the new Ambon port and contains approximately 50 ha of available land[1].

The boundaries of this port are determined by the new Ambon port, the north and south river and by the coast on the east.

Figure 3-1 Location two project boundaries (light blue), new Ambon port (dark blue)

[1] This available land area includes the national road crossing the location

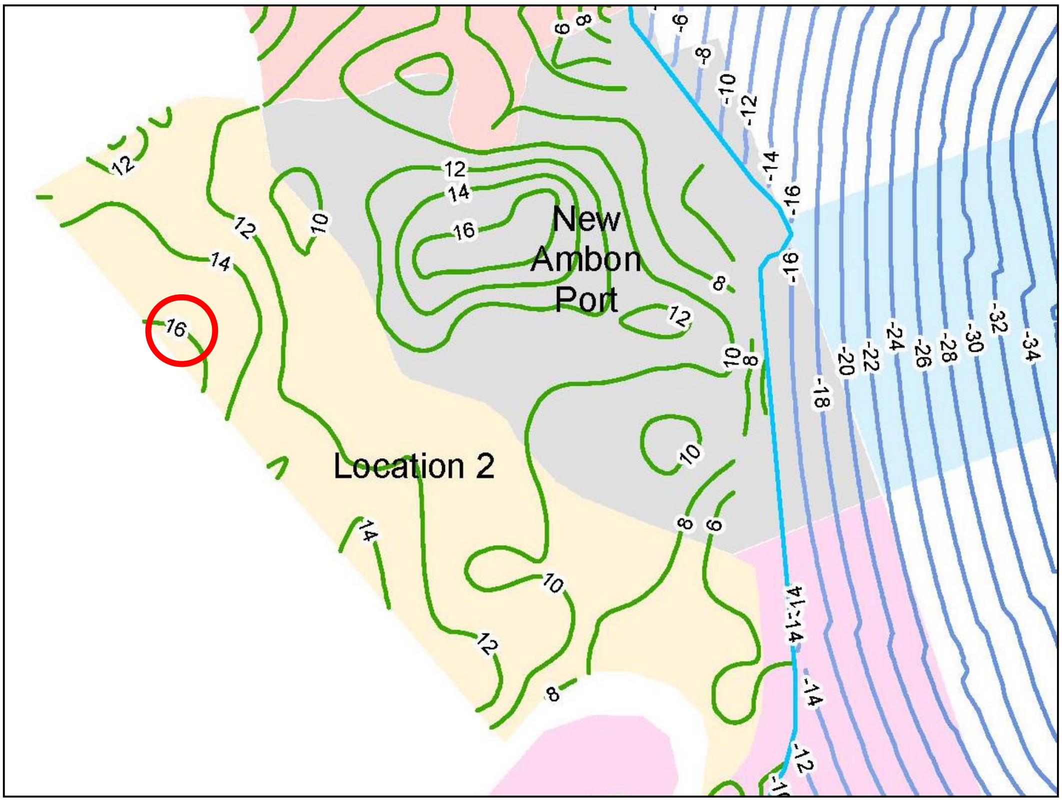
3.1.1 Topography and Bathymetry

Topography

Location two has a very flat surface area and is almost identical to the elevation on the location of the new Ambon port with peaks of 16 m at most, see figure 3-2.

Height measurements might contain a margin of error in general the heights measure the heights as seen on the locations. Water depths however are taken from the more accurate bathymetry survey held on location.

Figure 3-2 topography of location two, full image in appendix I



Bathymetry

According to the bathymetry survey held on location, the following water depths are measured:

Table 3-1 Water depths at the coast of location one

Distance from coast	Water depth
0 to 20 m	0 to 5 m
20 to 40 m	5 to 20 m
40 m +	20 m +

3.1.2 Physical Obstacles

Biotic obstacles

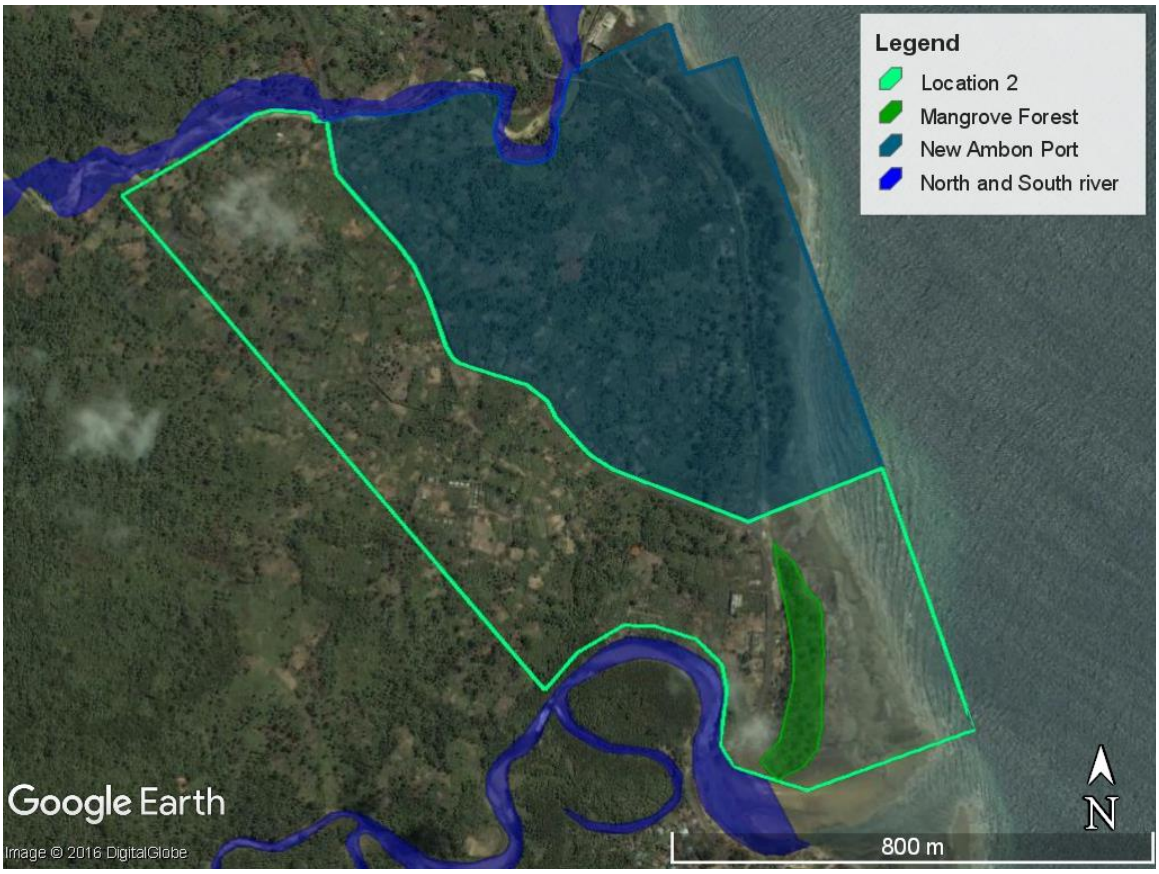
Table 3-2 describes the biotic obstacles present within the boundaries of location two.

Table 3-2 Biotic obstacles

Biotic Obstacle	Present on location	Details
Mangrove Forests	Yes	Along the shoreline of location two grows a mangrove forest of approximately 2 ha.
Woodlands	Yes	The woodlands on location two are spread out over the area, switching between farm grounds, and housing.
Rivers	Yes	Location two borders both the north and south river but doesn't cross them. The port boundaries are following the morphology of the river where possible.

Figure 3-3 shows the location and relative size of the biotic obstacles described in table 3-2.

Figure 3-3 north river splitting the expansion and the current port



A-biotic obstacles

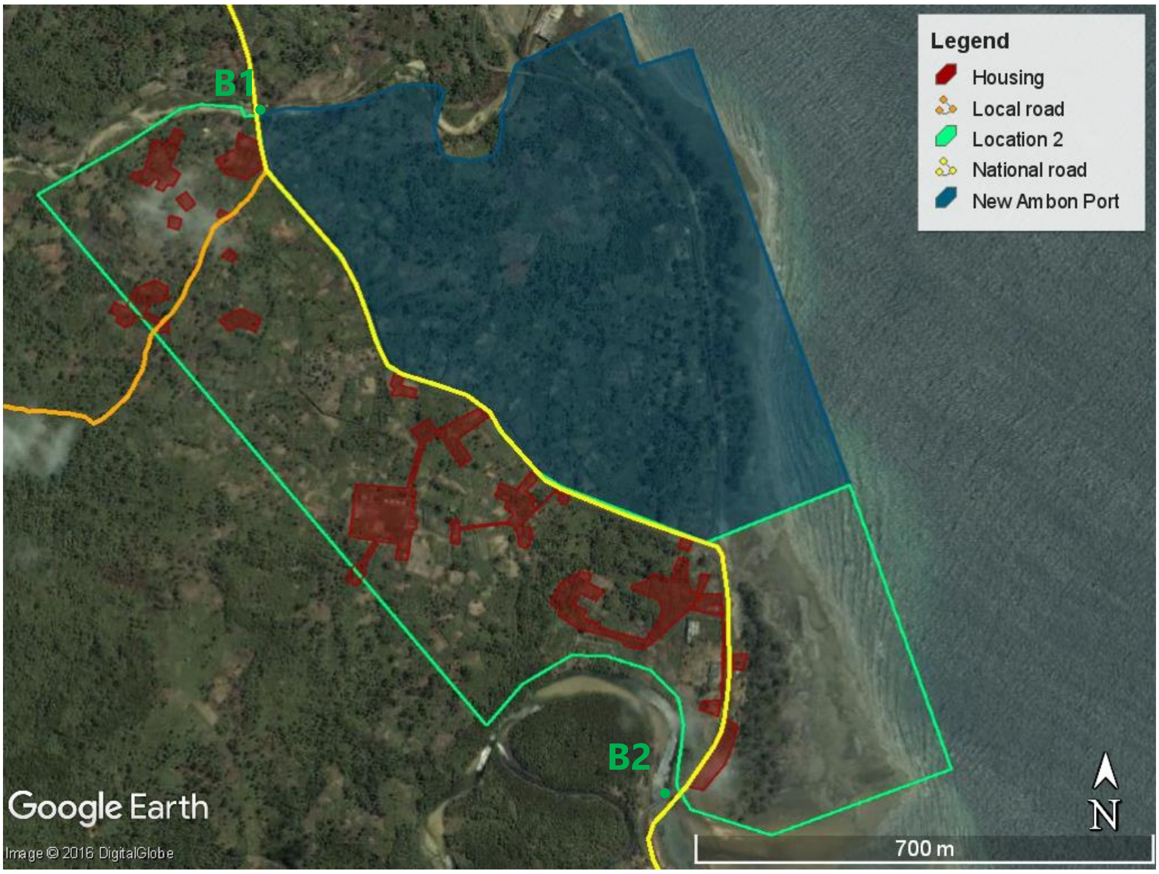
Table 3-3 describes the a-biotic obstacles present within the boundaries of location two.

Table 3-3 A-biotic obstacles of location two

A-Biotic Obstacle	Present on location	Details
Roads	Yes	In the north east side there is a local road which leads to a dead end. The national road runs through the whole location, from south to the north. The road is 8-10m wide.
Urban areas	Yes	Location two contains a total of approximately 6 ha of urban area, which consists of residential houses and farms.
Bridges	Yes	The area contains two bridges; both bridges are used by the national road. In figure 3-4 they are shown as B1 and B2.

Figure 3-4 shows the location and relative size of the a-biotic obstacles described in table 3-3.

Figure 3-4 Housing area within the first expansion proposal



3.2 Concept 2A

3.2.1 Layout

Figure 3-5 shows layout 2A. The national road is partially replaced in order to create room for the container terminal. The red part of the road is the current road; the green part is the future road.

The liquid bulk terminal crosses the national road. This will be done by placing the pipelines needed to transport the liquids, under the road. The storage tanks will be placed in the hinterland and the handling of the ships will be handled on the shore side.

The container terminal will be attached to the current container terminal in the new Ambon port, expanding its capacity.

Figure 3-5 Layout 2A and new Ambon Port

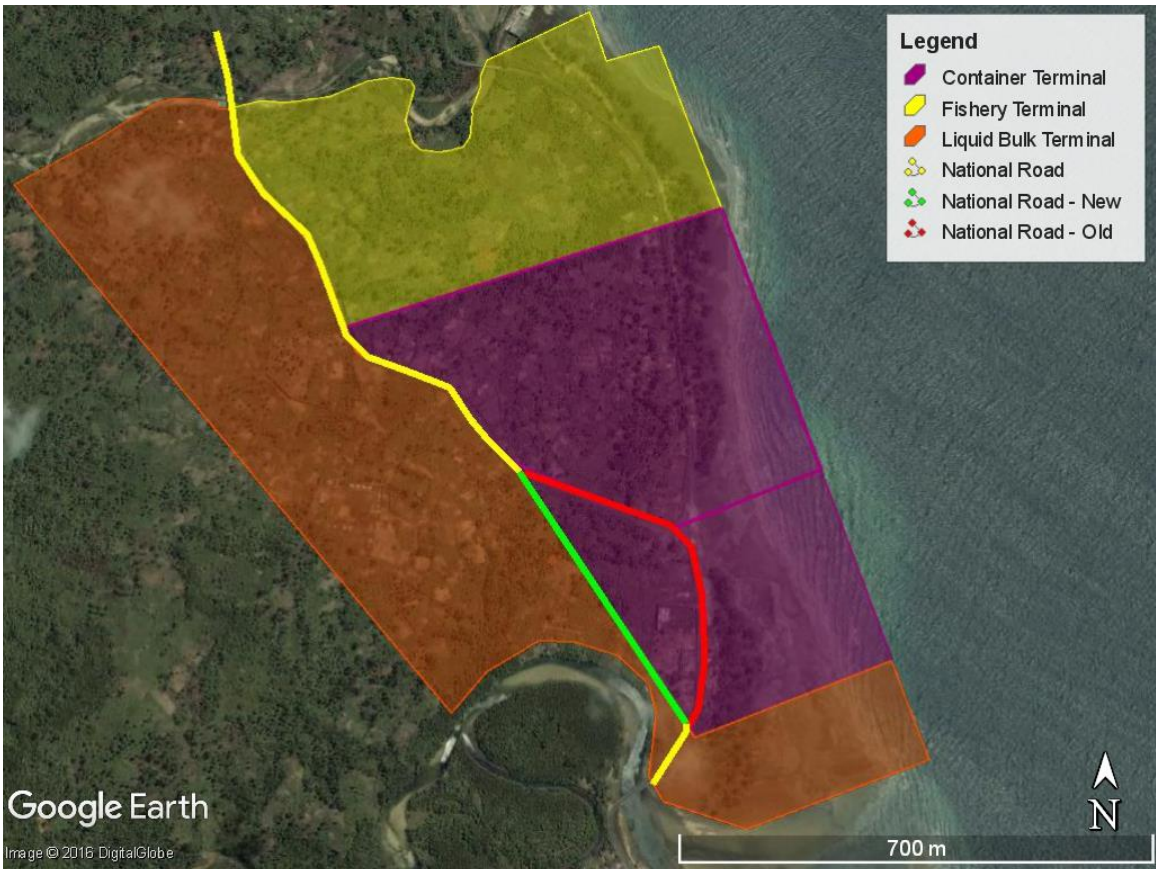


Table 3-4 shows the land usage in the situation of layout 1B as presented in figure 3-5.

Table 3-4 Land usage in expansion layout 2A

A-Biotic Obstacle	Detail	Value
Container Port	Available surface area: Quay length:	12 ha 300 m
Liquid Bulk Port	Available surface area: Quay length:	37.5 ha 160 m

3.2.2 Opportunities and constraints

Opportunities
+ Container terminal can be directly expanded
+ Already present container handling material can be used
+ Fulfils the area size requirements
+ Relatively little inhabitants will be required to relocate
+ Relatively flat
+ Container related industry does not need to cross the national road

Constraints
- Requires adjustments and crossing of/to the national road
- The local road on the North West of the location will be demolished

3.3 Concept 2B

3.3.1 Layout

Figure 3-6 shows layout 2B. The liquid bulk terminal crosses the national road. This will be done by placing the pipelines needed to transport the liquids, under the road. The storage tanks will be placed in the hinterland and the handling of the ships will be handled on the shore side.

The container terminal will be attached to the current container terminal in the new Ambon port, expanding its capacity. The terminal will also cross the national road, using the land on the west side of the road as storage area. Crossing the road might require adjustments to the national road in order to minimize the disturbance of the traffic flow.

Figure 3-6 Layout 2B and new Ambon Port

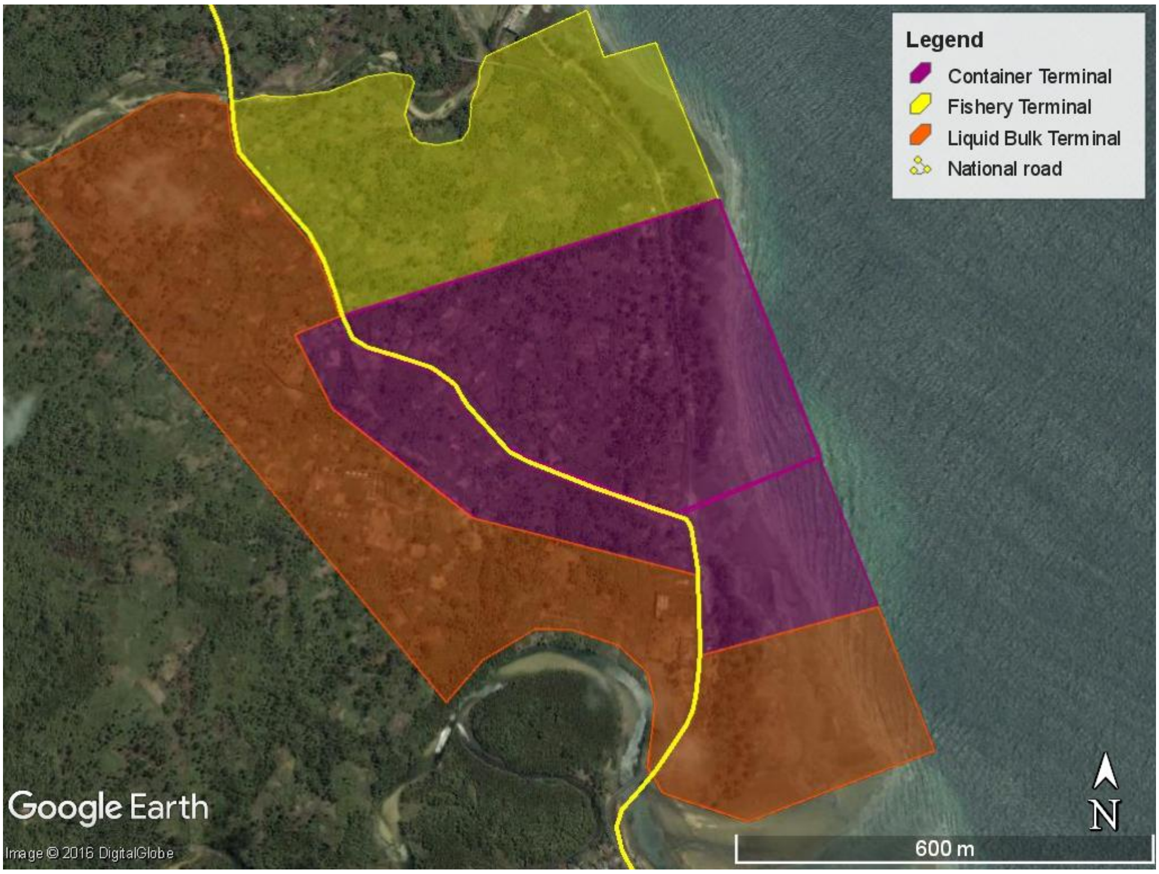


Table 3-5 shows the land usage in the situation of layout 1B as presented in figure 3-6.

Table 3-5 Land usage in expansion layout 2B

A-Biotic Obstacle	Detail	Value
Container Port	Available surface area: Quay length:	12.5 ha 250 m
Liquid Bulk Port	Available surface area: Quay length:	36.5 ha 200 m

3.3.2 Opportunities and Constraints

Opportunities
+ Container terminal can be directly expanded
+ Already present container handling material can be used
+ Fulfils the area size requirements
+ Relatively little inhabitants will be required to relocate
+ Relatively flat

Constraints
- Requires adjustments and/or crossing of/to the national road
- The local road on the North West of the location will be demolished
- Container related industry needs to cross the national road

4

LOCATION THREE

4.1 General Characteristics

Figure 4-1 shows the outline of location three. The expansion is located on the south side of the new Ambon port near the village of Tulehu. The expansion borders the container terminal of the new Ambon port and contains 42 ha of available land.

The boundaries of the expansion are determined by the national road to the west, the Tulehu Ferry port to the south and the new Ambon port to the north. The east side of the location follows the quay of the new Ambon port.

Figure 4-1 Location three project boundaries (red), new Ambon port (blue)

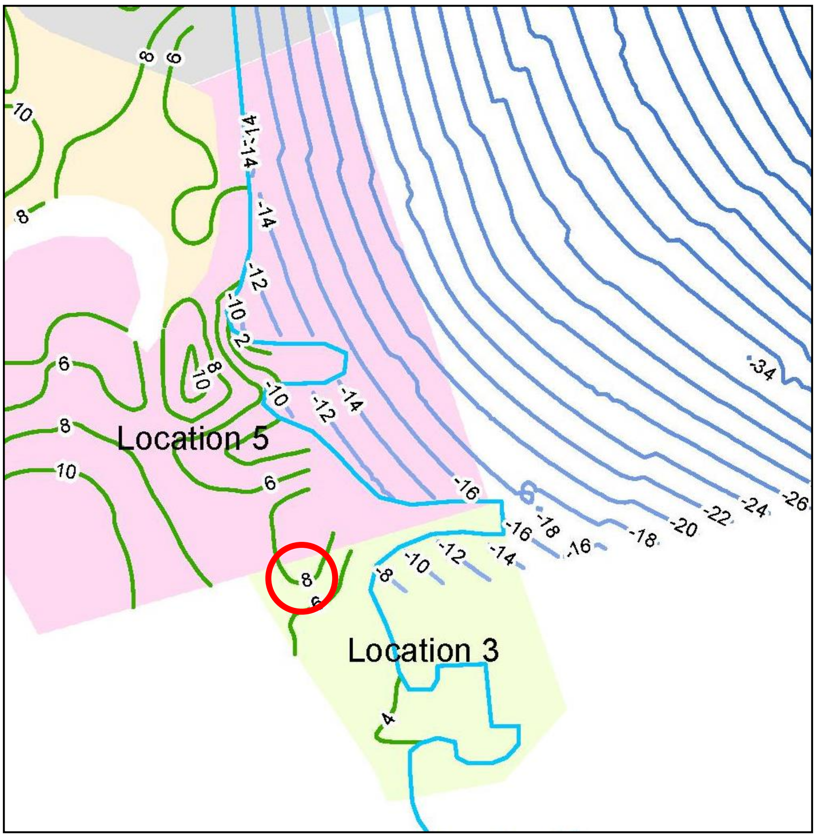
4.1.1 Topography and Bathymetry

Topography

Location three has a very flat surface area with a measured peak of 8 m high.

Height measurements might contain a margin of error in general the heights measure the heights as seen on the locations. Water depths however are taken from the more accurate bathymetry survey held on location.

Figure 4-2 topography of location three, full image in appendix I



Bathymetry

According to the bathymetry survey held on location, the following water depths are measured:

Table 4-1 Water depths at the coast of location one

Distance from coast	Water depth
0 to 20 m	0 to 5 m
20 to 40 m	5 to 20 m
40 m +	20 m +

4.1.2 Physical Obstacles

Biotic obstacles

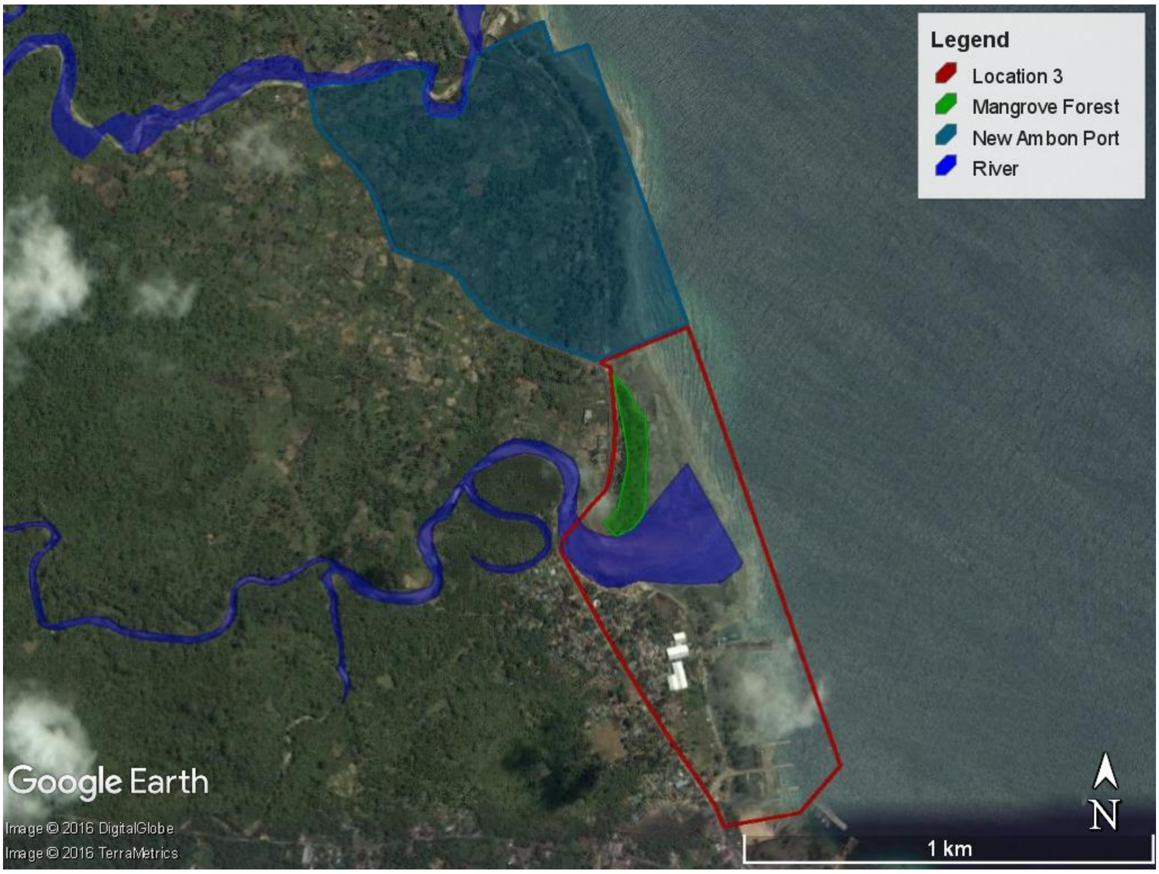
Table 4-2 describes the biotic obstacles present within the boundaries of location three.

Table 4-2 Biotic obstacles

Biotic Obstacle	Present on location	Details
Mangrove Forests	Yes	Along the northern shoreline of location three grows a mangrove forest of approximately 2 ha.
Woodlands	No	Location three does not contain woodlands
Rivers	Yes	Location three contains the south river. The river is 10 to 50 m wide.

Figure 4-3 shows the location and relative size of the biotic obstacles described in table 4-2.

Figure 4-3 Location three with the biotic obstacles: the south river and the mangrove forest



A-biotic obstacles

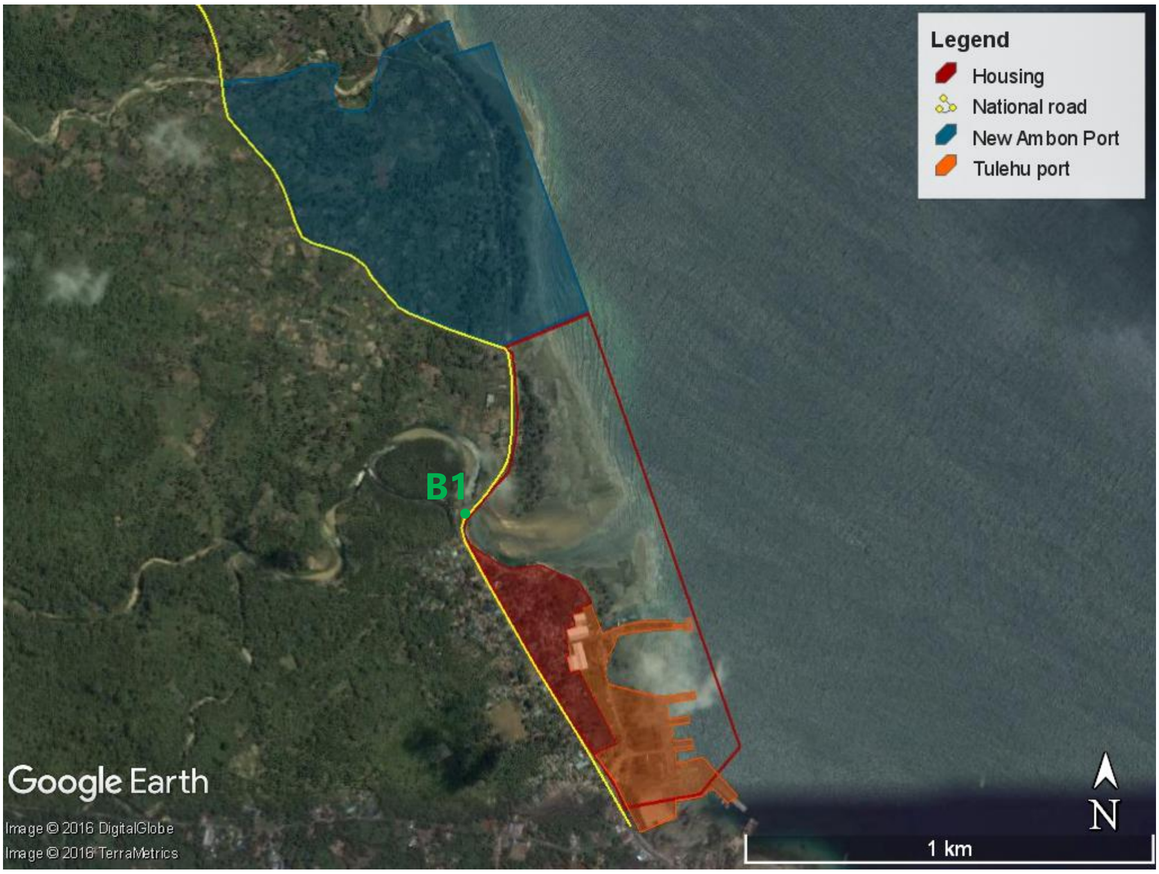
Table 4-3 describes the a-biotic obstacles present within the boundaries of location three.

Table 4-3 A-biotic obstacles of location three

A-Biotic Obstacle	Present on location	Details
Roads	No	Location three does not contain any significant currently existing roads. However, the national road does pass it along the entire west side of the project boundaries.
Urban areas	Yes	Location two contains a total of approximately 6 ha of urban area, which consists of residential houses and small businesses.
Bridges	Yes	The area contains one bridge. The bridge is used by the national road. In figure 4-4 the bridge is shown as B1
Ports	Yes	Location three spans over the already existing port of Tulehu which is used for both fishery and ferries.

Figure 4-4 shows the location and relative size of the a-biotic obstacles described in table 4-3.

Figure 4-4 Housing area within the first expansion proposal



4.2 Concept 3

4.2.1 Layout

Figure 4-5 shows layout 3. In order to cross the 'South River', the river will be channelled into a canal. The north side of the canal will contain the container port, which then borders the container terminal of the new Ambon port. The liquid bulk terminal is located on the south side of the canal.

Figure 4-5 Layout 3 and new Ambon Port

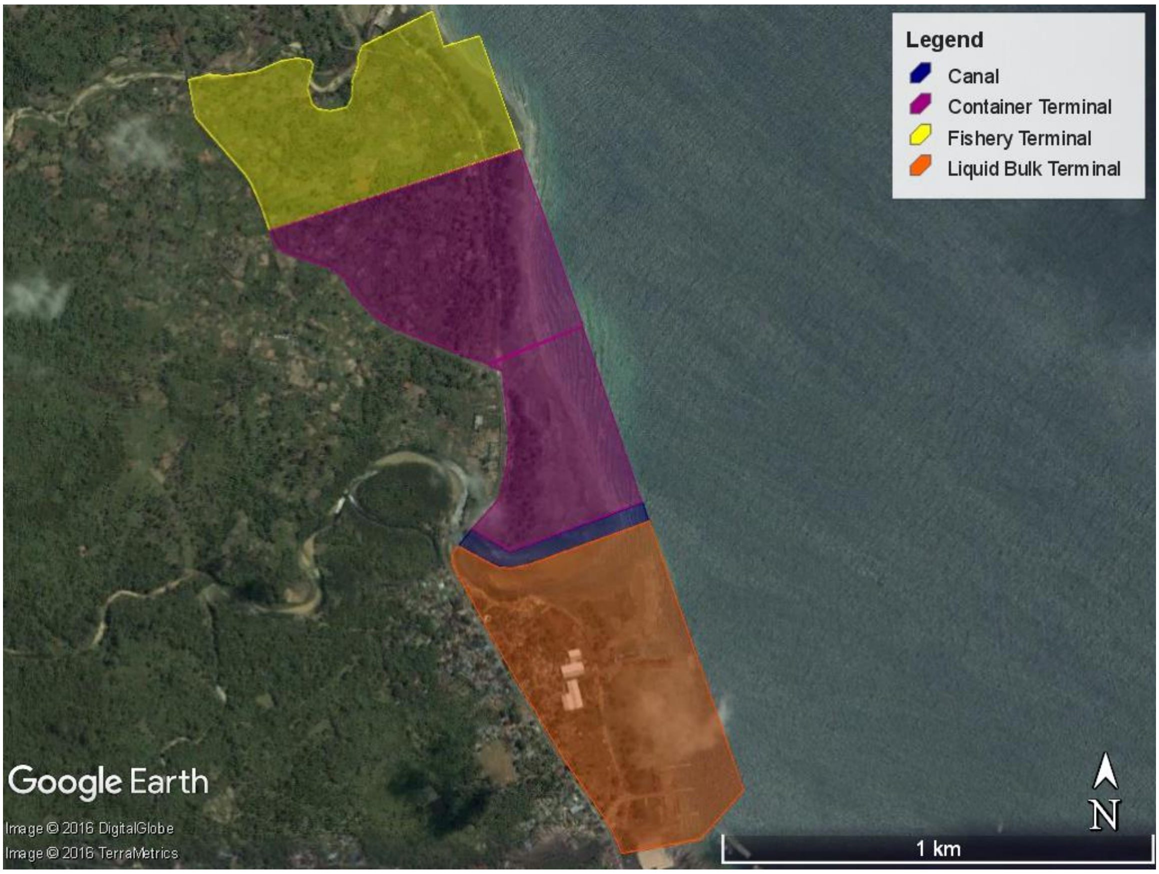


Table 4-4 shows the land usage in the situation of layout 1B as presented in figure 4-5.

Table 4-4 Land usage in expansion layout 3

A-Biotic Obstacle	Detail	Value
Container Port	Available surface area: Quay length:	12 ha 425 m
Liquid Bulk Port	Available surface area: Quay length:	30 ha 650 m

4.2.2 Opportunities and Constraints

Opportunities

+ Fulfils the wish of the local government to connect the Waai port with the Tulehu port.
+ Does not cross the national road
+ Does not cross the local road
+ Fulfils the area size requirements
+ Very flat surface area

Constraints

- Liquid bulk storage is directly located next to the village of Tulehu
- Requires the relocation of a lot of inhabitants
- Crosses a wide river
- Increased costs for the conversion of the river into a canal
- Risks regarding the river output on the docking ships in the port
- Possible increased sedimentation in the port due to the river

5

LOCATION FOUR

5.1 General Characteristics

The port expansion is located on the east side of the new Ambon port, see figure 5-1. The expansion is fully located in the sea, which will require either land reclamation or a pile sheet deck. The expansion does not contain any on-shore characteristics since there is no shore within the boundaries.

Figure 5-1 Location four project boundaries (red), new Ambon port (blue)

5.1.1 Bathymetry

Bathymetry
According to the bathymetry survey held on location, the following water depths are measured:

Table 5-1 Water depths at the coast of location one

Distance from coast	Water depth
0 to 20 m	0 to 10 m
20 to 40 m	10 to 35 m
40 m +	35 m +

5.2 Concept 4

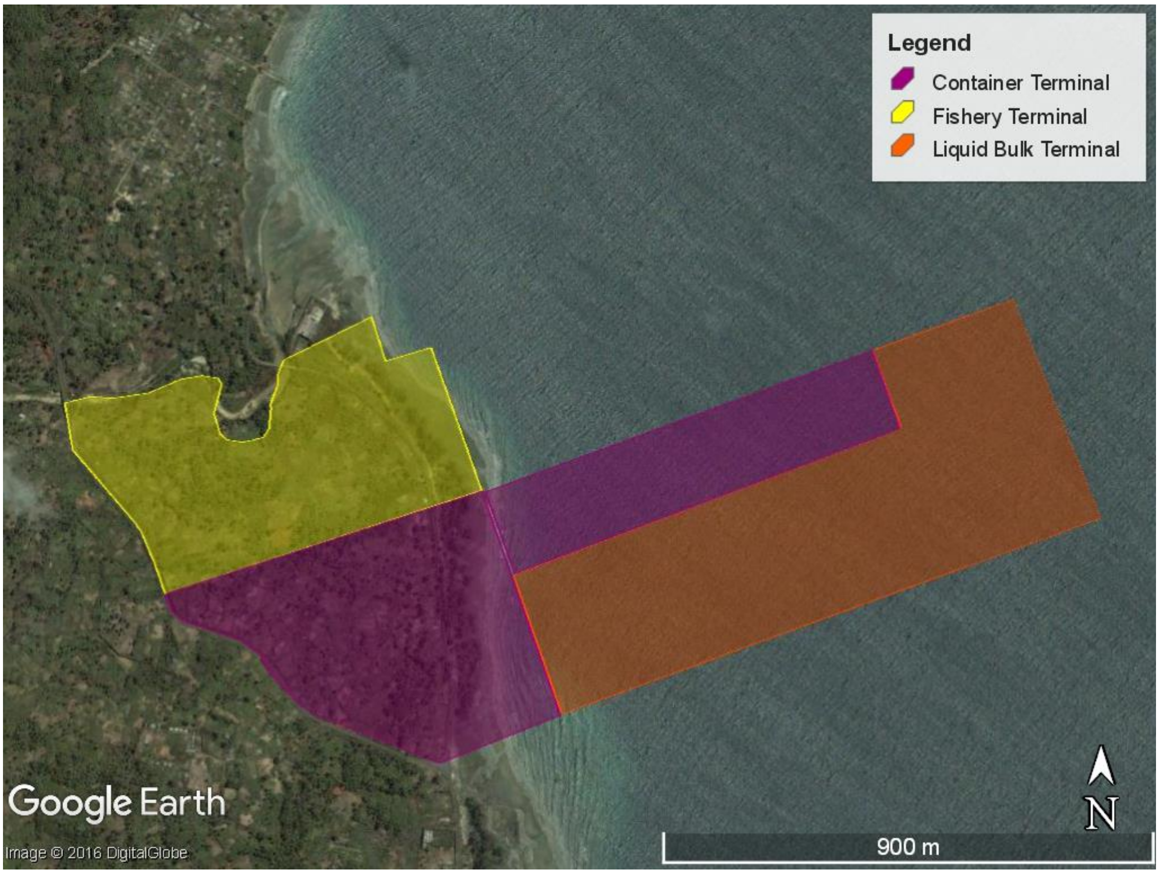
5.2.1 Layout

Figure 5-2 shows layout 4. The container terminal extends at the north side of the current container port and will be surrounded by the liquid bulk terminal. In order for the liquid bulk to reach the shore, adjustments will have to be made on the container terminal of the new Ambon port. Also the current quay usage of the container terminal will have to be removed.

Table 5-2 Land usage in expansion layout 4

A-Biotic Obstacle	Detail	Value
Container Port	Available surface area: Quay length:	12 ha 750 m
Liquid Bulk Port	Available surface area: Quay length:	34 ha 1750 m

Figure 5-2 layout 4 and new Ambon Port



5.2.2 Opportunities and Constraints

Opportunities

+ Does not cross the national road
+ Does not cross the local road
+ Fulfils the area size requirements
+ No requirement of inhabitants required
+ Doesn’t cross any rivers

Constraints

- Vastly increasing water depths require greater investments for land reclamation or a pile sheet deck
- The current quay wall will need adjustments and will be rendered useless, increasing costs
- Possible damage to the marine life along the shore

6

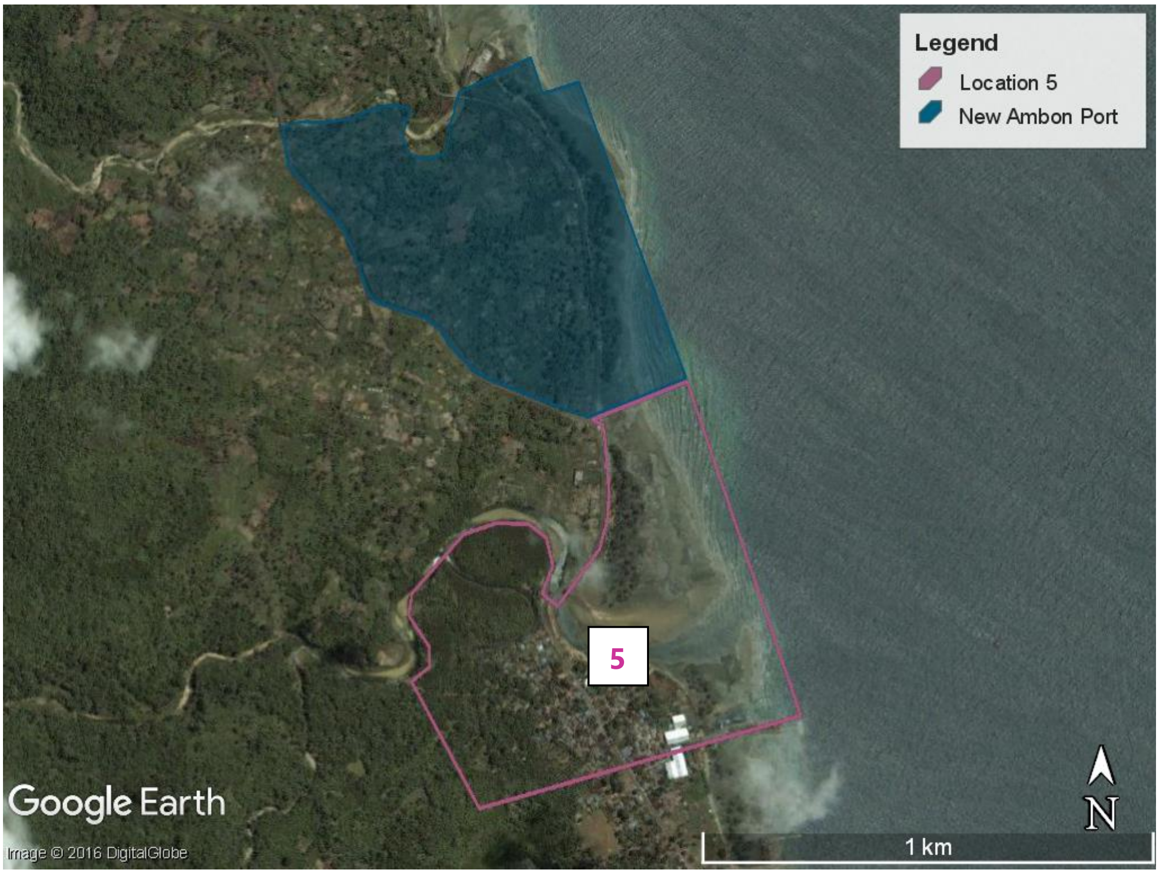
LOCATION FIVE

6.1 General Characteristics

The port expansion is located on the south side of the new Ambon port where it borders the container terminal. The expansion crosses the south river and slightly into the hinterland following the river.

The boundaries of the expansion exist of the new Ambon port to the north, the south river on the west and the Tulehu fishery port on the south. The quay length is a continued stretch of the quay from the new Ambon port.

Figure 6-1 Location five project boundaries (purple), new Ambon port (blue)



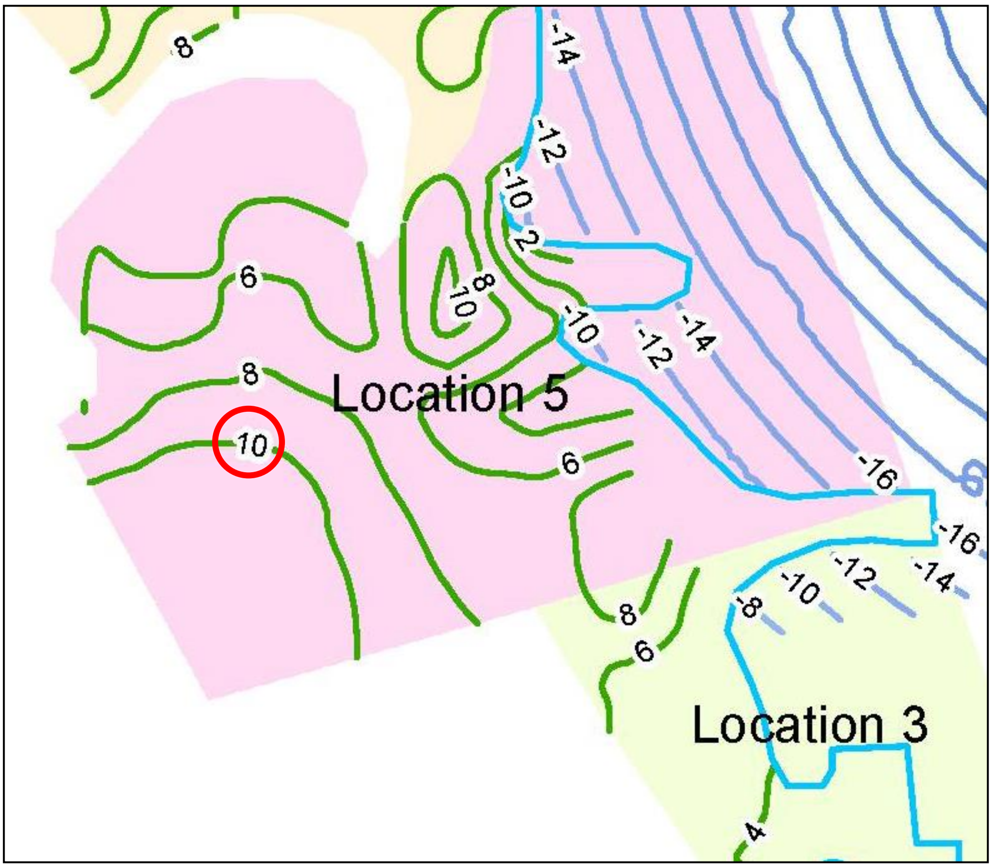
6.1.1 Topography and Bathymetry

Topography

Location two has a relatively flat surface area with peaks of 10 m at most, see figure 6-2.

Height measurements might contain a margin of error in general the heights measure the heights as seen on the locations. Water depths however are taken from the more accurate bathymetry survey held on location.

Figure 6-2 topography of location two, full image in appendix I



Bathymetry

According to the bathymetry survey held on location, the following water depths are measured:

Table 6-1 Water depths at the coast of location one

Distance from coast	Water depth
0 to 20 m	0 to 5 m
20 to 40 m	5 to 20 m
40 m +	20 m +

6.1.2 Physical Obstacles

Biotic obstacles

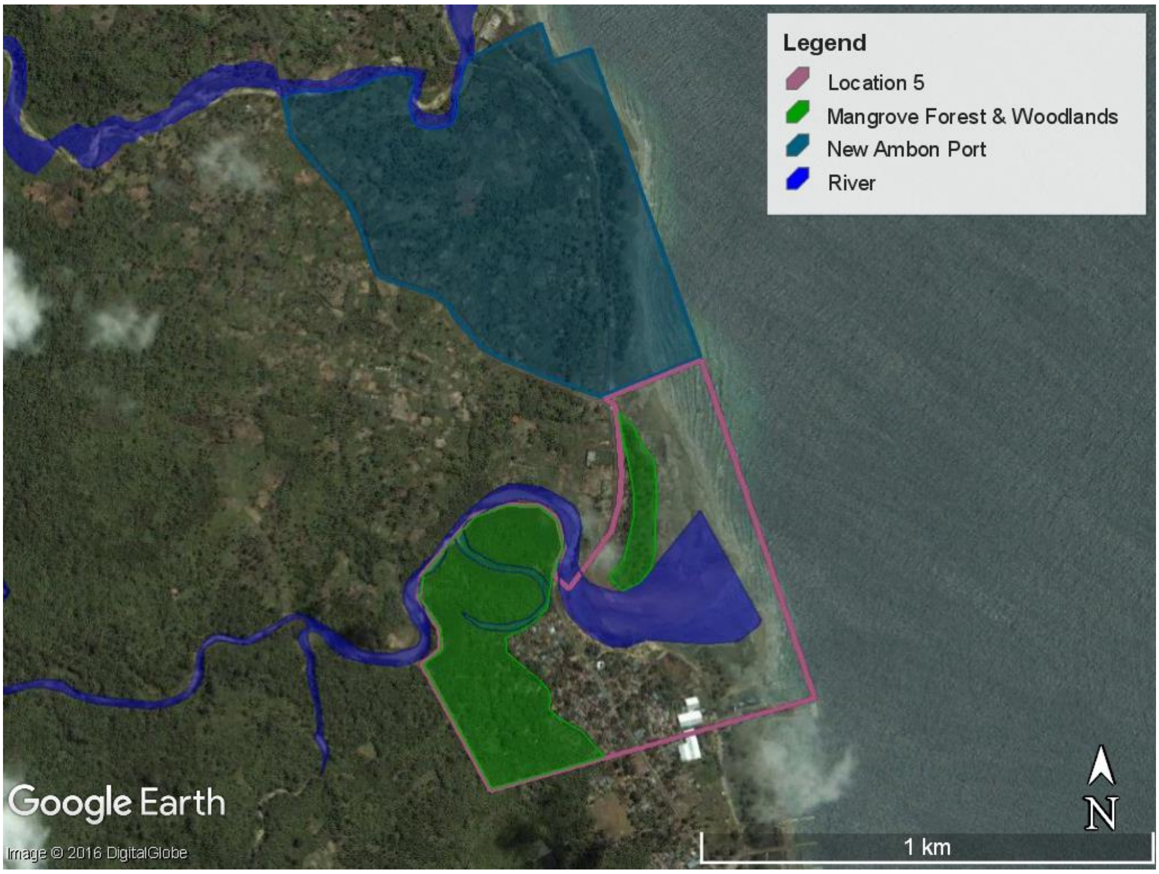
Table 6-2 describes the biotic obstacles present within the boundaries of location five.

Table 6-2 Biotic obstacles

Biotic Obstacle	Present on location	Details
Mangrove Forests	Yes	Along the northern shoreline of location three grows a mangrove forest of approximately 2 ha.
Woodlands	Yes	The location contains an area of approximately 14 ha of woodlands on the west.
Rivers	Yes	The location crosses the south river. The river is 10 to 50 m wide.

Figure 6-3 shows the location and relative size of the biotic obstacles described in table 6-2.

Figure 6-3 Biotic obstacles



A-biotic obstacles

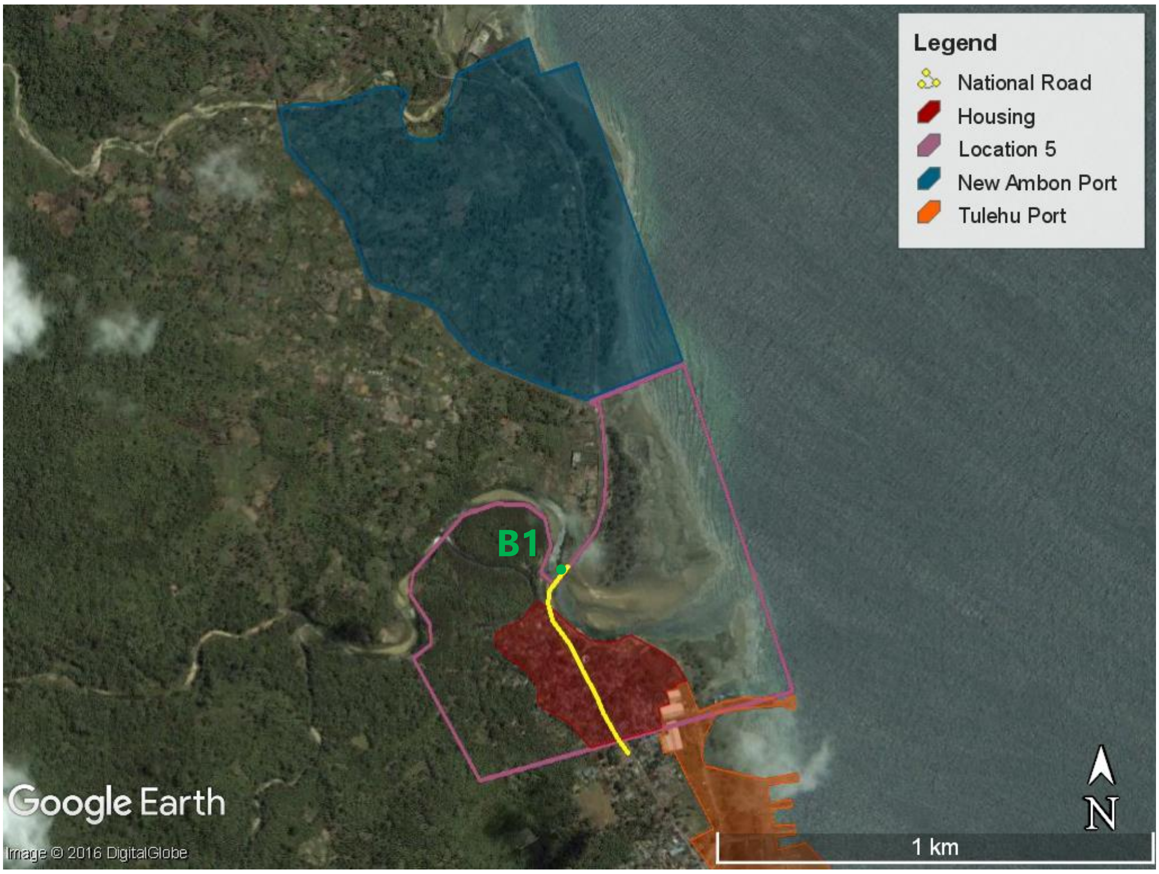
Table 6-3 describes the a-biotic obstacles present within the boundaries of location five.

Table 6-3 A-biotic obstacles

A-Biotic Obstacle	Present on location	Details
Roads	Yes	The national road crosses the middle of location five. This might result in adjustments to the road in order to maintain the accessibility for the neighbouring areas.
Urban areas	Yes	Location two contains a total of approximately 7.5 ha of urban area, which consists of residential houses and small businesses.
Bridges	Yes	The area contains one bridge. The bridge is used by the national road. In figure 6-4 the bridge is shown as B1
Ports	Yes	Location four borders the Tulehu fishery port. Of this port an area of approximately 1 ha is located in the location 5 project area.

Figure 6-4 shows the location and relative size of the a-biotic obstacles described in table 6-3.

Figure 6-4 A-biotic obstacles



6.2 Concept 5

6.2.1 Layout

Figure 6-5 shows layout 5. In order to cross the 'South River', the river will be channelled into a canal. The north side of the canal will contain the container port, which then borders the container terminal of the new Ambon port. The liquid bulk terminal is located on the south side of the canal and will border the Tulehu fishery port.

Figure 6-5 Layout 5 and new Ambon Port

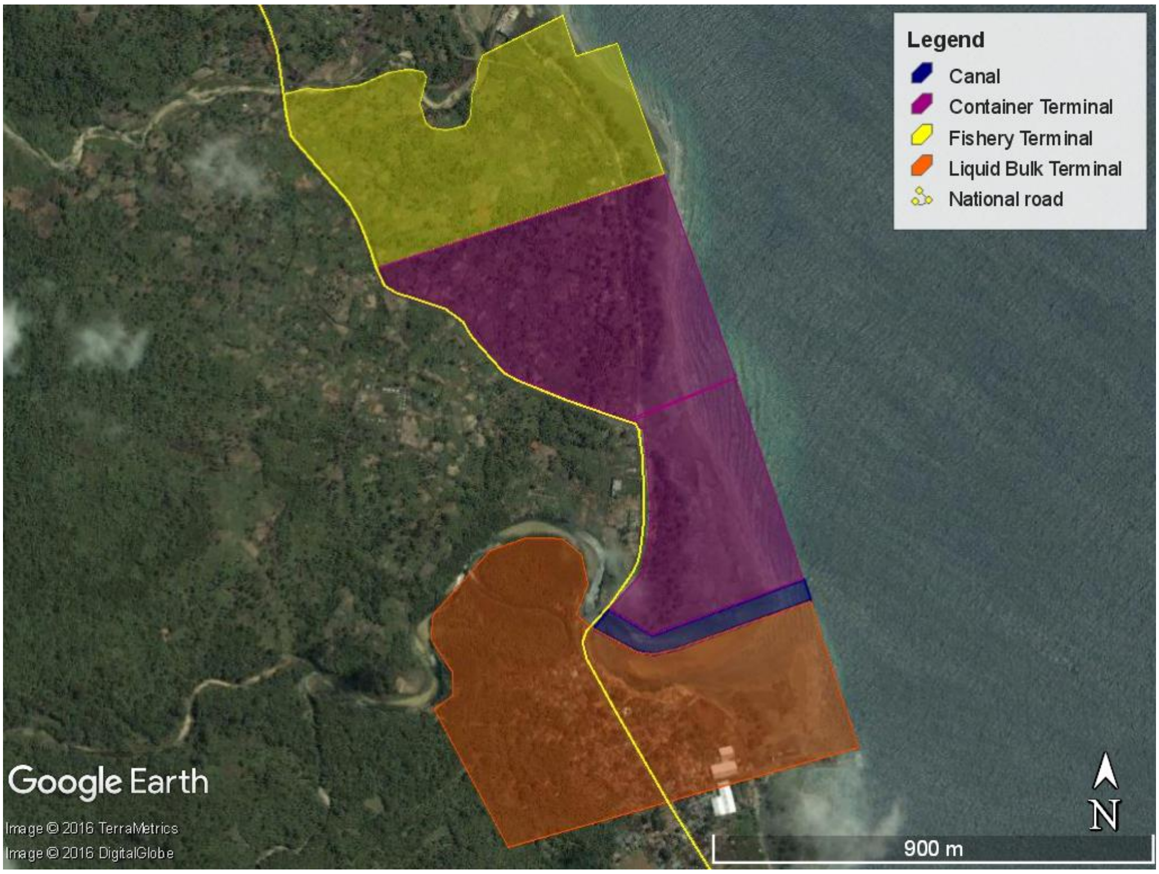


Table 6-4 shows the land usage in the situation of layout 5 as presented in figure 6-5.

Table 6-4 Land usage in expansion layout 5

A-Biotic Obstacle	Detail	Value
Container Port	Available surface area: Quay length:	12 ha 450 m
Liquid Bulk Port	Available surface area: Quay length:	32 ha 300 m

6.2.2 Opportunities and Constraints

Opportunities
+ Does not cross any mayor roads
+ Connects to Tulehu as requested by the local government
+ Fulfils the area requirements

Constraints
- Requires the relocation of a significant amount of inhabitants
- Increased costs for crossing the south river
- Liquid bulk storage is directly located next to the village of Tulehu
- Requires the relocation of a lot of inhabitants
- Crosses a wide river
- Increased costs for the conversion of the river into a canal
- Risks regarding the river output on the docking ships in the port
- Possible increased sedimentation in the port due to the river

VI

APPENDIX: LOCATION AND LAYOUT MCA

TABLE OF CONTENTS

1

INTRODUCTION

1.1 Purpose of the MCA

This Multi-Criteria Analysis (MCA) is used to form an objective selection of the most feasible location according to the required criteria. Once a location/layout is selected by the MCA it will be discussed with the stakeholders to ensure that the location endorsed.

1.2 Methodology

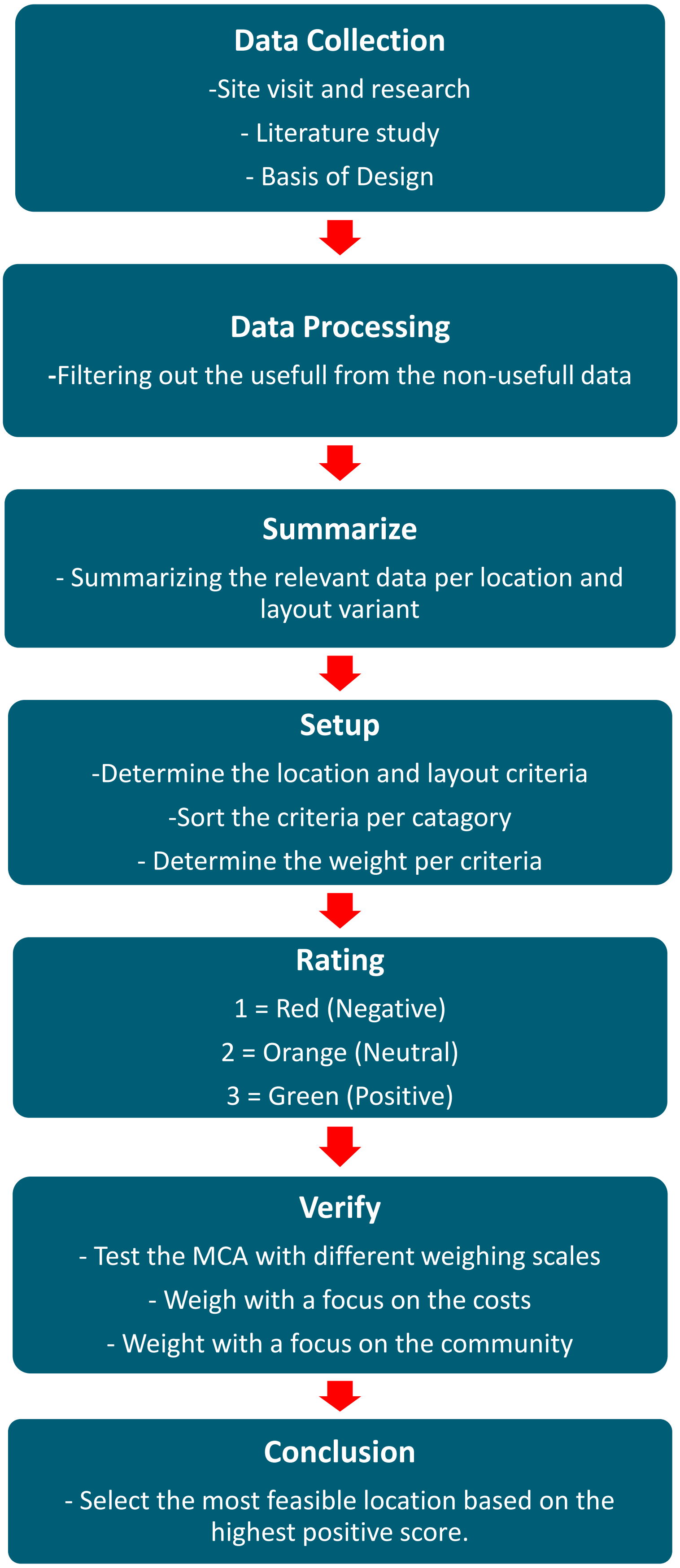
During the stakeholder meetings held in Ambon between the 17th and 21st of October, on-site data was collected in the area surrounding the new Ambon port. The data consists of physical conditions surrounding the rivers, interviews with locals and imagery of the areas. A bathymetry survey was held in a previous mission on the location. Also drone images of the location have been made in a previous mission.

The data used in the MCA is based on the collected on-site data, a literature study and the criteria from the basis of design. This data will be bundled together to form the MCA. The MCA will then, by presenting a score for each option, present the most feasible layout and location for the expansion of the port. A flowchart on the methodology is presented on the next page in figure 1-1.

1.3 Set-up of this document

Chapter one contains the introduction and purpose of this appendix. The second chapter describes the initial locations proposed for the expansion of the new Ambon port. The third chapter describes the seven layouts chosen. The final chapter, chapter four, contains the exploration and clarification of the Multi-Criteria Analysis.

Figure 1-1 flowchart of the Multi-Criteria Analysis



2

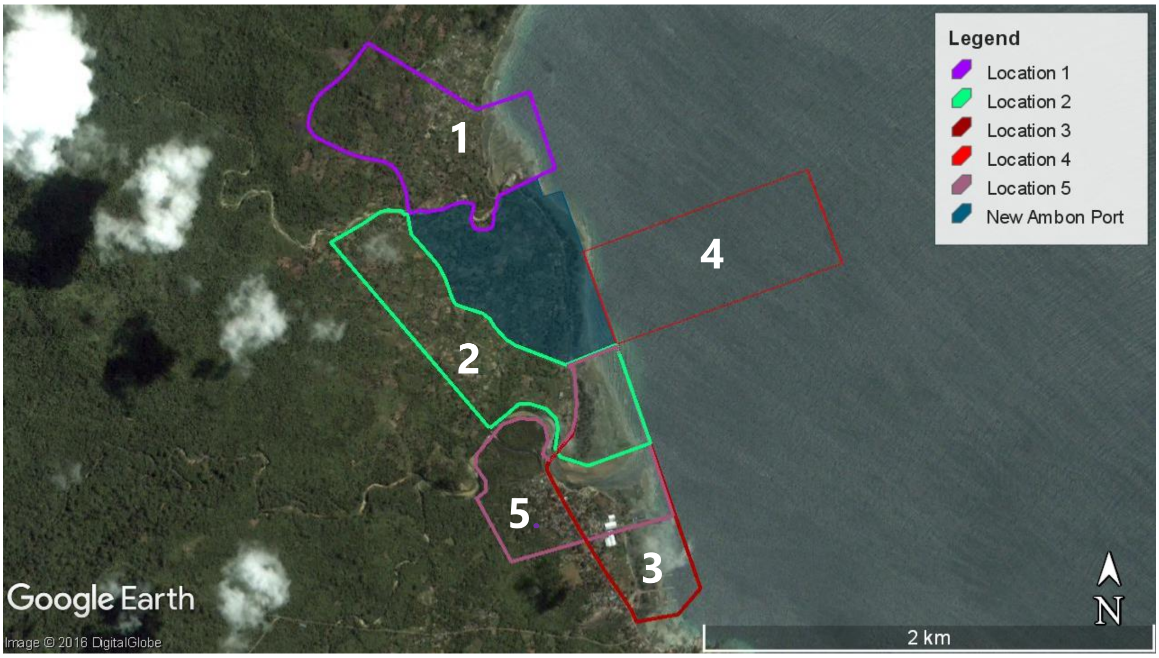
PROPOSED LOCATIONS

There are five proposed locations as to where the expansion can be developed, see table 2-1 and figure 2-1. The locations consist of four on-shore locations and one off-shore location. All locations meet the area requirements as stated in the basis of design. The boundaries of the chosen locations are based on both biotic and a-biotic obstacles such as rivers and roads.

Table 2-1 the four initial expansion proposals

Area	Details
Location One	On-shore, north of the new Ambon port in the direction of Waai
Location Two	On-shore, south and west of the new Ambon port, in the direction of Tulehu and the hinterland
Location Three	On-shore, south of the new Ambon port, in the direction of Tulehu
Location Four	Off-shore, east of the new Ambon port, in the direction of the sea
Location Five	On-shore, south of the new Ambon port, in the direction of Tulehu and the hinterland

Figure 2-1 the boundaries and of the five proposed locations for the port expansion



3

BASE LAYOUTS

3.1 Summary

The five locations are used to design the conceptual layout variants. This resulted in seven different layouts:

- Layout 1A and 1B
- Layout 2A and 2B
- Layout 3
- Layout 4
- Layout 5

Location one and two contain multiple layout variants while location three, four and five do not. In consultation with engineers from WiBo it was concluded that other variants of locations three, four and five, did not add any added benefit due to the basic characteristics of the environment and the connection to the new Ambon port. For location one and two the different variants in layout offer a notable difference to the usage and performance of the port and therefore contain two layout variants per location.

3.2 Layout overview

On the next page, figures 3-1 to 3-7 show the seven proposed layout variants. The different terminals are marked in different colours: the container terminal is marked in purple and the liquid bulk terminal is marked in orange. The yellow lines indicate the location of the national road. A further analysis of these layouts and the locations can be found in the location study, see appendix V

Figure 3-1 Layout 1A

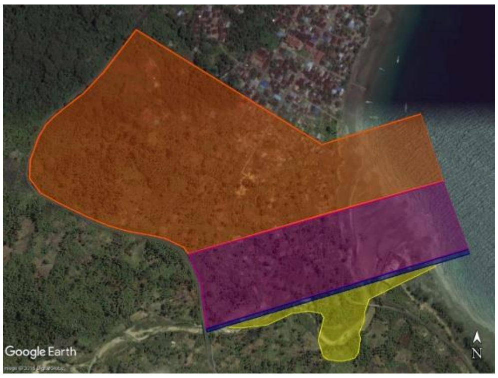


Figure 3-2 Layout 1B

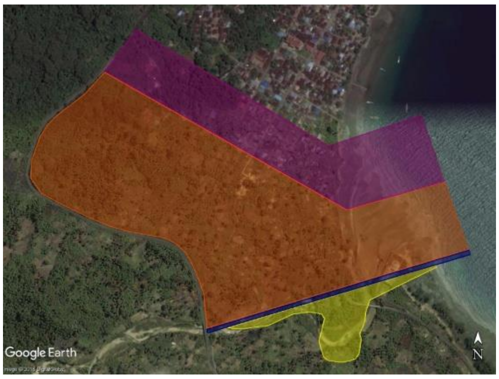


Figure 3-3 Layout 2A

Figure 3-4 Layout 2B

Figure 3-5 Layout 3

Figure 3-6 Layout 4

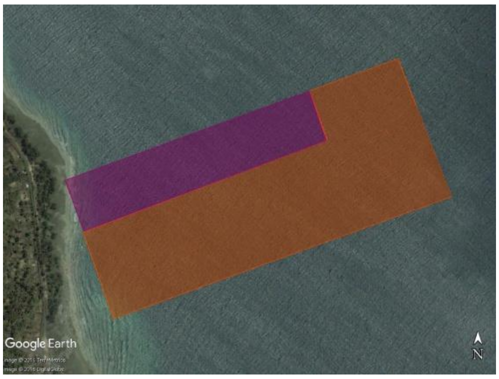


Figure 3-7 Layout 5

4

MULTI-CRITERIA ANALYSIS

4.1 Scoring the MCA

To allow proper scoring the selected criteria, the 'functional requirements' of the port were formulated and used as benchmark for scoring. Each criterion of each layout is scored on a scale of one to three with each a related colour, see table 3-1.

Table 4-1 Scoring guideline for MCA

Colour	Scoring	Numeric Score
Red/Orange	Negative	1
Yellow	Neutral	2
Green	Positive	3

In order to check the accuracy of the MCA, it is verified by conducting two more analyses with a different weighing. One of the extra analyses is focused on the costs of the development and the other one is focused on the local community. During this verification the same scoring of the criteria will be maintained.

4.2 Clarification

Each criterion has a weight of one to five appointed to it. A weighing of 'one', means the criterion is of lesser influence; a weighing of five means the criterion is of greater influence on the selection. The weighted criterion is then multiplied by the scoring it receives based on the characteristics of the location and layout.

The scoring weighted criterion (one to five) is multiplied by the score (one to three) in order to determine the final score per criteria per layout. An example is shown in figure 4-1.

Figure 4-1 example scoring of a MCA criterion

Example:
The safety for the surrounding inhabitants and environment is very important since the port is built to improve the economy of Ambon in order to create a better life standard on the island. Risking this would undo most benefits created by the port therefore; the aspect 'safety' has been given a relevance factor of 5.

Layout 1B scores 'positive' on the criterion; 'safety', which has a weighing factor of 5. This means the weighted score will result in: '$3 * 5 = 15$'. Giving Layout 1B a total score of 15 on the criterion 'Safety'.

Figure 4-3 shows the ten criteria, their weight and functional requirements used in the MCA. The criteria are split up in three different categories: Physical aspects, socio economic aspects and development aspects.

Table 4-2 the MCA criteria, functional requirements and weighing

Category	Criteria	Functional requirement	Weight
Physical Aspects	Biotic obstacles	Effort required to overcome natural obstacles such as water masses and flora	3
	A-biotic obstacles	Effort required to overcome man made obstacles such as infrastructural, residential and corporate constructions	5
	Topography	Height differentiation on the location	4
	Bathymetry	Dredging aspects regarding the required and available water depths	4
Socio Economic Aspects	Relocation	Forced relocation of inhabitants	5
	Regional Employment	Creation/loss of employment in the surroundings of the port	4
	Safety	Risks for the surrounding environment and inhabitants	5
Development Aspects	Road Interference	Influences on the regions road accessibility	2
	Phasing Options	Flexibility to develop the port in different phases depending on the actual growth and needs of the port	5
	Identified Risks	Present known risks on the location of the port expansion	5

Several aspects that are normally used in the selection of a port location are left out of this MCA. This is done because the proposed expansion locations are relatively closely located to each other, resulting in great amount of shared characteristics. Figure 4-3 on the next page shows the criteria left out of this MCA including the reasoning for it.

Table 4-3 Left out selection criteria

Criteria	Reason for leaving out
Available on-shore area	All locations fulfil the requirements regarding land size.
Spatial planning (RTRW)	Most of the area is already reserved for port related activities. The government of Ambon takes the remaining spatial obstacles for its account [Lit. 1]
Land ownership	This is the same in the all locations are in the possession of inhabitants, governments and businesses. Causing no differences between the locations
Land price	The land prices in the area are generally the same. The differences in costs depend on the constructions on the land, not the land prices them self.
Electricity availability	All locations depend on the same source of energy
Fresh water availability	All locations depend on the same source of water
Connectivity to the hinterland	All locations are only accessible by the same road and sea connections
Distance between port and	The difference in distance between the locations is a maximum of 2-minute driving time. which is

Criteria	Reason for leaving out
key locations (city/airport/etc.)	a non-substantial difference
Exposure to waves, winds and currents	All locations are connected to the new Ambon port, which is deemed very suitable considering the wave, wind and current conditions. Even smaller fishing ships encounter little to no hinder in this location. Therefore, its assumed the same location will not contain hinder on this field for liquid bulk- and container ships.
Nautical safety	Since the new Ambon port is deemed safe without implementing any measures, it is assumed this goes for the expansion as well.
Geotechnical aspects	Since the locations are located close to each other, the soil conditions are assumed to be generally the same as on the location of the new Ambon port and are therefore assumed as suitable for the expansion. Also, there is no detailed soil data of the location present making it impossible to compare the locations based on accurate data.
Earthquake and tsunami risks	All locations face the same risks regarding the occurrence of tsunamis and earthquakes, and will therefore not be taken into account.
Balance in port supply and demand	Due to the similarity in location and the intention to use the port as the main port on the island means there are no differences in the supply and demand to the different locations.
Improvements to the hinterland logistics	All locations will use the same connections to the hinterland, the road, leaving no option open for an improvement or implementation of other modes of transport.
Legal impact	At this point there is no information available regarding the legal aspects of the port development. These will be taken into account once the design switch from conceptual to conclusive design
Possibility to implement a PPS[1] system	This system is implementable on all locations and is dependable of the final fill in of the new Ambon port

4.3 Completed MCA

On the following pages, the MCA table is shown. The first three pages show the filled in MCA table, explaining how and why certain criteria are rated. The pages after that contain the selected weighing. Respectively; the main weighing, and two verifying weightings: focused on the community and focused on the costs

[1]Dutch acronym for '*Publiek-Private Samenwerking*', which translates to '*Public Private Partnership*'

Part 1/3			Layout 1A	Layout 1B	Layout 2A	Layout 2B	Layout 3	Layout 4	Layout 5	Weight
Category	Criteria	Functional requirement								
Physical Aspects	Biotic obstacles	Effort required to overcome natural obstacles such as water masses and plants	Requires crossing the north river and contains a 16 ha area of woodlands	Requires crossing the north river and contains a 16 ha area of woodlands	Contains a protected mangrove forest along the shoreline and sporadic woodlands	Contains a protected mangrove forest along the shoreline and sporadic woodlands	Contains a protected mangrove forest along the shoreline	No biotic obstacles expected	Contains a protected mangrove forest along the shoreline and crosses the south river and 14 ha woodlands	3
	A-biotic obstacles	Effort required to overcome man made obstacles such as infrastructural, residential and corporate constructions	Contains 15 ha of urban area	Contains 15 ha of urban area	Contains sporadic housing and both the national road and a local road	Contains sporadic housing and both the national road and a local road	Contains both the Tulehu fishery- and ferry port and 6 ha of urban area	No a-biotic obstacles expected	Contains the Tulehu fishery port and 7,5 ha of urban area	5
	Topography	Height differentiation on the location.	Height differences between 0 and 48m above sea level	Height differences between 0 and 48m above sea level	Height differences between 0 and 16 m above sea level	Height differences between 0 and 16 m above sea level	Height differences between 0 and 8 m above sea level	Requires land reclamation or a pile sheet deck	Height differences between 0 and 10 m above sea level	4
	Bathymetry	Dredging aspects regarding the required and available water depths.	Has a suitable water depth but risks sedimentation from the river	Has a suitable water depth but risks sedimentation from the river	Water depths are not suitable, dredging is required	Water depths are not suitable, dredging is required	Water depths are not suitable, dredging is required. Risk of sedimentation from the river	No dredging required	Water depths are not suitable, dredging is required. Risk of sedimentation from the river	4

Part 2/3			Layout 1A	Layout 1B	Layout 2A	Layout 2B	Layout 3	Layout 4	Layout 5	Weight
Category	Criteria	Functional requirement								
Socio Economic Aspects	Relocation	Forced relocation of inhabitants	Requires the relocation of 15 ha of urban area (half the Waai village)	Requires the relocation of 15 ha of urban area (half the Waai village)	Little relocation required	Little relocation required	Requires the relocation of 6 ha of urban area	No relocation required	Requires the relocation of 7.5 ha of urban area	5
	Regional Employment	Creation/ loss of employment in the surroundings of the port	Great Nett-loss of employment expected due to overlap with local businesses	Great Nett-loss of employment expected due to overlap with local businesses	No loss/winning of Nett total jobs expected	No loss/winning of Nett total jobs expected	Great Nett-loss of employment expected due to the overlap with two ports and local businesses	Creates new jobs	A Nett-loss in employment is expected due to the overlap with the fishery port and local businesses	4
	Safety	Risks for the surrounding environment and inhabitants	The liquid bulk terminal is located directly next to the village, endangering the inhabitants	No direct threats to the environment (other than the standard risks)	No direct threats to the environment (other than the standard risks)	No direct threats to the environment (other than the standard risks)	The liquid bulk terminal is located directly next to the village, endangering the inhabitants	Liquid bulk is stored on sea, high risk on pollution	The liquid bulk terminal is located directly next to the village, endangering the inhabitants	5

Part 3/3			Layout 1A	Layout 1B	Layout 2A	Layout 2B	Layout 3	Layout 4	Layout 5	Weight
Category	Criteria	Functional requirement								
Development aspects	Road Interference	Influences on the regions road accessibility	No direct contact with the national road	No direct contact with the national road	After relocating a section of the road, no further interaction	Intense interaction, since the container port is located on both sides of the road	No direct contact with the national road	No direct contact with the national road	Little movement over the road due to the port being located on both sides of the national road.	2
	Phasing Options	Flexibility to develop the port in different phases depending on the actual growth and needs of the port.	Port location has to be prepared all at once due to the present inhabitants and businesses	Port location has to be prepared all at once due to the present inhabitants and businesses	Due to the low population, phased building is fully possible for the liquid bulk terminal	Due to the low population, phased building is fully possible for the liquid bulk terminal	Port location has to be prepared all at once due to the present inhabitants and businesses	Due to the technical foundation, building in phases is undesirable	The hinterland part of the liquid bulk terminal can be partially build in phases	5
	Identified risks	Present risks on the location of the port expansion	The elevation differences between the port and the surroundings (especially after levelling) might cause mud slides	The elevation differences between the port and the surroundings (especially after levelling) might cause mud slides	Borders two rivers which might cause degradation of the river banks	Borders two rivers which might cause degradation of the river banks	No direct risks indicated on the location	Deep water trench causes financial and technical risks	The hinterland exists of woodlands and river banks which might expect an unreliable soil	5

					Main weighing											
	Weighing	Weight	Layout 1A		Layout 1B		Layout 2A		Layout 2B		Layout 3		Layout 4		Layout 5	
		42	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Physical Aspects	Biotic obstacles	3	1	3	1	3	2	6	2	6	1	3	3	9	1	3
	A-biotic obstacles	5	1	5	1	5	2	10	2	10	1	5	3	15	1	5
	Topography	4	1	4	1	4	2	8	2	8	3	12	1	4	3	12
	Bathymetry	4	2	8	2	8	2	8	2	8	1	4	3	12	1	4
Socio Economic Aspects	Relocation	5	1	5	1	5	3	15	3	15	2	10	3	15	2	10
	Regional Employment	4	2	8	2	8	3	12	3	12	1	4	3	12	2	8
	Safety	5	1	5	3	15	3	15	3	15	1	5	1	5	1	5
Development aspects	Road Interference	2	3	6	3	6	3	6	1	2	3	6	3	6	2	4
	Phasing Options	5	1	5	1	5	3	15	3	15	1	5	1	5	2	10
	Identified risks	5	2	10	2	10	2	10	2	10	3	15	1	5	2	10
	Total score:			59		69		105		101		69		88		71

Rank	**Version**	**Points**
1.	Layout 2A	105
2.	Layout 2B	101
3.	Layout 4	88
4.	Layout 5	71
5.	Layout 3	69
6.	Layout 1B	69
7.	Layout 1A	59

					Focus on the costs											
	Weighing	Weight	Layout 1A		Layout 1B		Layout 2A		Layout 2B		Layout 3		Layout 4		Layout 5	
		36	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Physical Aspects	Biotic obstacles	5	1	5	1	5	2	10	2	10	1	5	3	15	1	5
	A-biotic obstacles	5	1	5	1	5	2	10	2	10	1	5	3	15	1	5
	Topography	5	1	5	1	5	2	10	2	10	3	15	1	5	3	15
	Bathymetry	5	2	10	2	10	2	10	2	10	1	5	3	15	1	5
Socio Economic Aspects	Relocation	3	1	3	1	3	3	9	3	9	2	6	3	9	2	6
	Regional Employment	1	2	2	2	2	3	3	3	3	1	1	3	3	2	2
	Safety	3	1	3	3	9	3	9	3	9	1	3	1	3	1	3
Development aspects	Road Interference	1	3	3	3	3	3	3	1	1	3	3	3	3	2	2
	Phasing Options	5	1	5	1	5	3	15	3	15	1	5	1	5	2	10
	Identified risks	3	2	6	2	6	2	6	2	6	3	9	1	3	2	6
	Total score:			47		53		85		83		57		76		59

Rank	Version	Points
1.	Layout 2A	85
2.	Layout 2B	83
3.	Layout 4	76
4.	Layout 5	59
5.	Layout 3	57
6.	Layout 1B	53
7.	Layout 1A	47

					Focus on the local inhabitants											
	Weighing	Weight	Layout 1A		Layout 1B		Layout 2A		Layout 2B		Layout 3		Layout 4		Layout 5	
		40	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Physical Aspects	Biotic obstacles	3	1	3	1	3	2	6	2	6	1	3	3	9	1	3
	A-biotic obstacles	5	1	5	1	5	2	10	2	10	1	5	3	15	1	5
	Topography	3	1	3	1	3	2	6	2	6	3	9	1	3	3	9
	Bathymetry	3	2	6	2	6	2	6	2	6	1	3	3	9	1	3
Socio Economic Aspects	Relocation	5	1	5	1	5	3	15	3	15	2	10	3	15	2	10
	Regional Employment	5	2	10	2	10	3	15	3	15	1	5	3	15	2	10
	Safety	5	1	5	3	15	3	15	3	15	1	5	1	5	1	5
Development aspects	Road Interference	5	3	15	3	15	3	15	1	5	3	15	3	15	2	10
	Phasing Options	3	1	3	1	3	3	9	3	9	1	3	1	3	2	6
	Identified risks	3	2	6	2	6	2	6	2	6	3	9	1	3	2	6
	Total score:			61		71		103		93		67		92		67

Rank	**Version**	**Points**
1.	Layout 2A	103
2.	Layout 2B	93
3.	Layout 4	92
4.	Layout 1B	71
5.	Layout 5	67
6.	Layout 3	67
7.	Layout 1A	61

					Focus on the local inhabitants											
	Weighing	Weight	Layout 1A		Layout 1B		Layout 2A		Layout 2B		Layout 3		Layout 4		Layout 5	
		40	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Physical Aspects	Biotic obstacles	3	1	3	1	3	2	6	2	6	1	3	3	9	1	3
	A-biotic obstacles	5	1	5	1	5	2	10	2	10	1	5	3	15	1	5
	Topography	3	1	3	1	3	2	6	2	6	3	9	1	3	3	9
	Bathymetry	3	2	6	2	6	2	6	2	6	1	3	3	9	1	3
Socio Economic Aspects	Relocation	5	1	5	1	5	3	15	3	15	2	10	3	15	2	10
	Regional Employment	5	2	10	2	10	3	15	3	15	1	5	3	15	2	10
	Safety	5	1	5	3	15	3	15	3	15	1	5	1	5	1	5
Development aspects	Road Interference	5	3	15	3	15	3	15	1	5	3	15	3	15	2	10
	Phasing Options	3	1	3	1	3	3	9	3	9	1	3	1	3	2	6
	Identified risks	3	2	6	2	6	2	6	2	6	3	9	1	3	2	6
	Total score:			61		71		103		93		67		92		67

Rank	**Version**	**Points**
1.	Layout 2A	103
2.	Layout 2B	93
3.	Layout 4	92
4.	Layout 1B	71
5.	Layout 5	67
6.	Layout 3	67
7.	Layout 1A	61

4.4 Weighing and Verification

Figure 4-5 shows the ranked outcome of the main weighing. Layout 2A scores the highest in this weighing. In tables 4-6 and 4-7 the ranked outcome of the two verification weightings is shown. In both verification weightings; layout 2A scores the highest amount of points.

Figure 4-5 Original weighing

Original weighing		
Rank	**Variant**	**Points**
1.	Layout 2A	105
2.	Layout 2B	101
3.	Layout 4	88
4.	Layout 5	71
5.	Layout 3	69
6.	Layout 1B	69
7.	Layout 1A	59

Figure 4-6 Focus on local inhabitants

Focus on the local inhabitants		
Rank	**Variant**	**Points**
1.	Layout 2A	103
2.	Layout 2B	93
3.	Layout 4	92
4.	Layout 1B	71
5.	Layout 5	67
6.	Layout 3	67
7.	Layout 1A	61

Figure 4-7 Focus on the costs

Focus on the costs		
Rank	**Variant**	**Points**
1.	Layout 2A	85
2.	Layout 2B	83
3.	Layout 4	76
4.	Layout 5	59
5.	Layout 3	57
6.	Layout 1B	53
7.	Layout 1A	47

5

CONCLUSIONS

Based on this chapter, the following can be concluded:

- *Layout 2A is selected as the most feasible option based on the main weighing and both the verification weighing's, see tables 6-3 and 6-4. Layout variant 2B is the second most feasible option.*
- *Location two contains the most feasible conditions for the development of a port expansion, which is the main reason for the high scores of both variant 2A and 2B.*
- *Layout variant 4 is the third most feasible option, however is slightly less feasible than option 2A and 2B due to the environmental risks and the financial aspects required to build off shore.*
- *The ranking between layout variants varies little between the main weighing and the verification weightings. This is caused due to the significant differences per location of the variants such as the elevation, presence of rivers and housing etc.*
- *The expansion of the port on location two corresponds with the original plan of Witteveen+Bos regarding the location of the expansion [Lit. 17].*

VII

APPENDIX: CONTAINER TERMINAL – DIMENSIONS AND LAYOUT

TABLE OF CONTENTS

1

INTRODUCTION

The further designing of the new Ambon port expansion requires the conceptual design of the individual terminals within the port. However, these conceptual designs require a foundation based on research and calculations in order to be realistic. This ensures that the conceptual design will be as close to the final design as possible, increasing the reliability of the feasibility study.

The goal of this appendix is to define the minimum requirements for the quay length and storage area for both the general- and container cargo in the 2040 boldly optimistic scenario. These defined requirements will then be translated into a conceptual design indicating the possible layout of the future port. Based on calculations both the quay length and storage surface area will be estimated. These calculations are filled by a literature research and completed based on several assumptions in case there is no sufficient information available. Since this study contains a feasibility study and the calculations are based on a wide range of assumptions, a margin of error of 50 percent is deemed acceptable. As soon as new and more reliable information is available, this margin of error can be reduced.

This first chapter introduces the goal of the entire document, the work method and the document setup. The second chapter summarizes the basic conditions on which the calculations are based; these contain the trade quantities, vessel dimensions, etc. The third chapter will determine the required quay length for the container terminal and the fourth chapter determines the required storage surface area for the container terminal. In the fifth chapter the conceptual layout of the container terminal will be presented and in the sixth chapter all conclusions will be summarized.

2

BASIC CONDITIONS

2.1 Cargo Quantities

Table 2-1 shows the predicted quantities of general- and container cargo in the new Ambon port based on both the optimistic as on the boldly optimistic scenario. The quantities for the amount of TEU's are based on the average container traded in Ambon, which has a weight of 12 tons/container [Lit. 2].

Table 2-1 predicted cargo turnover in commodities with the optimistic scenario [Lit. 2]]

Scenario	Cargo	Unit	2020	2025	2030	2035	2040
Optimistic	Containers	'000 Tons	863	1190	1614	2163	2870
	Containers	TEU	46,917	99,167	134,500	180,250	239,167
	General Cargo	Tons	153,000	172,000	193,000	216,000	242,000
Boldly Optimistic	Containers	Tons	929,000	1,360,000	1,945,000	2,736,000	3,799,000
	Containers	TEU	77,417	113,333	162,083	228,000	316,583
	General Cargo	Tons	153,000	172,000	193,000	216,000	242,000

Table 2-2 shows the subdivision of the container cargo in the current Pelindo IV port on Ambon. These numbers will be used as a reference for the subdivision of the container cargo in the new Ambon port. The cargo contains three different types of stacks: Standard containers, reefers and empties. These stacks are separated in two sizes: 20 foot and 40 foot. For a more precise analysis, these stacks have to be separated in the groups 'import' and 'export', however, there is currently no reference available about the ratio between import and export.

Table 2-2 assumed cargo ratio per type based on the new Ambon port ratio [Lit. 2]

Cargo Type	% of Total Throughput	Amount in TEU's
20-foot Standard Container	52.2%	174,753
40-foot Standard Container	2.2%	6,965
Total Standard Containers	54.4%	181,718
20 Foot Reefers	39.3%	124,417
40 Foot Reefers	2.6%	8,231
Total Reefers	41.9%	132,648
20 Foot Empties	0.7%	2,216
40 Foot Empties	3.1%	9,814
Total Empties	3.8%	12,030

2.2 Vessel Dimensions

Based on the market research by the port of Rotterdam and the feasibility study by the Witteveen+Bos consortium; the expected vessel dimensions in the new Ambon port and the expansion are determined as shown in table 2-3. In both scenarios the expected amount of general cargo in the port is the same; therefore, there is no change in vessel predicted.

Table 2-3 dimensions of the expected cargo vessels in the optimistic and boldly optimistic scenario [Lit. 2]

Cargo Type	Scenario	Vessel type	Capacity	LOA	Draft
Container	**Optimistic**	Feeder	1,200 to 1,800 TEU	160-222 m	9 to 11 m
	Boldly Optimistic	Panamax	5,100 TEU	211-294 m	10 to 12 m
General Cargo	**(Boldly) Optimistic**	Vessel with Cargo Gear	6,400 ton 1,400 GT	120 m	9 to 11 m

2.3 Handling Equipment

Several types of equipment will be used to handle the cargo in the new Ambon port, see table 2-4. The table contains information container related efficiency variables; these are not available for general cargo due to the variety in sizes.

Table 2-4 types of cargo handling equipment in the new Ambon port

Equipment Type:	Nominal Stacking Height	m^2/TEU
Forklifts	**2**	**35-40**
	3	**25-30**
Reach stacker	**2**	**35-40**
	3	**25-30**
Mobile Harbour Crane	**N/A**	**N/A**

3

QUAY REQUIREMENTS

3.1 Method

Container cargo requires as solid quay with a direct connection to the storage area in order to handle the cargo. The formulas used to determine the quay length are based on [Lit. 9]. In order to determine the quay length required for the general cargo, first the throughput per berth will be determined by using formula (1.1) for general cargo and formula (1.2) for container cargo. Required amount of berths will be determined using formulas (1.1) for container and (1.2).

$$\boldsymbol{c_b} = \boldsymbol{P * N_{gs} * n_{hy} * m_b} \quad \textbf{(1.1)}$$

c_b	=	$throughput\ per\ berth$	[t/yr]
P	=	$average\ gang\ productivity$	[t/hr]
N_{gs}	=	$number\ of\ gangs\ per\ ship$	[-]
n_{hy}	=	$number\ of\ operational\ hours\ per\ year$	[hrs/yr]
m_b	=	$berth\ occupancy\ rate$	[-]

$$\boldsymbol{\overline{c_b}} = \boldsymbol{P * f_{TEU} * N_{cb} * n_{hy} * m_b} \quad \textbf{(1.2)}$$

$\bar{c_b}$	=	$average\ annual\ productivity\ per\ berth$	[TEU/yr]
P	=	$net\ production\ per\ crane$	[moves/hr]
f_{TEU}	=	$TEU\ factor$	[-]
N_{cb}	=	$number\ of\ cranes\ per\ berth$	[-]
n_{hy}	=	$number\ of\ operational\ hours\ per\ year$	[hrs/yr.]
m_b	=	$berth\ occupancy\ factor$	[-]

The TEU-factor in formula (1.2) is determined by using formula (1.3).

$$\boldsymbol{f_{TEU}} = \boldsymbol{\frac{N_{20'}+2*N_{40'}}{N_{20'}+N_{40'}}} \quad \textbf{(1.3)}$$

f_{TEU}	=	$TEU\ factor$	[-]
$N_{20'}$	=	$number\ of\ TEU's\ per\ time\ period$	[-]
$N_{40'}$	=	$number\ of\ FEU's\ per\ time\ period$	[-]

Using the throughput per berth and the total throughput of the port, the total required amount of berths is determined; this is done by using formula (1.4)

$$\boldsymbol{n} = \frac{\boldsymbol{C}}{\boldsymbol{c_b}} \qquad \textbf{(1.4)}$$

n	=	$number\ of\ berths$	[-]
C	=	$yearly\ general\ cargo\ throughput\ across\ the\ terminal$	[t/yr]
c_b	=	$throughput\ per\ berth$	[t/yr]

By using formula (1.5) the minimum length per berth will be determined. This formula is based on the free zone on both ends of a docking ship. This free zone is there for mooring margins and safety reasons. For smaller vessels this length can be 15 m, bigger vessels can require a free zone up to 30 m.

$$\boldsymbol{L_q} = \begin{cases} \boldsymbol{L_{s,max} + 2 * L_f} & \boldsymbol{for\ n = 1} \\ \boldsymbol{1.1 * n * (\overline{L_s} + L_f) + L_f} & \boldsymbol{for\ n} > 1 \end{cases} \qquad \textbf{(1.5)}$$

L_q	=	$quay\ length$	[m]
$L_{s,max}$	=	$max\ length\ of\ the\ main\ vessel$	[m]
L_f	=	$free\ zone\ between\ for\ safety\ and\ mooring$	[m]
n	=	$number\ of\ berths$	[-]

3.2 General Cargo Quay

3.2.1 Number of Berths

In order to determine the number of berths required to handle the expected general cargo in 2040, several variables will have to be defined. According to table 1-1 the port expects a total throughput of 242,000 ton of general cargo. Table 3-1 shows the average gang production per type of general cargo. According to the current cargo turnover (general- and container cargo) in the current Pelindo IV ports in Ambon; the port main import product is cement (38.4%). Followed by food and lifestyle products such as sugar (9%), noodles and snacks (8%) and bottled water (8%). These types of product are mostly described as break-bulk. However, according to the Port of Rotterdam, most of the imported cargo is containerised. An estimate of 70% containerised and 30% break-bulk will be used as basis. In the calculation this will be written in the time of handling, 30% of the operational hours will be handling break-bulk (10 t/hr) and 70% of the operational hours will be handling containerized general cargo (50 t/hr). The bigger amounts of containerised general cargo are partially explained by the high amounts of food produces being exported from Ambon; for example, 21% of the total export consists out of cloves, 28% out of frozen fish and 30% out of copra (coconut flesh).

Table 3-1 average gang productivity per type of general cargo [Lit. 9]

Type of general cargo	t/hr
Conventional general cargo (break-bulk)	8.5 to 12.5
Timber and timber products	12.5 to 25
Steel products	20 to 40
Containerised cargo	30 to 55

The vessels docking the general cargo quay are estimated at a length of 120 m, a vessel of this size has an average of 2 gangs. Assuming the port works two eight hour shifts per day, six days per week; the port berth will have 4992 operational hours per year. Of these hours, an estimated 1997 hours are used for break-bulk and 2995 hours are used for containerized general cargo. The Indonesian waters are known for extreme weather conditions, especially in the wet season. Therefore, a lower occupancy rate of 0.65 can be expected due to delays in shipping.

Table 3-2 annual productivity per berth

	Variable	Unit	Break-Bulk	Containerized General Cargo
Variables	P	t/hr	10	50
	N_{gs}	-	2	2
	n_{hy}	hrs/yr	1747	3494
	m_b	0.65 to 0.90	0.65	0.65
Result	c_b	t/yr	19,467	227,110

By combining the berth productivities of both; break-bulk and containerized general cargo, the average throughput per berth is determined. This results in the following calculation:

$$c_b = 19{,}467 + 227{,}110$$
$$c_b = 246{,}579\ t/yr$$

The berth productivity is then used to determine the total amount of berths required to handle the total annual throughput of the terminal. The annual throughput of 242,000 tons will be divided by the annual capacity per berth. This is done with formula (1.4):

$$n = \frac{C}{c_b}$$

$$n = \frac{242{,}000}{246{,}579}$$

$$n = 0{,}98$$

n = 1 berth

In order to handle the total expected quantity of general cargo in 2040 during the boldly optimistic scenario; a single berth is required for the (un-)loading of general cargo.

3.2.2 Berth Length

Formula (1.5) is used to determine the minimum berth length based the maximum length of docking vessels. In the previous chapter the amount of berths required was estimated at a single berth. The $L_{s,max}$ for the general cargo vessels is assumed on 120 m and the free zone for safety and mooring is set at 15 m [Lit. 2] and [Lit. 9]. Filling this data into the formula results in:

$$L_q = L_{s,max} + 2 * L_f$$

$$L_q = 120 + 2 * 15$$

$$L_q = 150\ m$$

From this it is concluded that a minimum berth length of 150 m is required.

3.3 Container Cargo Quay

3.3.1 Number of Berths

In order to determine the number of berths required to handle the expected general cargo in 2040, several variables will have to be defined. According to table 1-1 the port expects a total throughput of 3,799,000 ton or 316,583 TEU. In order to reach this capacity, a certain amount of berths is required. The amount of berths depends on the capacity of the berth itself and the total required capacity of the port. Formula (1.2) is used to calculate the average annual production per berth.

The net productivity per crane 'P' is defined as; "*the average number of containers moved from ship to shore and vice versa during the period between berthing completed and deberthing started*". This period includes all sorts of unproductive intervals such as for crane repositioning from one bay to another, removal of hatches and replacing them, time loss between shifts and simple repairs of the cranes. Since the new Ambon port is expected to mainly handle feeder vessels with a TEU capacity of 1,200 TEU to 1,800 TEU and Panamax vessels with a TEU capacity of 2,800 TEU to 5,100 TEU the following assumptions will be used as a base for the new Ambon port:

"A modern terminal which receives 4,000 to 5,000 TEU vessels on a regular basis and working 24 hours per day, 360 days per year and receives average vessels of approximately 2,000 TEU and a length of 250 meter contains an average of three cranes per berth, a low berth occupancy factor of 35% and a net crane productivity of 25 moves per hour and a TEU-factor of 1.5." [Lit. 9]

This is further supported by the imagery in the feasibility report conducted by the consortium wherein three STS cranes are shown. In order to use formula (1.2), first the TEU-factor will have to be determined using formula (1.3). Based on the ratio between container types, stated in table 2-2 a summary is made in table 3-3.

Table 3-3 annual productivity per berth

	%	TEU
20 ft. containers	92,1	291,573
40 ft. containers	7,9	25,010

Using the numbers from table 3-3 in formula (1.3) this results in:

$$f_{TEU} = \frac{N_{20'}+2*N_{40'}}{N_{20'}+N_{40'}} \quad (1.3)$$

$$f_{TEU} = \frac{291{,}573+2*25{,}010}{291{,}573+25{,}010}$$

$$f_{TEU} = 1.08$$

Table 3-4 annual productivity per berth

	Variable	Unit	Value
Variables	P	moves/hr	25
	f_{TEU}	-	1.08
	N_{cb}	cranes/berth	3
	n_{hy}	hrs/yr	8640
	m_b	-	0.35
Result	$\bar{c_b}$	TEU/yr	244,944

Using the productivity per berth and the total capacity requirement; the required amount of berths can be determined. This will be done using formula (1.4).

Using the data from table 1-1 and the calculated $\bar{c_b}$ value in formula (1.4); this results in:

$$n = \frac{316{,}583}{244{,}944}$$
$$n = 1{,}3$$
$$n = 2\ berth$$

In order to handle the amount of TEU's expected in 2040 in the boldly optimistic scenario two berths are required for the (un-)loading of container cargo.

3.3.2 Berth Length

Besides the depending on the capacity per m[1]; the quay length depends on the length of the vessels which visit the port. According to the market research study, the boldly optimistic scenario will handle bigger vessels then in the optimistic scenario, see table 1-3. This results in a bigger range in vessel sizes docking at the port. In chapter 3.3.1 it is determined that 2 berths will be required in the port in order to reach the required capacity. The biggest size vessel will dock sporadically compared to the smaller sizes of vessels.

The quay requires two berths; these berths have to fit two Feeder vessels at the same time and a single Panamax vessel. Therefore, the length of the quay should fit two $222\ m$ feeder vessels with $15\ m$ free zone, as well as a single $294\ m$ Panamax vessel with $25\ m$ free zone (not at the same time). Using this data in formula (1.5) results in the following calculations:

$$L_q = L_{s,max} + 2 * L_f$$
$$L_q = 294 + 2 * 20$$
$$L_q = 334\ m$$

And:

$$L_q = 1.1 * n * \left(\bar{L_s} + L_f\right) + L_f$$
$$L_q = 1.1 * 2 * (222 + 15) + 15$$
$$L_q = 536\ m$$

The quay length needs to fit both scenarios of vessels and therefore the bigger quay requirement is selected.

$$536\ m > 334\ m$$

$$L_q = 536\ m$$

The minimum required overall quay length for the container cargo is 536 meters and contains two berths. One of the berths requires a minimum length of 334 m.

3.4 Conclusions

Table 3-5 shows the quay requirements concluded in chapter 3.2 and 3.3.

Table 3-5 Summary of the quay length requirements

Cargo Type	Requirement:	Unit:	General Cargo
General Cargo	Total Quay Length	m	150
	Berths	-	1
Container Cargo	Total Quay Length	m	536
	Berths	-	2
Total	Quay length	m	686
	Berths	-	3

The current new Ambon port design contains a $400\,m$ quay wall. This design will need an $286\,m$ expansion. However, since the general cargo terminal and container terminal both contain a free zone at the end, of which one end will be unnecessary, this length can be shortened by $15\,m$, resulting in a length of $271\,m$. This will be topped off which results in a $270\,m$ quay expansion of the current new Ambon port in the boldly optimistic scenario.

This conclusion is based on the following assumptions:

- The new Ambon ports' container terminal will acquire a 400 m quay length as stated in the new Ambon feasibility report [Lit. 10]
- The cargo is handled by reach stackers, forklifts and mobile harbour cranes
- In contrast with the optimistic scenario, the general cargo and container cargo will get their own berthing area but will still remain within the same terminal
- The vessels docking the port are as predicted by the Port of Rotterdam [Lit. 2]

4

STORAGE SURFACE AREA

4.1 Method

Containerised cargo is stored on a concrete floor in the open. Reefers require the same type of area with the addition of an electricity supply in order to cool the cargo. For general cargo there are several storages required depending on the specific characteristics of the cargo these storages consist of: open yards and sheltered storage halls. Formulas used to determine the required surface area are based on [Lit. 9]. Two different formulas are used to determine the required surface area for general- and container cargo.

General cargo

Formula (1.6) is used to determine the surface area required for the storage of general cargo. This type of cargo varies widely in shape, size, packaging and weight. As a result, this formula will be completed using several assumptions which will be handled in chapter 3.2.

$$A_{gr} = \frac{f_{area} * f_{bulk} * n_c * \overline{t_d}}{m_c * h_s * \rho_{cargo} * 365} \qquad \textbf{(1.6)}$$

A_{gr}	=	$required\ floor\ area$	[0.65 to 0.70]
f_{area}	=	$ratio\ gross\ over\ net\ surface, accounting\ for\ traffic\ lanes\ etc.$	[-]
f_{bulk}	=	$bulking\ factor\ due\ to\ stripping\ and\ seperatly\ stacking\ etc.$	[-]
N_c	=	$total\ tonnage\ handeld\ annually$	[t/yr]
$\overline{t_d}$	=	$average\ dwell\ time$	[days]
m_c	=	$acceptable\ average\ occupancy\ rate$	[0.65 to 0.70]
h_s	=	$average\ height\ in\ the\ storage$	[m]
ρ_{cargo}	=	$average\ relative\ density\ of\ the\ cargo\ in\ the\ vessel$	[t/m^3]

Container cargo

Formula (1.7) is used to determine the surface area required for the storage of container cargo. Container cargo is divided in stacks (import, export, standard containers, reefers and empties). Since these stacks have different values, the required surface area will have to be determined for each stack separately. The formula will be completed using several assumptions which will be handled in the chapter 3.3.

$$A = \frac{N_c * \overline{t_d} * A_{TEU}}{r_{st} * 365 * m_c} \qquad \textbf{(1.7)}$$

A	=	$area\ required$	[m^2]
N_c	=	$number\ of\ container\ movements\ per\ year\ per\ type\ of\ stack\ in\ TEU's$	[m]
$\overline{t_d}$	=	$average\ dwell\ time$	[days]
A_{TEU}	=	$required\ area\ pet\ TEU\ inclusive\ of\ equipment\ traveling\ lanes$	[m^2]
r_{st}	=	$average\ stacking\ height/nominal\ stacking\ height$	[0.6 to 0.9]
m_c	=	$acceptable\ average\ occupancy\ rate$	[0.65 to 0.70]

4.2 General Cargo Storage

The storage surface area for general cargo is calculated by using formula (1.6). Most variables for formula (1.6) can be determined based on information from the basis of design (Appendix II) and [Lit. 9] with the main exception of the cargo density. The cargo density 'ρ_{cargo}' in the feasibility study is unrealistically high and will therefore have to be redefined. The feasibility study assumes cargo vessels with an average of 1,200 GT and a load of 6,400 tons. This amounts to an average ρ_{cargo} of $5{,}400\ kg/m3$. This density is unrealistically high and will therefore be determined by analysing the weights and density of the expected cargo. Table 4-1 shows the import percentage of each commodity of cargo imported and exported by the Pelindo IV ports in Ambon [Lit. 2]. The commodity 'other' is assumed to be the same as the average of the other commodities combined. For several commodities the density depends on more specific types of the product, for example sugar (brown, cane, etc.). For these situations the highest weight is used to determine the density.

Table 4-1 cargo characteristics and ratios in 2015 [Lit. 2], [Lit. 11] and [Lit. 15]

Import			Export		
Commodity	**Density in kg/m³**	**Percentage of total Import**	**Commodity**	**Density in kg/m³**	**Percentage of total Export**
(Portland) Cement	1,506	38%	**Copra**	401	30%
Frozen Chicken	1,113	5%	**Frozen Fish**	881	28%
Wheat Flour	561	7%	**Cloves**	440	21%
Bottled Water	1,000	8%	**Nutmeg**	687	17%
Soap and Shampoo	240	8%	**Scrap Metal**[1]	5,000	3%
Noodles and Snacks	737	9%			
Sugar	881	9%			
Other	N/A	16%			
Total Average kg/m³	1,085	100%	**Total Average kg/m³**	726	100%

Table 4-2 shows the values used in formula (1.6) in order to determine the surface area required for the storage of general cargo. The 'ratio gross over net surface' is set on 1.5 and the 'bulking factor' is set on 2, both values are common in developing ports while stacking 2 m high. The port will handle 242,000 ton of general cargo in 2040 with an average occupancy rate of 0.65. From table 4-1 the lowest density is used, since this requires most storage area, this is the export density with an average of 0,7 t/m³.

Table 4-2 variables and area requirements for the different container cargo stacks

	Variable	Unit	Value
Variables	f_{area}	-	1.5
	f_{bulk}	-	2
	N_c	t/yr	242,000
	$\bar{t_d}$	days	7
	m_c	0.65 to 0.70	0.65
	h_s	m	2
	ρ_{cargo}	t/m³	0.7
Result	A_{gr}	m²	15,300

[1] The density of scrap metal varies widely, therefore this is merely an assumption

4.3 Container Cargo Storage

The storage surface area for container cargo is calculated by using formula (1.7). The required area depends foremost on the type of container, the dwell time and the cargo quantity. According to table 1-1 the port will handle a total of 316,583 containers in the year 2040. The storage area is split up into three different stacks: standard containers, reefers and empties, the ratio of which is shown in table 1-2. At the current stage of the port development there is no available ratio between import and export of the container cargo. While a difference in dwell time between import and export, there is no standard indication to assume this since this varies per port [Lit. 20]. It will therefore be assumed that both the import and export cargo contain the same dwell time; three days for full containers, two days for reefers and six days for empties (appendix II), [Lit. 2] and [Lit. 9].

The surface area required varies per type of handling equipment. The containers will mainly be handled by forklifts, reach stackers and mobile harbor cranes. Each type of equipment has its own m²/TEU margin, see table 4-3. The new Ambon port will stack containers to a nominal stacking height of 3 and the A_{TEU} value is assumed to be 30 $m2/TEU$.

Table 4-3 types of cargo handling equipment in the new Ambon port

Equipment Type:	Nominal Stacking Height	m²/TEU
Forklifts	2	35-40
	3	25-30
Reach stacker	2	35-40
	3	25-30
Mobile Harbour Crane	N/A	N/A

All these variables are put together in table 4-4 to determine the total required area of the container terminal based on the three different types of stacks.

Table 4-4 variables and area requirements for the different container cargo stacks

Cargo Type	Variable	Unit	Standard Containers	Reefers	Empties
Variables	N_c	TEU	181,718	132,648	5,699
	$\bar{t_d}$	Days	3	2	6
	A_{TEU}	m²	30	30	30
	r_{st}	0.6 to 0.9	0.9	0.9	0.9
	m_c	0.65 to 0.70	0.65	0.65	0.65
Result	A	m²	76,593	37,273	4,804

This results in a total storage area requirement of:

$$A = 76{,}593 \text{ m}^2 + 37{,}273 \text{ m}^2 + 4{,}804 \text{ m}^2$$
$$A = 118{,}670 \text{ m}^2$$
$$A = 12 \; ha$$

4.4 Conclusions

Quay Wall

- *The total required length of the container terminal quay for both the current and expansion of the port is* $686\ m$ *(two* $222\ m$ *vessels and one* $120\ m$ *vessel).*
- *The current new Ambon port has a quay length of* $400\ m$*, therefore, based on the requirements in the BoD, an expansion of approximately* $200\ m$ *is required.*

Surface Area

- *The total required surface area for the container port is 20.4 ha. This includes the storage area for both general- and container cargo, as well as the "other".*
- *The current container terminal of the new Ambon port has a total surface area of 15 ha. Therefore, based on the values in the BoD, an expansion is required in order to handle the predicted cargo quantities in the 'boldly optimistic' scenario in 2040.*
- *The required surface area as stated by the Port of Rotterdam in [Lit. 2] is higher than calculated in this chapter, see table 4-5.*

Table 4-5 differences in surface area requirement

	Port of Rotterdam	Previous chapters	Difference
Required Surface Area:	27 ha	20.4 ha	6.6 ha

VIII

APPENDIX: LIQUID BULK TERMINAL – DIMENSIONS AND LAYOUT

TABLE OF CONTENTS

1

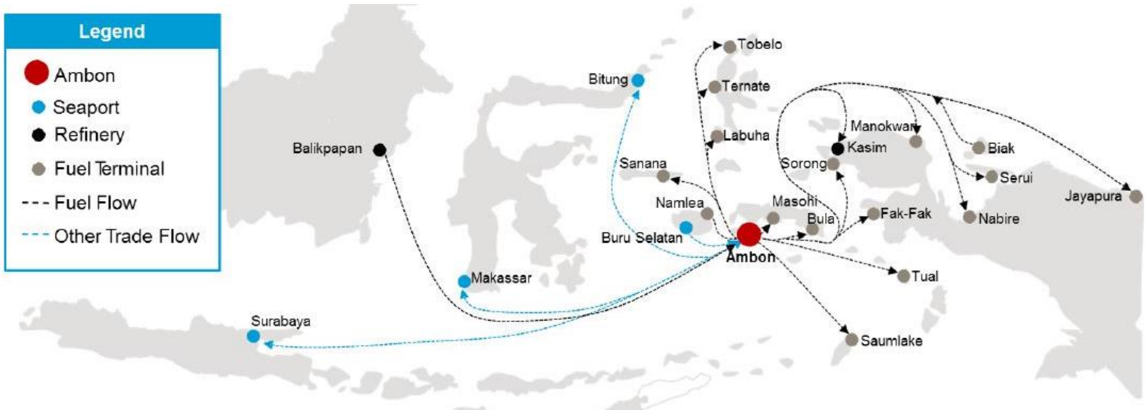
INTRODUCTION

The further designing of the new Ambon port expansion requires the conceptual design of the individual terminals within the port. However, these conceptual designs require a foundation based on research and calculations in order to be realistic. This ensures that the conceptual design will be as close to the final design as possible, increasing the reliability of the feasibility study.

The goal of this appendix is to define the minimum requirements for the quay and storage area for the liquid bulk cargo in the 2040 boldly optimistic scenario. These defined requirements will then be translated into a conceptual design indicating the possible layout of the future port. Based on calculations both the quay length and storage surface area will be estimated. These calculations are filled by a literature research and completed based on several assumptions in case there is no sufficient information available. Since this study contains a feasibility study and the calculations are based on a wide range of assumptions, a margin of error of 50 percent is deemed acceptable. As soon as new and more reliable information is available, this margin of error can be reduced.

The liquid bulk terminal of the new Ambon port will function as a replacement for the Wayame port currently located in the bay of Ambon. With the development of a bigger liquid bulk terminal, Ambon aims to be the main fuel hub in east Indonesia, as shown in figure 1-1.

Figure 1-1 Ambon as a regional transport hub [Lit. 16]



This first chapter introduces the goal of the entire document, the work method and the document setup. The second chapter summarizes the basic conditions on which the calculations are based; these contain the trade quantities, vessel dimensions, etc. The third chapter will determine the required mooring method and the fourth chapter determines the required storage surface area for the liquid bulk.

2

BASIC CONDITIONS

2.1 Cargo Quantities

Table 2-1 shows the predicted quantities of liquid bulk in the new Ambon port based on both the optimistic as on the boldly optimistic scenario. The predictions assume that Pertamina relocates its current liquid bulk activities on Ambon from the Wayame port to the new Ambon port in the year 2030. In the optimistic scenario there is no liquid bulk terminal planned.

Table 2-1 predicted cargo turnover in commodities with the optimistic scenario [Lit. 2]

Scenario	Cargo	Unit	2020	2025	2030	2035	2040
Optimistic	Liquid Bulk	Tons	-	-	-	-	-
Boldly Optimistic	Liquid Bulk	Tons	0	0	540,000	581,000	625,000

In accordance with the current activities of the Wayame port and the requirements set up in the 'base of design' (appendix II) and the 'feasibility study on the new Ambon port' [Lit. 10] the liquid bulk terminal of the new Ambon port will focus on the handling of oil. The exact ratio of different oil types is not currently unavailable; however, it is assumed that three types of oil will be handled in the liquid bulk terminal of the new Ambon port, see table 2-2.

Table 2-2 oil types in the liquid bulk terminal and their density based on the assumptions of the POR [Lit. 2]

Type of liquid bulk:	Kilolitre per ton	ton/m^3
Average Liquid Bulk	800-970	0.786

2.2 Vessel Dimensions

Based on the market research by the port of Rotterdam and the feasibility study by the Witteveen+Bos consortium; the expected vessel dimensions in the new Ambon port and the expansion are determined as shown in table 2-3. In both scenarios the expected amount of general cargo in the port is the same; therefore, there is no change in vessel predicted.

Table 2-3 dimensions of the expected cargo vessels in the optimistic and boldly optimistic scenario [Lit. 2]

Scenario	Cargo Type	Vessel type	Capacity	LOA	Draft
Boldly Optimistic	**Liquid Bulk**	Handysize	10,000 to 25,000 ton	176 to 183 m	9 – 11 m

2.3 Reference Ports

In order to determine the required area for the liquid bulk terminal, several sources have been used as references in order to determine the size. Tables 2-4 and 2-5 show the operational numbers of liquid bulk ports in South-Africa and their capacity per ha.

Table 2-4 Operational numbers of liquid bulk ports in South-Africa [Lit. 21]

Liquid Bulk Port	Terminal area (ha)	Total Berths	Usable berths	Berth length (m)	Installed Capacity (mtpa[1])	Design capacity (mtpa)	Installed capacity/design capacity
Saldahna	3,6[2]	1	1	360	6,946,229	25,000,000	28%
Cape Town	11	2	2	489	3,400,000	3,400,000	100%
Port Elizabeth	16	1	1	242	972,208	2,926,829	33%
Durban	157	9	8	1765	11,000,000	21,000,000	52%
Richards Bay	73	2	2	600	1,011,432	3,152,778	32%
East London	19	1	1	259	918,688	3,000,000	31%
Mossel Bay[3]	0	2	2	0	1,893,127	7,971,600	24%

Table 2-5 mtpa/ha capacity of liquid bulk ports in South-Africa based on the installed- and design capacity

Liquid Bulk Port[4]	mtpa/ha (Installed Capacity)	mtpa/ha (Design Capacity)
Saldahna	1,929,508	6,944,444
Cape Town	309,091	309,091
Port Elizabeth	60,763	182,927
Durban	70,064	133,758
Richards Bay	13,855	43,189
East London	48,352	157,895

A gross estimate for the required surface area of a liquid bulk terminal can be made using a capacity ratio of: 40-50 t/yr per m2 for crude oil [Lit. 4]. This comes down to 500,000 t/yr per ha; which is either a much higher capacity then is reached in the ports from tables 2-4 and 2-5 or a much lower capacity.

[1] Metric Tons Per Annum

[2] As stated on page 41 of [Lit. 21] instead of the original table on page 29

[3] The Mossel Bay operates with a fully offshore operating SBM system and therefore uses no terminal and berth on shore

[4] Mossel bay is left out since there is no capacity per ha available

3

QUAY REQUIREMENTS

3.1 Amount of Berths

Liquid bulk berths have an extremely high efficiency which can be as high as 70 $million\ t/yr/berth$ when using VLCC and ULCC tankers. But also for smaller vessels the tanker berths have a relatively high capacity and a low occupancy [Lit. 9]. Considering the total yearly amount of 625.000 ton in 2040, a single berth has enough capacity to fulfil the capacity requirements. However, on-shore mooring systems often contain more berths to fit difference vessel sizes for offshore berths this is no factor (with the exception of a fixed offshore terminal). The Wayame port in the bay of Ambon for example, contains three berths, each of which has a different length in order to handle a different type of vessel. Having several berths will also allow the deliverance of different types of liquid bulk at the same time without a total cleaning of the pipeline. A minimum of two berths will be required in order to fit different sized vessels and different cargo types.

3.2 Mooring Method

There are several different methods to (un-)load liquid bulk. In general, the mooring methods are split up in two main groups: 'on-shore mooring' and 'off-shore mooring', see table 3-1.

Table 3-1 on-shore and off-shore mooring methods [Lit. 9]

On-shore mooring	Off-shore mooring
L Jetty	Multi Buoy Mooring (MBM)
T Jetty	Single Buoy Mooring (SBM)
Finger Piet	Fixed offshore terminal

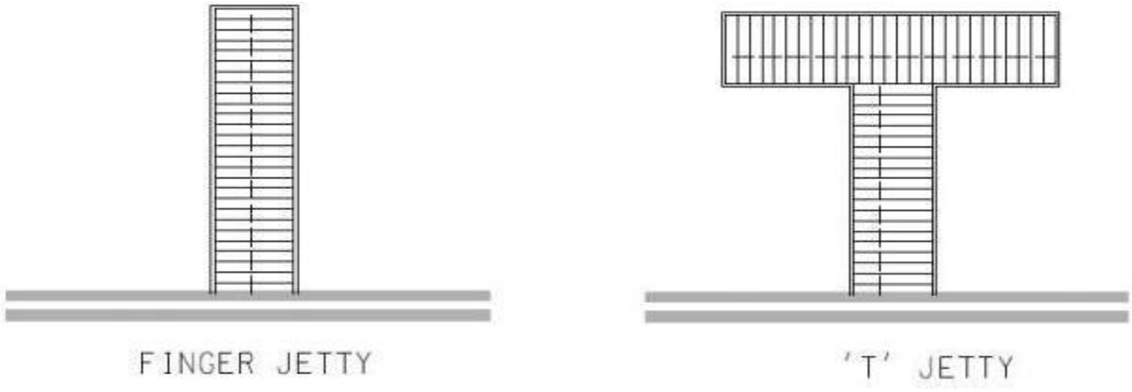
3.2.1 On-shore mooring

On-shore mooring systems contain a direct connection between the sea and the land. The mooring systems consist of rigid structures such as L jetties, T jetties and finger jetties (piers). The difference between these options is the shape of the pier. Figure 3-1 shows the difference between a finger- and t-jetty.

The finger jetty is capable of having berths on both sides of the pier with a possibility of joint use of the approach bridge. However, this might require a broad platform. The usual distance between the dolphin and ships is 35 to 50 m. This would mean a finger pier requires a platform width of more than 70 m. Finger piers are more suitable for handling smaller vessels. Since finger piers are located closely to the shore, water depths can prohibit bigger ships from mooring [Lit. 22].

L and T jetties are generally capable of handling a single ship at the time. However, since the docking location at these piers is located further from the coastline, this setup is capable of handling bigger vessels than would be possible at a finger jetty.

Figure 3-1 Finger Jetty and T-shaped jetty [Lit. 25]



3.2.2 Off-shore mooring

There are two options for off-shore mooring: Single Buoy Mooring (SBM's) and Multi-Buoy Mooring (MBM's). Both of these mooring systems exist of floating buoy(s) and a submarine pipeline as a connection between the buoy on sea and the storage on land. These mooring systems can be located on distances relatively far from sea[1].

Single Buoy Mooring

The strong point of this method is the simplicity and the low investment costs. As a comparison, a fully equipped VLCC jetty requires approximately 2.5 times the investments required for a SBM with a 5 km submarine pipeline [Lit. 4]. A ship docking at an SBM always takes the most favourable position in relation to the surrounding influences such as wind, currents and waves. Docking at an SBM does not require the usage of tug boats; however, the maintenance costs are higher than those of rigid structures such as jetties.

Multi Buoy Mooring

MBM's can only be used in relatively sheltered areas due to the maximum permissible wave height of $1\,m$. This mooring system can be located relatively far away from the shore, just like the SBM system. The berthing and de-berthing on a MBM requires relatively long due to the multiple connection points.

Figure 3-2 SBM with multiple-chain anchoring [Lit. 4].

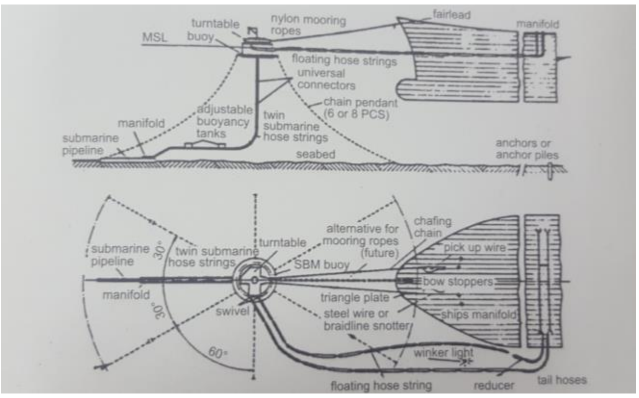
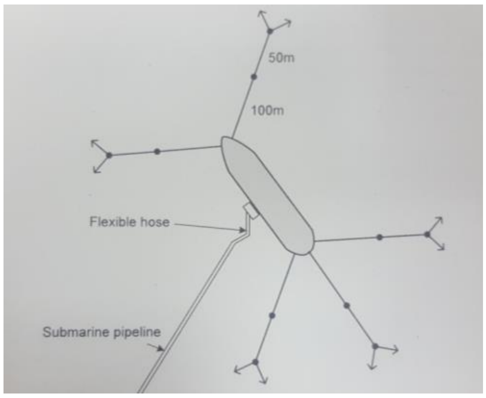


Figure 3-3 Multi-Buoy Mooring system [Lit. 4]



3.2.3 Mooring MCA

Table 3-2 shows the main options of mooring used to load and unload liquid bulk: Jetty's, fixed offshore terminal, Multiple Buoy Mooring (MBM) and Single Buoy Mooring (SBM). Each of these methods has its own

[1] SBM's and MBM's on 5 km distance from the coast are normal practices

strengths and weaknesses. Table 3-2 shows a simplified comparison between the different methods. In this table there is no difference between L and T jetties and finger piers.

Table 3-2 comparison of three mooring systems [Lit. 9]

Aspects:	Jetty (L, T and Finger Pier)	Fixed offshore Terminal	Multiple Buoy Mooring	Single Buoy Mooring
Access from shore	Direct	By Sea	By Sea	By Sea
Number of hoses	1-8	1-8	1-4	1-3
Time between arrival and start of pumping	2 Hours	2 hours	5 Hours	2 Hours
Mooring possible with wind up to 30 knots and head waves of:	1.0 – 2.0 m	1.0 – 2.0 m	1.0 m	2.0 - 2.5 m
Mooring possible with wind up to 40 knots and head waves of:	1.5 - 2.0 m	1.5 - 2.0 m	2.0 - 2.5 m	3.0 - 4.5 m
Ship has to leave berth with wind of 60 knots and waves higher than:	-	-	2.0 - 3.0 m	3.5 - 5.0 m
Preference regarding ease of berthing and de-berthing:	2	3	4	1
Possible tidal effects:	Yes	Yes	No	No
Damage sensitive parts	Fenders	Fenders	Buoy Chains	Hoses
Assistance during berthing and mooring	Tugs and Flats	Tugs and Flats	Flats	Flats
Assistance for the departure	Tugs and Flats	Tugs and Flats	Flats	Flats

In order to further determine the strengths and weaknesses of the different mooring methods, the data from table 3-2 and further literature is combined in an MCA. This MCA is used to determine the most feasible mooring method for the new Ambon port based on selected criteria.

3.2.4 Scoring the MCA

To allow proper scoring the selected criteria, the 'functional requirements' of the port were formulated and used as benchmark for scoring. Each criterion of each layout is scored on a scale of one to three with each a related colour, see table 3-3.

Table 3-3 scoring guidelines for the MCA

Colour	Scoring	Numeric Score
Red/Orange	Negative	1
Yellow	Neutral	2
Green	Positive	3

3.2.5 Clarification

Each criterion in analysed and weighed on a scale of one to five. One meaning the criterion is of lesser influence; five meaning the criterion is of greater influence. The scoring (1 to 3) is then multiplied by the weighing factor (1 to 5) to determine the final score. An example of this scoring is shown in figure 3-4

Figure 3-4 Example of weighing criteria

Example:
The vessel size capacity is very important since the port requires the handling of a certain type of vessel; therefore; the aspect 'Vessel Size Capacity' has been given a relevance factor of 5.

MBM scores 'positive; on the criterion: 'Vessel Size Capacity', which has a weighing of 5. This means the scoring will be: '$3 * 5 = 15$'. Giving MBM a score of 15 on the criterion 'Vessel Size Capacity', this is done for each method.

The criteria are split up in three different categories: Physical aspects, socio economic aspects and development aspects. Table 3-4 shows the nine criteria, their weight and functional requirements as used in the MCA.

Table 3-4 the MCA criteria, functional requirements and weighing

Category	Criteria	Functional requirement	Weight
Financial Aspects	Construction Costs	The financial requirements to construct the primary construction	3
	Maintenance Costs	The financial requirements related to maintenance of the primary construction	3
Physical Aspects	On-shore Surface Requirements	The amount of on-shore area that is require to develop this mooring system	3
	Tidal effect	Do tidal conditions limit the operational capacity of the mooring system	4
Functionality Aspects	Vessel Size Capacity	The possibility to dock ships bigger vessels (based on their draft), without dredging works	5
	Starting Time	The time between arrival and the start of pumping	4
	Ease of Berthing	Ease of berthing a vessel to the mooring system	5
	Mooring Assistance	Assistance equipment required to dock ships	5
	Option to Clean and Maintain	Option to perform maintenance and cleaning on vessels in the port	3

3.2.6 Completed MCA

On the following pages, the MCA table is shown. The first three pages show the filled in MCA table, explaining how and why certain criteria are rated. The pages after that contain the selected weighing. Respectively; the main weighing, a weighing

Part 1/2 Category	Criteria	Functional requirement	L and T Jetty	Finger Pier	Fixed offshore terminal	MBM	SBM	Weight
Financial Aspects	Construction costs	The financial requirements to construct the primary construction	The rigid construction requires a high financial investment	The rigid construction requires a high financial investment	The rigid construction requires a high financial investment	The investments required are relatively low, but several buoys will be required per mooring location	The SBM system is respectively 2.5 times lower in price then the investment for a rigid on-shore construction	3
	Maintenance costs	The financial requirements related to maintenance of the primary construction	The rigid construction requires little maintenance and most maintenance is easy accessible	The rigid construction requires little maintenance and most maintenance is easy accessible	The rigid construction requires little maintenance but the added submarine pipeline require more maintenance	The buoys and sub-marine pipeline are hard to reach for maintenance and require regular inspections, resulting in high maintenance costs	The buoy and sub-marine pipeline are hard to reach for maintenance and require regular inspections, resulting in high maintenance costs	3
Physical Aspects	On-shore surface requirement	The amount of on-shore area that is require to develop this mooring system	Requires the setup of a L/T Jetty on the shoreline itself, which takes relatively little land space but requires a free zone for safety reasons	Requires the setup of a finger pier on the shoreline itself, which takes relatively little land space but requires a free zone for safety reasons	The offshore terminal is located in Open sea, on shore there will be a connection point and related free zone	The MBM is located in Open sea, on shore there will be a connection point and related free zone	The SBM is located in Open sea, on shore there will be a connection point and related free zone	3
	Tidal effects	Do tidal conditions limit the operational capacity of the mooring system?	Yes, since the rigid construction is not able to adjust to the changing water levels	Yes, since the rigid construction is not able to adjust to the changing water levels	Yes, since the rigid construction is not able to adjust to the changing water levels	No, since the buoys height adjusts along with the tidal conditions	No, since the buoys height adjusts along with the tidal conditions	4

Part 2/2		Functional requirement	L and T Jetty	Finger Pier	Fixed offshore terminal	MBM	SBM	Weight
Category	Criteria							
Functionality Aspects	Vessel size capacity	The possibility to dock ships bigger vessels (based on their draft), without dredging works	Suitable for all ships if the bathymetry allows it.	Ships dock very close to the shoreline, which limits the water depth and therefore vessel capacity	Ship size depends on the location where its build, but is inherent capable of handling all sizes of ships	Unlimited, can be placed in deeper waters of 75 to 100 m depth easily	Unlimited, can be placed in deeper waters of 75 to 100 m depth easily	5
	Starting time	The time between arrival and the start of pumping	2 hours	2 hours	2 hours	5 hours	2 hours	4
	Ease of berthing	Ease of berthing a vessel to the mooring system	Average	Average	Average	Hard	Easy	5
	Mooring assistance	Assistance equipment required to dock ships	Tugs and flats	Tugs and flats	Tugs and flats	Flats and (sometimes) tugs. Tugs have to be present but no guarantee of usage	Flats and (sometimes) tugs. Tugs have to be present but no guarantee of usage	5
	Option to clean and maintain	Option to perform maintenance and cleaning on vessels in the port	Yes	Yes	No	No	No	3

			Main weighing									
	Weighing	Weight	L and T jetty		Finger Pier		Fixed offshore terminal		MBM		SBM	
		35	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Financial Aspects	Construction costs	3	1	3	1	3	1	3	2	6	3	9
	Maintenance Costs	3	3	9	3	9	3	9	1	3	1	3
Physical Aspects	On-shore surface requirement	3	2	6	2	6	3	9	3	9	3	9
	Tidal effects	4	2	8	2	8	2	8	3	12	3	12
Functionality Aspects	Vessel size capacity	5	2	10	1	5	2	10	3	15	3	15
	Starting time	4	3	12	3	12	3	12	1	4	3	12
	Ease of berthing	5	2	10	2	10	2	10	1	5	3	15
	Mooring assistance	5	2	10	2	10	2	10	1	5	1	5
	Option to clean and maintain	3	3	9	3	9	1	3	1	3	1	3
	Total score:			77		72		74		62		83

Rank	**Version**	**Points**
1	SBM	83
2	L and T jetty	77
3	Fixed offshore terminal	74
4	Finger Pier	72
5	MBM	62

	Weighing	Weight	Focus on the costs									
			L and T jetty		Finger Pier		Fixed offshore terminal		MBM		SBM	
		38	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Financial Aspects	Construction costs	5	1	5	1	5	1	5	2	10	3	15
	Maintenance Costs	5	3	15	3	15	3	15	1	5	1	5
Physical Aspects	On-shore surface requirement	3	2	6	2	6	3	9	3	9	3	9
	Tidal effects	3	2	6	2	6	2	6	3	9	3	9
Functionality Aspects	Vessel size capacity	5	2	10	1	5	2	10	3	15	3	15
	Starting time	5	3	15	3	15	3	15	1	5	3	15
	Ease of berthing	4	2	8	2	8	2	8	1	4	3	12
	Mooring assistance	5	2	10	2	10	2	10	1	5	1	5
	Option to clean and maintain	3	3	9	3	9	1	3	1	3	1	3
	Total score:			84		79		81		65		88

Rank	Version	Points
1	SBM	88
2	L and T jetty	84
3	Fixed offshore terminal	81
4	Finger Pier	79
5	MBM	65

	Weighing	Weight	L and T jetty		Finger Pier		Fixed offshore terminal		MBM		SBM	
			Focus on efficiency									
		35	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Financial Aspects	Construction costs	3	1	3	1	3	1	3	2	6	3	9
	Maintenance Costs	3	3	9	3	9	3	9	1	3	1	3
Physical Aspects	On-shore surface requirement	3	2	6	2	6	3	9	3	9	3	9
	Tidal effects	5	2	10	2	10	2	10	3	15	3	15
Functionality Aspects	Vessel size capacity	5	2	10	1	5	2	10	3	15	3	15
	Starting time	5	3	15	3	15	3	15	1	5	3	15
	Ease of berthing	5	2	10	2	10	2	10	1	5	3	15
	Mooring assistance	3	2	6	2	6	2	6	1	3	1	3
	Option to clean and maintain	3	3	9	3	9	1	3	1	3	1	3
	Total score:			78		73		75		64		87

Rank	Version	Points
1	SBM	87
2	L and T jetty	78
3	Fixed offshore terminal	75
4	Finger Pier	73
5	MBM	64

3.2.7 Results

Table 3-5 shows the ranked outcome of the main weighing. Single Buoy Mooring scores the highest in this weighing. In tables 3-6 and 3-7 the ranked outcome of the two verification weightings is shown. In both situations Single Buoy Mooring scores the highest amount of points.

Table 3-5 original Weighing

Rank	Version	Points
1	SBM	83
2	L and T jetty	77
3	Fixed offshore terminal	74
4	Finger Pier	72
5	MBM	62

Table 3-6 focus on efficiency

Rank	Version	Points
1	SBM	87
2	L and T jetty	78
3	Fixed offshore terminal	75
4	Finger Pier	73
5	MBM	64

Table 3-7 focus on the costs

Rank	Version	Points
1	SBM	88
2	L and T jetty	84
3	Fixed offshore terminal	81
4	Finger Pier	79
5	MBM	65

3.3 Conclusions

Single Buoy Mooring is selected as the most feasible docking method for the new Ambon port. This method results in lower investment costs for the liquid bulk quay in comparison with the other mooring options. Dredging is not needed with SBM since the ships can dock on deeper locations further from the coastline. Also, there is no interaction between the general- and container cargo vessels and the liquid bulk vessels in the port; minimizing the risks of collision and related consequences.

4

STORAGE SURFACE AREA

4.1 Storage Method

In general, liquid bulk is stored in containment tanks. The type of containment tank in which liquid bulk is stored depends on the type of bulk. In the case of the new Ambon port expansion, the liquid bulk consists of cruel- and refined oil; both can be stored in the type of containment tank, see figure 4-1. Meaning they do not require special cooling/heating systems as would be required for LNG or certain chemical bulk products.

Figure 4-1 fuel containment tanks in Crainey Island, Virginia, USA

4.2 Storage Requirements

4.2.1 Storage Capacity per Tank

According to the 'new Ambon feasibility study' and benchmark assumptions from similar operations in South East Asia each containment tank in the new Ambon port will have a storage capacity of $10{,}000\ kilolitres$ on a 0.8 ha surface area [Lit. 2] and [Lit. 10].

$C \quad = \quad 10{,}000\ m^3/tank\ per\ 0.8\ ha$

4.2.2 Number of Storage Tanks

According to the 'new Ambon feasibility study' and benchmark assumptions from similar operations in South East Asia each containment tank in the new Ambon port will have an average dwell time of 60 days. This means in a full year each tank can storage 6 storage units of 10,000 m^3 ($60\ days\ x\ 6\ =\ 360\ days$) which results in an annual storage capacity of 60,000 m^3 per tank. Based on the annual throughput of 625,000 tons and a storage capacity of $60{,}000\ m3/yr/tank$, a minimum of 11 tanks is required to store the bulk. This however, does not account for peak storage and variety of bulk types. As a margin for the peak storage and a variety in bulk types and maintenance/cleaning of the tanks, the minimum amount of tanks is multiplied by a safety factor of '2'. Multiplying the eleven storage tanks by a factor of 1.4 results in:

$n \quad = \quad 22\ storage\ tanks$

4.2.3 Storage Surface Requirement

Based on a total of 22 containment tanks with a surface area of 0.8 ha each requires the following surface area:

$$A = 22 * 0.8$$
$$A = 17.6 \text{ ha}$$

This area does not include any area reserved for the barriers surrounding the tanks, roads, offices etc.

4.3 Conclusions

Based on this chapter, the following conclusions are drawn.

Mooring Method

- *A minimum of 2 berths is recommended for the liquid bulk terminal in order to handle varying vessel sizes and types of liquid bulk.*
- *Based on the Multi-Criteria Analyses; "Single Buoy Mooring" is recommended as the most feasible method for this port.*
- *A SBM system requires a limited amount of shoreline/quay since the mooring takes place in open sea. The only required point is the station where the off-shore pipelines connect to the on-shore pipelines.*
- *All conclusions regarding the liquid bulk terminal are recommendations only, since there is no available input from the future exploiter of the liquid bulk terminal.*

Surface Area

- *Based on this chapter, a total of 22 containment tanks with a capacity of 10,000 kilolitres each are required for the storage of liquid bulk in the liquid bulk terminal. Each tank has 0.8 ha of surface area results in a total storage area of 17.6 ha required. This does not include roads, pipelines, offices and other facilities.*
- *The height of the barriers surrounding the containment tanks, is relatively low. While a height of 1.35 m is commonly used in SEA, it is relatively low compared to containment tanks in other locations where heights up to 3 m are common. Increasing the barrier heights increases the capacity and lowers the required surface area.*
- *Table 4-1 shows a difference of 5.6 ha between the market study of the Port of Rotterdam and this thesis. Taking into account that this thesis used a factor 2 for peak storage and a maximum ratio for the area used by roads, offices and other constructions, and still results in a lower surface area usage. It is highly likely that the 30 ha requirement is an unrealistic situation.*

Table 4-1 differences in surface area requirement

	Port of Rotterdam	Previous Paragraphs	Difference
Required Surface Area:	30 ha	23.5 ha	6.5 ha